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Научен редактор:
проф. д-р арх. Николай ТУЛЕШКОВ
проф. д-р инж. Дончо ПАРТОВ

Художник:
Юлиан ТУЛЕШКОВ

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MESSAGE FROM THE ORGANIZERS

This is the first time we organize Academy of Sciences and Arts International Conference in Bulgaria, a major event that brings together many of the worlds' architects, environmental architects and structural engineers to Sofia, Bulgaria. The motivation behind organizing the Conference is based on the Bulgarian architectural and structural engineering traditions, on our longstanding links to UNESCO and ICOMOS – as we keep history of architectural and structural engineering education going back more than one-hundred years, our famous orthodox cathedrals in Sofia, our research activities and other successfully organized international conferences.

Our success in being able to organize such an event is representative of the intensive architectural and structural engineering activity which has been ongoing over the last twenty five years in along with and also because of changes in the Bulgarian political system and its recent membership in the Europian Union. As a result, Bulgarian architects, environmental architects and structural engineering are facing new challenges that are typical not only of Bulgaria but are characteristic of our rapidly changing world, too. To respond to these challenges it requires a joint effort, regardless of the geographical location and geometrical size of the different hystorical types of structures.

This is why we are offering the architects, environmental architects and structural engineers a platform to discuss a wide range of topics related to: *Social and economic integration of culture heritage; Culture heritage being part of the local and regional, social and economic stability; Culture heritage in urban areas; Vulnerability of culture heritage to hazards, and preventive measures; Documentation, interpretation, presentation and publication of culture heritage; Degradation of culture heritage in surrounding environment; Indoor climate and tourism effects; Biodegradation of culture heritage; Historic materials and their diagnostics; New materials for safeguarding culture heritage; Historic structures and their monitoring; New technologies for safeguarding culture heritage; Restoration of historical masonry, timber and steel structures-criteria - innovative solutions and case studies; Seismic rehabilitation of historical masonry, timber and steel structures; Conservation and preservation of historical masonry, timber and steel structures; Consolidation, rebuilding and strengthening of historic structures; Culture heritage under catastrophic events: fire, flood and blast loading.*

To date, definite interest has been expressed in the themes selected from **14 contries**, confirmed by the receiving of more than **60 abstracts**. Based on selected papers we are well ascertain that the technical programme will provide for an interesting global view for all participant.

We also wish to use this opportunity to introduce all Conference participants to the cultural aspects of Sofia and Bulgaria. Both during and after the Conference the participants may relaxingly submerge into Sofia unique atmosphere while enjoying Bulgarian music and dance and some traditional meals and wines during the welcome party, conference dinner and tours. Participants and accompanying people will visit the Sofia National Opera (near the Conference venue). In addition we have organized post-conference technical tours to some of our most interesting heritage sites, and other sightseeing places. We will do our best to ensure that participants enjoy our reknowned Bulgarian hospitality during the Conference.

We look forward to receiving you in Sofia, in November 2016!

Prof. Arch. Nikolay Tuleshkov,PhD
Vice-chairman of the Organizing Committee



Prof. Eng. Doncho Partov, PhD
Chairman of the Organizing Committee



MESSAGE FROM THE PRESIDENT OF BASA

For the first time in the history of the Bulgarian Academy of Sciences and Arts (BASA), the Scientific Institute for Architecture, Construction and Urban Planning is going to host the International Conference on: Preservation of Culture Heritage.

It is my pleasure to invite you to attend this Conference in Sofia, to meet with international experts and discuss number of important topics. This year, the focus of the Conference will clearly be on the future of preservation of the culture heritage in Bulgaria and across the world. This is expressed in the selection of the conference topics such as: *Conservation and preservation of historical masonry, timber and steel structures; Consolidation, rebuilding and strengthening of historic structures; Degradation of culture heritage in surrounding environment; Vulnerability of culture heritage to hazards and preventive measures.* In particular, attractive subject areas will be on the programme, like: *Culture heritage under catastrophic seismic loading; Seismic rehabilitation of historical masonry, timber and steel structures; New technologies for safeguarding culture heritage; Restoration of historical masonry, timber and steel structures-criteria - innovative solutions and case studies;*

Information on these topics will be shared among designers, contractors, operators, suppliers, government agencies and researchers to the benefit of the profession and society at large. In addition, this conference will serve as a valuable opportunity for international networking.

It is also my particular wish, once again, to encourage young architects and engineers to attend the forum and meet with experienced colleagues from around the world, while at the same time take advantage of the best presentations under the "Young Researcher" award prepared by the organizers and BASA fellows. The organizers will offer reduced registration fees and shall make special effort to facilitate contact between young architects and engineers and experienced colleagues on the other hand. Also, a Young-engineer Meeting Point will be set up. The traditional prize for the three most outstanding contributions by young authors born in 1983 or later will again be awarded, constituting a great deal of honour to the awardees.

Sofia, the city of 7000-year-history, possesses a rich and fascinating history, as well as a vibrant culture heritage. It is a perfect setting for this conference, for in addition to its important historic background the future is also happening in Bulgaria. This progress was founded on a recognized architectural and structural engineering tradition and illustrated by a number of world famous cathedrals, monasteries, basilicas and churches. The final technical and social event of the Conference will be held in Kustendil - a technical excursion on Friday.
BASA is grateful to its Scientific Institute for Architecture, Construction and Urban Planning, in co-operation with the sponsors for organizing this promising Conference to be held in November 2016.

I look forward to meeting you in Sofia.

Prof. DSc Grigor Velev, Academician of BASA
President of BASA

НАПРАВЛЕНИЕ 1

Социална и икономическа интеграция на културно-историческото наследство; Културно-историческото наследство като инструмент за местна и регионална, социална и икономическа устойчивост; Културно-историческото наследство в градските и селски райони; Уязвимост на културно-историческото наследство срещу природни бедствия и превантивни мерки за неговото съхраняване.

TOPIC 1

Social and economic integration of culture heritage; Culture heritage for local and regional social and economic stability; Culture heritage in urban areas; Vulnerability of culture heritage to hazards and preventive measures.

ИНДОКТРИНАЦИЯ ПРИ ОПАЗВАНЕТО НА ПРОМИШЛЕНАТА АРХИТЕКТУРА И ЛАНДШАФТ В БЪЛГАРИЯ

Стефан Аспарухов[1], Веселин Рангелов[2], Веселин Шахънов[3]

Университет по архитектура строителство и геодезия – гр. София / Лесотехнически университет – гр. София

THE INDOCTRINATED PRESERVATION OF THE INDUSTRIAL HERITAGE OF ARCHITECTURE AND LANDSCAPE IN BULGARIA

Stefan Asparuhov, Veselin Rangelov, Veselin Shahanov

University of Architecture, Civil Engineering and Geodesy – Sofia / University of Forestry - Sofia

***Abstract**: After the serial demolitions of the industrial heritage in Plovdiv city (2016) the Bulgarian society put precise questions to the governing bodies once again. Unfortunately the answers are still blurred. The main purpose of this article is to make approach to our national values and actions in the context of the negative effects during the controversial stages of Bulgarian development. The tasks of preserving the few industrial remainings from the period until the First World War and preserving the built later acquire compulsory nature. In this sense if we do not learn from our mistakes in the past and do not use the good foreign practices and experience (adapted to national identity), the doctrine "sustainable development" will irreparably remain a utopia for the Bulgarian society.*

***Key words**: architecture, industrial buildings, heritage, sustainable development*

1. Увод

Опазването на промишлената архитектура, в т.ч. и ландшафта, определен от нейните обекти и субекти, е значим процес за устойчивото развитие на обществото. През годините след Стокхолмската конференция от 1972 г. до днес доктрината „устойчивото развитие“ натрупа достатъчно количествени и качествени изменения, чрез които се следва нов път за развитие, с траектория, противопоставяща се на негативния мултиплициращ ефект от непрекъснатата борба между бедни и богати – траектория, която предполага балансираност между икономиката, екологията и социалното развитие в контекста на културните различия на локален и глобален фон.

Човечеството започна да проявява силна загриженост за своето оцеляване, пречупвайки своите ценности през призмата на „устойчивостта“. В много области на

[1] Стефан Аспарухов, доктор, архитект, главен асистент в УАСГ, 1046 София, бул. Христо Смирненски №1, каб. 716А, asparuhov_stefan@abv.bg
[2] Веселин Рангелов, доктор, ландшафтен архитект, главен асистент в ЛТУ,veskorangelov@abv.bg
[3] Веселин Шахънов, доктор, ландшафтен архитект, асистент в ЛТУ, veshaha@abv.bg

познанието обаче това „пречупване“ придоби комерсиални изражения под натиска на едрия капитал. Неуравновесеното притегляне на икономическите аспекти на развитието – за сметка на екологичните и социалните аспекти, превърна доктрината „устойчиво развитие“ в средство за печалба, повишаващо нивата на финансова неравнопоставеност. В края на миналия век много от усилията на учените и експертите от международните организации бяха концентрирани в търсене на липсващия (свързващия) елемент в троицата компоненти на устойчивостта (икономически-социални-екологични): културният аспект. През 1995 г. ЮНЕСКО публикува дефиниция на културата като *"целия комплекс от отличителни духовни, материални, интелектуални и емоционални черти, които характеризират дадено общество или социална група. Тя включва не само изкуствата и литературата, но също различните модуси на живот, фундаменталните човешки права, ценностните системи, традициите и вярванията*".

Един от първите поддръжници на културния аспект на устойчивото развитие – Джон Хоукс предлага задълбочен поглед върху понятието. Според него културата включва: (1) нашите ценности и стремежи; (2) начините, по които се развиваме, получаваме и предаваме тези ценности и (3) стиловете на живот, които тези процеси произвеждат [9].

В допълнение Хоукс посочва: *„Нашата култура въплъщава смисъла, който придаваме на живота си; тя се крепи върху ценностите, които споделяме и начините, по които ние приемаме различията си; тя е свързана с това, което наистина има значение за хората и общностите: взаимоотношения, памет, опитности, идентичности, произход, надежди и мечти в цялото им многообразие. А най-вече, нашата култура изразява визията ни за бъдещето: какво искаме да предадем на бъдещите поколения. Нашата култура свързва нашето настояще с нашето минало, както и с бъдещето, което си представяме. Чрез културата осъществяваме връзките, мрежите от значения и ценности, както и тези от приятелства и интереси, които ни събират заедно във времето, пространството и обществото."* (превод: доц. Л. Сазонова).

Организацията TIICIH (The International Committee For The Conservation Of Industrial Heritage) дава следното определение за индустриално наследство: *„Индустриалното наследство се състои от останките от индустриална култура, които могат да бъдат с исторически, технологичен, социален, архитектурен или научен характер..."*. ЮНЕСКО вече разпознава тези обекти като важен компонент на човешката история. От декларираните 690 обекта на световното наследство 28 са такива на индустриалното наследство, а 22 от тях се намират в Европа. Това са 5,3 % от всички културни обекти и 5 % от всички обекти на културното наследство [1].

Високата роля на културния аспект в доктрината „устойчиво развитие“ поражда необходимост от съпоставяне на степента и начина на прилагане на прокламираното, като се изследва какво е разбирането за индустриалното наследство в чужбина и какво е то у нас. Отчитайки спецификите на българските ценности, отговорът на поставения въпрос би ни дал относителна яснота за бъдещото развитие на нашето общество и би ни дал насока за ревизията, която трябва да направим по пътя към устойчивостта. Корекции са необходими, особено предвид събитията в тютюневите складове в Пловдив (2016 г.), представляващи по същество ***остра форма на индоктринация***, чрез която безспорно се ощетяват бъдещите поколения. Отчитаме разрушаването на тютюневите складове в Пловдив като световен прецедент. Нима една европейска столица на културата е възможно да се сбогува с внушителни ценности на индустриалното наследство?

Известно е, че *индоктринацията* е процес на насилствено внедряване на идеи, нагласи, познавателни стратегии или професионални методи чрез принуда, която

представлява практика за убеждаване и склоняване към извършване на действия от едно лице или група лица чрез сила или заплаха. Още повече, индоктринираните биват убеждавани в конкретни елементи на дадена област на познание, без да разбират широкия смисъл на темата, виждайки през предварително моделирана призма – в условия на пълна неспособност за критичен анализ на индоктринирания субект върху собствените ценности.

С цел установяване на субектите „индоктриниран“ и „индоктриниращ“ в областта на опазването на индустриалната архитектура в България, на първо място е необходим процесуално-адаптивен и сравнителен анализ, започващи с кратък исторически преглед.

2. Обща хронология

От зараждането на промишлената архитектура в края на XVIII в. до съвременните тенденции за глобализация на производствените процеси в условията на дигиталната революция се наблюдава логично изменение на архитектурния облик на промишлените сгради. Тези трансформации са следствие предимно на технологичното новаторство, оказващо пряко влияние върху сградното строителство, условията на труд и производителността на предприятията. Чрез хронологичен преглед на развитието на технологиите и неговото отражение върху архитектурата на промишлените сгради и съоръжения, посредством примери от световната практика, се установява, че производствените сгради, подобно на жилищните и обществените сгради, имат своето историческо развитие и архитектурни стилове [2].

Динамиката на технологичните трансформации поставя все по-трудната задача за създаване на критериален апарат, чрез който да бъде определяна стойността на индустриалното наследство.



а)



б)

Фиг. 1. Разрушаващо се и разрушено индустриално архитектурно наследство от края на XIX в.: а) Захарната фабрика в София (1898 г.); б) Спиртната фабрика в Княжево, София (1882 г.)

Във времето за натрупване на начален капитал, след Освобождението до края на XIX в., в България функционират над 160 предприятия, от които 40 са по-големи, а проектите им са разработени в чужбина. Държавната печатница в София (1887 г.), Захарната фабрика в София (1898 г.) (Фиг.1. а), Пивоварните фабрики в Шумен (1892 г.) и във Велико Търново (1892 г.), Спиртната фабрика в Княжево, София (1882 г.) (Фиг.1. б), фабриката за вълнени изделия „Евлоги Георгиев“ в Карлово (1891 г.) са едни от добрите примери с висока архитектурна стойност. За съжаление при нито един от тях не наблюдаваме опазване както на физическите обекти на архитектурата – сградите, съоръженията и обкръжаващата ги среда, така и на

нематериалните ценности – производствени технологии, социални отношения и бизнес отношения на работещите, производствена среда и пр. Тези обекти отдавна не съществуват, а някои от тях са разрушени до неузнаваемост.

През 1905 г. е приет Закона за насърчаване на местната индустрия и търговия, подпомагащ индустриалния капитал. Чрез него се продължават и доразвиват тенденциите и принципите, залегнали в Закона от 1895 г. Взимайки под внимание вече променените политически, микро- и макро-икономически условия, в Закона се предвиждат *„специални насърчения за едрата индустрия, като се признават тия облаги за множество още индустрии, които старият закон не обемаше и които практиката показа, че се нуждаят от покровителство"* [3].

За социално-икономическия ефект от насърченията (отменени през 1933г.) и развитието на българската икономика през периода до Втората световна война може да се съди по това, че през 1911 г. броят на предприятията е 345, а броят на служителите в тях – 16 000, през 1922 г. – 1 538 предприятия и 55 300 служители, през 1939 г. – 3 500 предприятия и 104 000 служители [4].

До 1920 г. две-трети от предприятията са част от хранителната (42%) и текстилната (24%) промишленост, а 13 години по-късно техният дял е три-четвърти – 60% от хранителната промишленост и съответно 16% от текстилната. За този период отличителна архитектура се наблюдава при първата фабриката за хартия и мукава „Книгата" в Белово по проект на арх. Данчов (1900 г.) (Фиг.2. а), Текстилната фабрика във Варна (1905 г.), Текстилната фабрика „Добри Карталов" в Габрово (1900 г.), Пивоварната фабрика на братя Прошек в София (1906 г.) (Фиг.2. б), Фабриката за керамика на гара Батановци (1914 г.), Печатницата в София - днес музей „Земята и хората" (1915 г.), Кланицата в София по проект на арх. П. Марковски и арх. С. Бобчев (1928-1932 г.) [5].



а)



б)

Фиг. 2. Разрушено индустриално наследство от началото на XIX в.: а) Фабриката за мукава и хартия в Белово (1905г.); б) Пивоварната фабрика на братя Прошек в София (1906 г.)

Добрият пример за конверсия на индустриална архитектура е сградата на арсенала, превърната в музей "Земята и хората", която е не само добре пригодена за новите си функции, но се използва много рационално за различни културни дейности [6].

Но нима това е достатъчно – на фона на изгубените стотици предприятия?

През годините на планова икономика след 1944 г. и особено през ускорената индустриализация от 70-те и 80-те години на XX в. у нас се прилагат индоктринационни прийоми за икономически растеж, различни от тези в пазарната икономика. Но въпреки различията в политическите режими на страните от Западния свят и страните от „Източния блок" преди 1989 г. е налице една обща

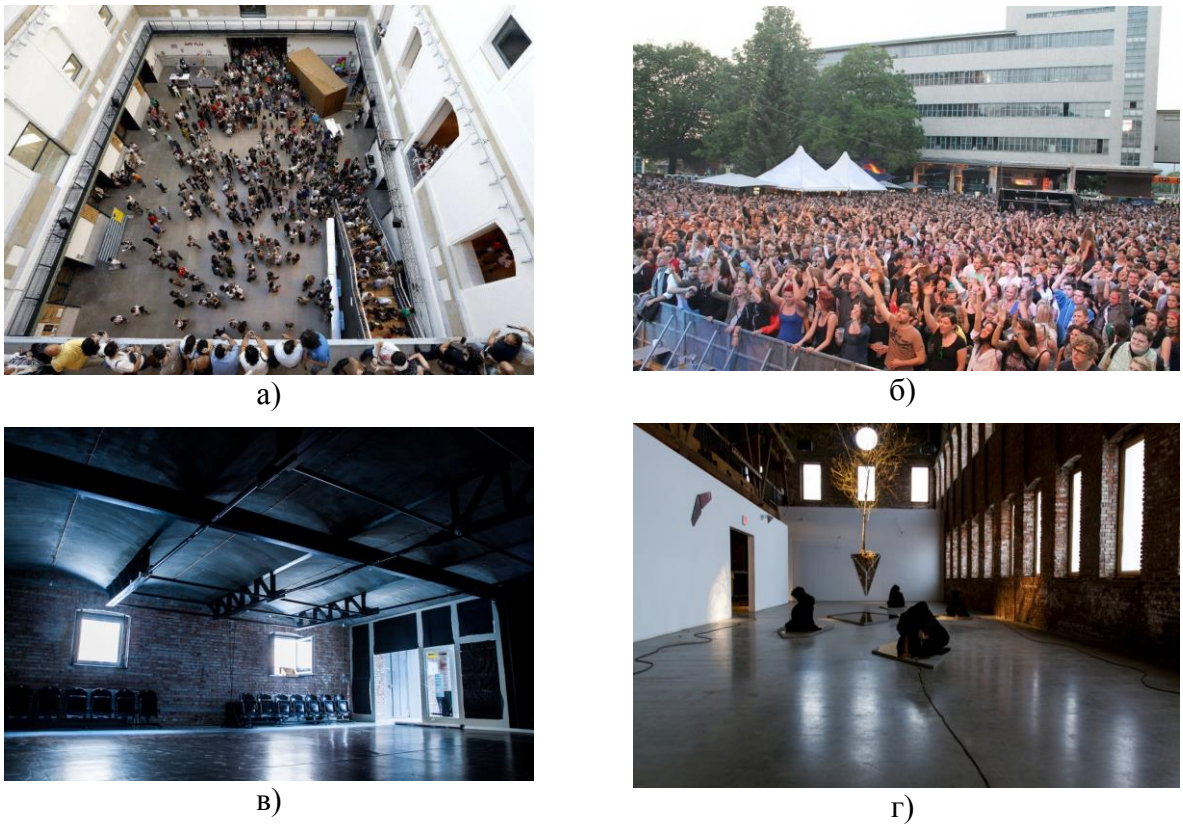
тенденция, която за съжаление се наблюдава до днес: при интензивен икономически растеж разрушаването на индустриалното архитектурно наследство се ускорява и респективно – в години на финансово-икономически кризи, съпътствани от преосмисляне на миналото, този негативен процес утихва.

3. Специфични аспекти от практиката по света и у нас

Предвид комплексността на проблематиката, следва да се отчете спешна необходимост от инициатива за създаване и финансиране на интегрирана база данни, чрез която да се управлява индустриалното наследство на България по устойчив начин. Като доказателство за тази необходимост могат да се приведат редица официални документи още от края на миналия век, насочени пряко към европейските страни. През 1985 г. на проведено в Лион разискване между представители на Съвета на Европа, френската секция на ИКОМОС и френски министерства е изработен документ, задаващ някои жалони за политиките по опазване на индустриалното наследство [7]. Още тогава, преди настъпването на дигиталната революция, се отправят актуални и днес препоръки към управляващите висши европейски органи, като за приложението на мерките, следва:

- Политиките да се основават на мултидисциплинарната концепция за индустриалното наследство, за която не е достатъчно да се разглеждат само обектите на архитектурата и обкръжаващата ги физическа среда, а заедно с тях да бъдат изследвани съвкупността от познания за обекта, производствените технологии и начина на живот на персонала;
- Политиките да създават условия за по-добро споделяне и по-голяма подкрепа, за: (1) превенция от разрушаване на компоненти на техническото и индустриално наследство, като заедно с това се направят изменения на фискалните политики и финансови закони; (2) селективно опазване на бизнес архиви, които разкриват колективната памет на фирмите; (3) подпомагане на фирмите чрез данъчни облекчения и стимули за насърчаване на управленските традиции; (4) стимулиране и социални придобивки на персонала, навършил или навършващ пенсионна възраст, който да участва в създаване, анализиране и съхранение на архивите на предприятието; (5) насърчения за популяризиране на индустриалното наследство сред широката общественост, политиците, професионалистите и обучаващите се;
- Да се подпомага научния подход за индустриалното наследство на европейско равнище, чрез: (1) насърчаване на научните изследвания посредством програми, насочени към националните университети и европейски научно-изследователски институти; (2) създаване на единна инвентаризационна система за установяване на засегнатите промишлени сектори и конкретни обекти, подлежащи на мерки по опазването;

Следвайки препоръките в чужбина са реализирани и продължават да се реализират редица проекти по опазване на промишлената архитектура в контекста на индустриалното наследство. В областта на тютюневата индустрия например такива реализации са: фабриката *Tabakalera* в Сан Себастиан, Испания (1913-2003 г.) – конверсия в смесени функции – публични и жилищни (фиг.3, а); фабриката *Tabakfabrik* в Линц, Германия (1935-2009 г.), за която е приложена конверсия с промяна на производствените функции (фиг.3, б); фабриката *Tabačka* в Кошице, Словения – превърната в център за съвременни изкуства и култура (фиг.3, в); фабриката в Любляна, Словения (1885 г.), която е превърната в културен център *Tobačna 001* (фиг.3, г) [8].



а) б) в) г)

Фиг. 3. Регенерация на тютюневи фабрики: а) *Tabakalera* в Сан Себастиан, Испания; б) *Tabakfabrik* в Линц, Германия; в) *Tabačka* в Кошице, Словения; г) *Tobačna 001* в Любляна, Словения.

Образцов пример за интерактивно и адаптивно опазване на индустриалното наследство чрез отворена база данни е дългосрочният научен проект *„Индустриална топография на Република Чехия“*, разработен от Изследователския център за индустриално наследство (FA CTU) в Прага през периода 2011-2015г. [10].

У нас възниква въпросът *„Защо не можем и ние българите да създадем подобна база данни?“*, отчитайки, че: (1) Възможности за финансиране има; (2) Разполагаме с богато архивно наследство от проектантските организации от близкото минало; (3) Разполагаме с научна инфраструктура и специалисти, концентрирани в специализирани катедри към висши училища и институти към научни организации; (4) Човешкият капитал и неговия спомен е все още достъпен, макар и в критично състояние, поради естествената подмяна на поколенията; (5) Функционира специализиран институт за недвижимо културно наследство; (6) Разполагаме с отлична оптична свързаност и специалисти в областта на информационните технологии.

Базирайки се на този потенциал, следва спешно да се координират действията на заинтересованите страни на високо равнище с цел обогатяване на познанието за опазването на индустриалното наследство, водещо до минимизиране на ефекта от индоктринацията в тази област, а оттам и разкриване на нашата самоидентификация – личностна, народностна и национална.

Подходящ репер на ниско равнище например би било изследването на арх. Игор Христов, който под ръководството на проф. А. Писарски, в дисертационния си труд създава *комплексна методика за оценяване на архитектурния потенциал при конверсия на индустриални сгради*. Приложните приноси на колегата, които след допълнителни изследвания, могат да се интегрират в цялостния модел за управление

на индустриалното наследство, обхващат: (1) типология на подходите за съживяване на промишлените сгради, отразяваща степента на намеса в сградния фонд и ефективността на въздействие спрямо принципите за устойчиво развитие; (2) систематизация на обобщени типологиини модели на индустриални сгради, показващи потенциала на различните видове конверсия; Подходът е с възможност за определяне на насоките за избор на подходящи функции и обекти в процеса на планиране и проектиране; (3) форма за графическо изобразяване на архитектурния потенциал за конверсия, изразена чрез специални диаграми [1].

4. Заключение

По аналогия на принципа на неопределеността (изведен от Вернер фон Хайзенберг през 1927г.), според който *координата и импулса на една микрочастица не могат да бъдат измерени едновременно*, можем да направим заключение, че днес в областта на опазването на индустриалното наследство в България *размерът на нанесените щети и отговорните за това субекти (индоктринатори) не могат да бъдат определени едновременно*.

Всичко казано дотук ясно идентифицира индоктринирания субект – българското общество и то не „активната“ част от него, представлявана от неправителствени организации, спонтанно организирани социални групи и „нечистоплътни“ медийни компании (също неосъзнато подведени от индоктриниращия субект), а онази част от обществото, която ще бъде лишена от възможността да предаде на бъдещото поколение ключа към вече разрушената фабрика, наречена „Устойчиво развитие“.

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ЕСТЕТИКА И ФУНКЦИИ НА ГОРСКОДЪРВЕСНАТА РАСТИТЕЛНОСТ В ПРИРОДНАТА СРЕДА НА НЕДВИЖИМИ КУЛТУРНИ ЦЕННОСТИ

Емил Галев

Лесотехнически университет

***Резюме**: Изследването е насочено към установяване на специфичната естетическа и функционална роля на горската растителност в обхвата на защитените територии за опазване на културно-историческото наследство в природна среда и насоки за нейната оценка. В последните години развитието на процеса на опазване на културно-историческото наследство създава необходмост от комплексни туристически продукти и същевременно съхраняване на естествената горска среда и защита на културните ценности в нея. Това предполага извеждане на насоки за формиране на обемно-пространствени структури на дървостоите със силно визуално въздействие, които да са и функционално пригодни към основните видове културно-туристически дейности. Способността на дървесните насаждения да формират и разделят пространства, да спомагат или ограничават интензивността на туристическия поток и не на последно място да разкриват и прикриват историческите елементи и структури е приета в изследването като водеща при оценка на значението й за опазване и експониране на ценностите в природна среда.*

***Ключови думи**: горскодървесна растителност, недвижими културни ценности, природна среда, културно-туристически дейности*

Въведение

Горскодървесните насаждения в обхвата на защитените територии на недвижимите културни ценности в природна среда са основен техен елемент. Тяхната роля може да бъде с водеща културна значимост, когато са носител на автентична информация за миналото, или с второстепенна, когато насажденията са създадени вторично с оглед на формиране на природосъобразна обстановка. При всички случаи горскодървесната растителност е факторът определящ функционалната зониране и имащ значение за общия облик на територията. Фокусът на настоящото изследване е насочен именно върху функционалната и естетическата роля на растителността и нейното значение за осъществяването на туристическата дейност в специфичната среда.

Материал и метод

Богатото културно наследство на България в последните години се развива в посока на създаване на цялостни туристически продукти. Очаква се чрез

популяризиране на ценностите и осигуряване на по-голяма привлекателност и атрактивност да се увеличи броя на туристите, а оттам и икономическата облага за общините. Безспорно това повишава ролята на наследството за устойчивото развитие на територииите.

Разположените в природна среда недвижими културни ценности са особено привлекателни за туристите, за което безспорно значение има и комфортът на природната обстановка. За паметниците на културата, намиращи се в горска среда, дървесната растителност, откритите горски поляни или периферните и полузакритите пространства, подпомагат визуалното им възприемане и физическия комфорт на туриста [3]. Теоретичните съображения относно изследваните в тази статия проблеми са многобройни и са засягани в редица други публикации като например [1, 2], но материята с визуалното възприемане и естетичните качества е сложна и подлежи на по-нататъшно изследване.

Може да се обобщи, че обемно-пространствената характеристика на насажденията е определящият фактор за пригодността на територията за културно-познавателен туризъм и качеството на отдиха. Доколкото естетиката на насажденията е *субективно* оценяван фактор, физическият комфорт се изразява чрез *обективни* количествени и качествени показатели. Това, с оглед на спецификата на разглежданите територии, дава възможност да се набележат някои качества на горскодървесната растителност, имащи особено значение за културно-туристическия отдих.

За онагледяване на изследването е анализиран авторски илюстративен материал от наскоро осъществен и считан за завършен културно-туристически продукт в природна среда – Цари Мали град, край с. Белчин, община Самоков. Степента на запазеност на крепостните стени, както и църковният ансамбъл, състоящ се три надграждани една върху друга църкви от различни епохи, градени върху древно тракийско светилище, превръща обекта в уникална културно-историческа ценност, значима както за общината, така и за България и Европа. [4] Обектът се отличава с наситеност на прилежащата територия с разнообразна в обемно-пространствено отношение горскодървесна растителност, резултат от разнообразни по вид и степен горскостопански мероприятия (Фиг. 1).



Фиг. 1. Общ изглед на горските територии от хълма
Св. Спас, върху който е разположено старинното селище „Цари Мали град"
(фотография – автора)

Резултати и дискусии

В разглеждания обект могат да се наблюдават изцяло закрити горски пространства, полузакрити и полуоткрити с изредена дървесна растителност, както и напълно открити участъци в резултат на пълно прочистване на терена от съществуваща растителност с цел експониране на реставрираните елементи. Чрез анализ на положителните и отрицателните въздействия на горскодървесната растителност са представени и оценени някои аспекти на нейната естетическа и функционална роля.

Закритите пространства в разглежданата територия преобладават и се концентрират в подножието и страничните участъци на хълма. Те съпътстват посетителя при движението му по главните алеи за достъп. Фигура 1 ясно показва пълната склопеност на смесените широколистно-иглолистни насаждения в подстъпите към билото на хълма. Безспорен е комфортът, който осигуряват на посетителя при изкачване на височината. Приятната в естетическо отношение горска обстановка е резултат и от вертикалната склопеност. Смесеният видов състав пък спомага целогодишното използване на територията – през лятото широклистните насаждения осигуряват необходимото засенчване, през зимата – просветляване при обезлистването на растенията. Гъстотата на насаждението е равномерна по цялата му площ и по този начин има определяща роля за проходимостта. Ниската степен на проходимост, обусловена едновременно от терениния наклон и от разстоянията между отделните индивиди насочва туристическия поток по предвидените трасета. По този начин природната среда се предпазва от нежелано навлизане и уплътняване на почвата. Ясно се очертава ролята на закритото горско пространство за регулирането на туристическия поток и за осигуряване на емоционален комфорт.

Полузакритите пространства са разположени в периферията на основния преобладаващ дървесен масив и създават плавен преход при наближаване на туристическата атракция (Фиг. 2). По-малката гъстота на насажденията, както и по-малката склопеност осигуряват по добра *физическа проходмост* извън установената алейна мрежа, както и частична *визуална проходимост* към реставрираните обекти. Това създава у посетителя удовлетворение от приближаването към туристическия обект и засилва неговото любопитство.



Фиг. 2. Полузакрито пространство по периферията на дървесния масив с увеличена, визуална и физическа проходимост при приближаване към туристическата атракция (фотография – автора)

В полузакритите пространства са разположени и множество допълнителни съоръжения, които нямат тематична връзка с културния обект, но спомагат за разнообразяване на културно-туристическата дейност с други необходими утилитарни дейности (Фиг. 3). Сравнително ниската степен на визуална проходимост създава визуална изолация от архитектурно-археологическия комплекс и по този начин разграничава чисто утилитарната от културната дейност.



Фиг. 3. Полузакритите пространства
са наситени с кътове за отдих,
детски съоръжения и други атракции (фотография – автора)



Фиг. 4. Полуотворено пространство, осигуряващо отлична видимост и осветяване на археологическите структури (фотография – автора)

Полуоткритите пространства в разглежданата територия се разполагат непосредствено след полуоткритите при достигане на туристическата атракция. Малката гъстота на дърветата в насаждението и ниската склопеност осигуряват отлична видимост и осветяване и насочват директно туристите (Фиг.4). Фокусът е изцяло върху културния обект и растителността се явява допълващо средство с цел осигуряване на плавен преход и частично засенчване.



Фиг. 5. Открито пространство в средата на археологическите структури с единични възрастни дървета (фотография – автора)



Фиг. 6. Открито пространство в периферията на археологическите структури за осигуряване на визуална връзка с околните територии (фотография – автора)

Откритите пространства играят важна структурообразуваща роля в обемно-пространствената композиция на обектите от културното наследство разположени в горска среда.

Фигура 5 илюстрира *открито пространство* в средата на разкритите археологически структури. Липсата на насаждения позволява възпремането в цялост на културните елементи. Единичните възрастни дървета позволяват създаване на комфортно пребиваване през летните месеци, както и емоционален комфорт на възприятието на историческия контекст. На фиг. 6 е илюстрирана ролята на *откритите пространства* за осигуряване на визуална връзка на обектите на културно-историческото наследство с околните територии.

Изводи

Естетическата и функционалната роля на горскодървесната растителност в природната среда на обектите на културно-историческото наследство е комплексна. Тя следва да се свежда както до пресъздаване на характерна историческа обстановка, така и до формиране издържана в естетическо и функционално отношение среда.

Съставът, строежът, възрастта, гъстотата и пространствената структура на горските насаждения определят обемно-пространствената характеристика на разглежданите територии, а оттам и естетическата и функционалната им пригодност за осъществяване на отдиха в отделните участъци.

Горските насаждения притежават качеството да зонират функционално разглежданите територии. Това се изразява в способността им да формират пространства с определена характеристика, подходяща за една или друга дейност. Като основно качество се очертава способността да регулират, разпределят и насочват туристическия поток, изразена чрез визуалната и физическата им проходимост.

Установяването на комбинацията от лесовъдски признаци на насажденията, съобразно конкретиката на културно-туристическия обект, с цел естетическа и функционална пригодност, е необходимо условие за набелязване на правилни мероприятия по тяхното създаване, отглеждане и възобновяване.

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ИЗТОЧНАТА ОС НА СОФИЙСКИЯ ЦЕНТЪР

Борислав Борисов [1]

Декан на Архитектурен факултет
Висше Строително Училище „Любен Каравелов" - София

THE EASTERN AXIS OF SOFIA CITY CENTER

Borislav Borisov

Dean of the Faculty of Architecture
University of Structural Engineering & Architecture (VSU) "Lyuben Karavelov"- Sofia

***Abstract**: Sofia has no sustainable urban development concept for the eastern axis of its main urban center. Forgotten and abandoned is the main social function of this part of the historic city, of its unique eastern axis and the emblematic for Bulgaria squares, old streets and public pedestrian spaces. Revitalization, socialization and integration of the architectural and urban memory of the heritage of all historical periods, including from Antiquity and the period of the Third Bulgarian Country, by creating a modern transport relieved zone is a real professional challenge for this part of the main city center.*

***Key words**: sustainable urban development concept, architectural-urban memory, square spaces, socialization, integration*

София няма устойчива градоустройствена концепция за източната ос на своя главен градски център. Това провокира преосмислянето на градоустройственото решение на тази изключително важна част от центъра, наследяваща уникални ценности в архитектурната памет на столичния град. Забравена и изоставена е основната обществена функция на тази част от историческия град, на неговата неповторима източна ос, на емблематичните за България площади и стари улици, на публичните пешеходни пространства. Те чакат своето възраждане като най-важни елементи в архитектурно–градоустройствената композиция на София и нейния център. Това мотивира изследването на възможностите за обновяване на източната ос на главния градски център като транспортно успокоена зона с оптимизирана организация на движението и доминиране на пешеходната функция. София може да има своята нова пешеходна зона, по-красива и по-богата от всяка друга пешеходна зона, не само в столичния град, но и в много други големи български и европейски градове. Това безспорно може да бъде бул. „Цар Освободител" и околните

[1] Борислав Борисов, професор/доктор арх., гр. София, ул. Средна гора № 73, archbb@abv.bg

пространствата от площад „Независимост“ до Софийския университет. По своя градоустройствен потенциал източната ос на главния градски център на София няма аналог в страната ни. По тази ос в продължение на векове са се развивали главните исторически събития от миналото на българската държава след националното ни освобождение. Погледнато абстрактно, може да се твърди, че тази ос свързва двете най-важни, най-оживени и най-представителни площадни зони на главния градски център, от запад това е историческото сърце на центъра, където е бил разположен древния римски град „Сердика“ от античния период /сега характерен с площадите „Независимост“, „Атанас Буров“ и „Александър Първи“/, а от изток това са най-забележителните обществени пространства от съвремието на столицата ни, каквито са площадите „Александър Невски“, „Народно събрание“, „Васил Левски“, „Николай Гяуров“, както и пространствата пред Народната библиотека и пред Софийския университет. По тази ос са разположени и много други обществени сгради и пространства, които са емблематични и символизират софийския център. Източната ос е уникална с богатството си на обществени сгради, улични и площадни пространства, зелени площи, исторически места, паметници на видни личности от историята ни, архитектурно-градоустройствено наследство, недвижими културни ценности, забележителности, специфичен релеф, образ и градска памет. Днес обаче бул. „Цар Освободител“ представлява по-скоро транзитна улична артерия, която разделя, а не обединява пространствата от двете страни на автомобилното движение, а площадите са кръстовища и обикновени паркинги.

Оживяването, социализирането и интегрирането на архитектурно-градоустройствената памет от наследството на всички исторически епохи, включително от античността и от периода на третата Българска държава чрез създаване на съвременна транспортно успокоена зона е истинско професионално предизвикателство за тази част от главния градски център. Разстоянието между двете сгради на Народното събрание /историческите сгради на Парламента и на бившия Партиен дом/ с двата площада „Народно събрание” и „Александър I“ е около 600 м. Двете парламентарни сгради са разположени приблизително в двата края на възможно най-интересната и най-"софийската” зона, съчетаваща богатството на българската история с архитектурно-градоустройственото наследство на градския център. За сравнение разстоянието между пл. Независимост и централния вход на НДК е повече от два пъти по-голямо /около 1400 м./. Дори дължината на чисто пешеходната зона по бул. „Витоша“, /около 650 м./, измерена от бул. „Патриарх Евтимий“ до ул.„ Алабин“ е по-голяма. От тези сравнения между двете оси на главния градски център се вижда,че източната ос в цитирания отрязък е дори по-къса и напълно съизмерима с пешеходната ос по бул. „Витоша“. В посочения пример на сравнение и двете оси се кръстосват от седем на брой напречни пресичания, но в случая с бул. "Цар Освободител" тези пресичания водят до уникални архитектурни и градоустройствени обекти, обогатяващи съдържанието на източната зона. Всъщност двете оси са коренно различни по своя облик, структура и функция. Те наследяват двете древни, най-големи улици на Сердика, „Кардо-максимус“ и „Декуманус-максимус“, където е бил съсредоточен обществения живот на града, а римляните построили форума на техния кръстопът. Оживяването и социализирането на паметта от античния период е една и от целите на проекта за антична Сердика, който се реализира наскоро в центъра и остави противоречиви мнения в професионалната колегия. Местоположението на днешния център на София е исторически неизменно и уникално. То е определено преди осем хилядолетия като пресечна точка на основните и най-важни пътища през софийското поле и до минералния извор в центъра на града. Това са включително и пътят между Европа и Азия, който преминава през Балканския полуостров и пресича полето и другият от север на юг

през същото място към Егейско море. Всичко това по никакъв начин не означава, че автомобилния транзит днес трябва до разкъсва историческата градска тъкан в центъра. Напротив това ни задължава да преосмислим организацията на движението и да освободим центъра от излишния транзит.



а) Връзка на източната ос с плана на откритите останки от древна Сердика

б) Запазване на източната ос с проекта от 1881г. върху среднов. градска структура

Фиг. 1. Графична илюстрация за историческата обусловеност на източната ос

И в миналото и сега обществените пространства имат основополагащо значение за градоустройството на всяко населено място. Град София не само, че не прави изключение, но има огромен потенциал на своите исторически улици, площади и градини, които му придават неповторим, разпознаваем и уникален характер и образ на един от най-красивите европейски градове. Ето защо обновяването на източната ос като най-представителната и най-емблематичната за софийския център обществена зона, възраждането на съществуващите и създаването на нови обществени пространства в тази част на центъра на град София се превръща в актуална и отговорна професионална задача с първостепенно значение. В това отношение от особено значение е проучването на градоустройствения потенциал за обновяване и реабилитиране на исторически изгубилите се функции, за възраждане на автентичното предназначение и за превръщането на обществените пространства в центъра от паркинги, кръстовища и транзитни автомобилни артерии в най-удобните, приятни и красиви места.

Първата метаморфоза на източната ос на главния градски център може да се анализира от сравняването на плановете на „антична Сердика" и на „града от османския период". Ясно личи връзката между Баня „Башиджамия" и Конака по улица „Булевардна" и улица „Чаршия". Градската градина на север достига до сградата на Конака, като по този начин връзката на източната ос с Цариградския път е непосредствена. Бъдещите направления по бул. Дондуков и по ул. „Орханийска" /Московска/ са унаследени и в средновековната османска структура на града от входно-изходната ситуация пред източната порта на древноримския град, т.е.в паметта и градоустройствения контекст на София са запазени специфичните за това място ценности от миналото. Плановете от периода след националното освобождение (Фиг.2а) отново показват градоустройствената метаморфоза, при която се запазва трасето на източната ос с малки отклонения и изключения. Пред царския дворец, унаследил конака се обособява двор, който преграждa непосредственото улично провеждане на източната ос в зоната на двореца, но мотивира двата основни портала към него от изток и от запад. Тогава се ситуират новите и най-важни за периода сгради на Столицата именно по източната ос на главния градски център. Оформя се преобладаващата и най-съществена част от сегашния облик. Конакът е коренно преустроен в новия царски дворец, предвиждат

се сградите на Парламента, на църковния храм „Александър Невски" и на Народната банка. Създава се неповторим ансамбъл от няколко различни по форма, големина и предназначение площади и връзките между тях. Това са правоъгълния площад „Александър Първи", който приблизително е запазил формата си независимо от промените след втората световна война, овалния площад „Александър Невски", полукръглия - „Народно събрание", кръглия - „Васил Левски" и триъгълния площад пред руското посолство. Положени са основите на уникалните качества и особености на източната градоустройствена ос.



а) Съхраняване на оста от 1928г. б) Промяната от 1947г.

Фиг. 2. Подчертаване на източната ос в плановете на София от 1928 г. до 1947 г.

От плана на София от 1947 г. (Фиг.2б) личи, че след втората световна война се възобновява преминаването пред Царския дворец, т.е непосредствено се провежда източната ос в зоната на двореца, който е загубил след монархията дворцовото си предназначение, като по този начин се обособява пространството пред него и се наименува заедно с другия, съседно разположен площад /бивш „Александър I" с името „Девети септември". Впоследствие се реализира голямата градоустройствена промяна с построяването на бившия „Партиен дом" и другите две квартални застройки от двете страни на „Ларгото".

През последните години софийските улици и площади в зоната на източната ос от главния градски център загубиха своята привлекателност и исторически автентичната си пешеходна функция. Те постепенно се превърнаха в обикновени и транзитни автотранспортни улици, кръстовища и паркинги. Беше изоставено тяхното основно предназначение на обществени места, където гражданите да могат спокойно да се движат пеша или с велосипед, да се събират или да се срещат помежду си, да посещават музеи, изложби, представления и всякакви други културни изяви, да пазаруват или да се наслаждават на заведенията за обществено хранене, да се забавляват или просто да се радват на свободното си време прекарано в подходяща пространствена среда, отговаряща на високи архитектурно-градоустройствени критерии. Още Леон Батиста Алберти в "Десет книги за архитектурата" подчертава значението на градския площад, все едно че пише конкретно за София: "Най-главното украшение на града придават положението, направлението, съотношението и разпределението на улиците и особено на площадите. По-късно също и Паладио в "Четири книги върху архитектурата" пояснява: "Необходимо е градът да има повече или по-малко площади, които са неговата главна част". Българският градостроител проф. арх. Любен Тонев в своя фундаментален труд "Площадът" издаден в БАН 1949 г., давайки примери и от София отбелязва: "Площадът по своето предназначение и роля за градския организъм, по своята пространствена и архитектурно – композиционна стойност е бил винаги и продължава да бъде най-съществения градски елемент". Той добавя, че с предназначението си площадът е пълна противоположност на кръстовището. И арх. Филев също дефинира понятието площад : "Площадът представлява свободно

селищно пространство обособено в градоустройствено и функционално отношение, предназначено да служи за обществени изяви, политически и културни начинания, за развлечения, общуване, разходки и отмора. Той трябва да бъде съобразен преди всичко с удобствата на пешеходците и тяхното спокойно събиране, пребиваване и движение". Всъщност историческите площади и улици и въобще публичните пространства на центъра навсякъде по света са задължителна и главна структурна единица към всеки градоустройствен план. Те играят ролята на своеобразно ядро-център, който може да е средище с търговско, религиозно, политическо, културно, мемориално, рекреационно, административно-представително или друго предназначение и според своята функция, форма, големина и др. особености да се групират или класифицират на различни видове. Те до голяма степен определят художествено-естетическите качества и функции на града като цяло. Правилното планиране, проектиране и архитектурно-художествено оформяне на тези обществени пространства винаги е било и продължава да бъде първостепенна задача за градоустройството. Те имат разнообразна и уникална пространствена организация – различно оформена градоустройствена рамка и разположени сгради около или в тях, паметници, зелени площи, преместваеми обекти, декоративни и информационно-рекламни елементи, настилки, чешми и перголи, елементи на градското обзавеждане и др. Най-разнообразни са взаимовръзките помежду им, както и с останалите градски пространства, вкл. подходите и отношението им към комуникационно-транспортната система на града.



а) Схематично изображение за обновяване на съществуващи и за създаване на нови площади като ансамбъл от обществени зони и пешеходни пространства в източната част на главния градски център.



б) Схематично изображение на потенциална възможност за запазване на зоната „жълтите павета", достъпността на контактните пространства от двете страни на пешеходната ос и илюстриране ролята на булеварда като структурен обединител.

Фиг. 3. Схематични графични проучвания за обновяване и развитие на източната ос.

С графичното изображение на фиг. 3а могат да се илюстрират потенциалите за градоустройствена намеса даващи възможност за реабилитация на площадната функция в една от най-важните части от главния столичен център. Логично е да се обобщят няколко извода, които да послужат като опорни точки при създаване на задание за реконструкция и обновяване на центъра. Част от тези изводи биха могли да се дефинират чрез специализирано проучване на конкретна тематика, обхващащо произход, историческо развитие, градоустройствени особености, приемственост, градски образ, памет, съвременни аспекти и т.н., касаещи: жълтите павета, достъпността на контактните пространства от двете страни на пешеходната ос, ролята на булеварда на обединител, а не на делител, композиционно оформяне и структуриране на зелените пространства в единна система и обогатяването им с

водни площи, площад "Атанас Буров" заедно с площад "Александър I" като възлово обществено пространство и портална ситуация за източната ос. Преустройството на площад „Александър Невски“ изисква освобождаването от транзитните транспортни функции, както и от прекомерното паркиране. Оформянето му следва да бъде като пешеходна зона особено пред катедралния храм от запад и в пространството за церемониали пред „Вечния огън". В участъка на художествената академия е целесъобразно изграждането на представителна обществена сграда с публични функции, която да рамкира площада от изток и да позволява реализиране на пешеходна връзка в дълбочина до паметника „Кирил и Методий" пред Народната библиотека. На юг, североизток и запад се осъществяват пешеходни връзки съответно с площадите „Народно събрание", „Васил Левски" и „Николай Гяуров".

Възможно е площад „Народно събрание"да придобие постоянна пешеходна функция, без да се премахва изцяло движението по бул. Цар Освободител". Транспортното успокояване чрез обхождане на паметника от юг, освен че ще реабилитира площадното значение на пространството пред „Народното събрание", но допълнително ще даде възможност за по-добро ансамблово обвързване на сградата на Парламента и паметника пред нея като неразделно функционално и обемно-пространствено единство.

Площад „Васил Левски" от своя страна също може да придобие постоянна пешеходна функция чрез извеждане на автомобилния транзит от изток и преобразуване на кръстовището от кръгово в триклонно, така че паметника да бъде естествен завършек и кулминация на пешеходната ос пред него. Това ще позволи да бъде решен проблема с достъпността на паметника от посоката на барелефа с лика на Апостола. Не случайно паметникът е проектиран от арх. Антонин Колар в контекста на кръгъл площад с идеята барелефният портрет да бъде обърнат към центъра на града и да бъде общодостъпен за всички граждани.

Площад „Николай Гяуров" (бивш „Червеният площад") е напълно възможно да стане изцяло пешеходен чрез реализиране на транзитното автомобилно движение по ул. „Раковска" на подземно ниво, така както е заложено в действащия ОУП на Столична община. При такова решение се постига освен реабилитиране на площадната функция на приземно ниво и допълнително подобряване на пропускателната способност на ул. „Раковска" в участъка между бул. „Дондуков" и „Цар Освободител". Градоустройствено се осмисля пешеходната връзка между площад „Александър Невски" и „Градската градина", както и достъпността до Руската църква "Свети Николай Чудотворец". Подземния урбанизъм и обособяването на спирката на обществения транспорт на долно ниво ще даде допълнителни възможности за обвързване на археологическите ценности под черквата „Света София“ с подходите от запад.

Софийската опера е единствената голяма обществена сграда с общоградско и национално значение, която не притежава площадно пространство. Условията, при които тя е била проектирана от арх. Парашкеванов са довели до ситуация, при която сградата е от всички страни обрамчена с улици и квартали до такава степен на затвореност, че всеки усеща липсата на подходящо открито обществено пространство даващо възможност на пешеходеца да възприема фасадите на операта по подходящ начин. Тази важна обществена сграда е недопустимо притеснена и изисква сама по себе си увеличаване на пешеходната площ пред централната фасади и встрани от нея. Схематичното изображение от фиг. 3 илюстрира потенциалните възможности за създаване и на нов площад като част от ансамбъл на обществени зони и пешеходни пространства в източната част на главния градски център на София. Новата пешеходна зона по ул. „Раковска" осъществява по убедителен начин връзка на проектните площадни пространства около централния вход на Операта с

триъгълния площад на юг и от там към монументалния площад „Ал. Невски" на изток. По този начин пешеходната достъпност на Софийската опера става много по-добра и уникална заради ансамбловото съчетание на повече обществени пространства в синтез помежду си в цялостна пешеходна зона с общоградско значение.

Огромни потенциални възможности за развитие на нов и уникален градски площад „Римски амфитеатър" са заложени в зоната на новооткритото архитектурно наследство от античния период до кръстовището на бул. Ал. Дондуков" и ул. „Будапеща". Западно това пространство се рамкира от бившия младежки театър, източно от бившата сградата на НИПК -сега НИНКН и хотел „Арена ди Сердика", северно от разширението пред Битовия комбинат, което може да се ползва за пешеходен подход и подлез към площада на подземно ниво и на юг с новопроектирана в бъдеще рамка, даваща възможност за достойно експониране на ценното недвижимо културно наследство и градската памет от античния период. Чрез архитектурно-градоустройствено оформяне на пространството около къщата с часовника е възможно да се осъществи добра пешеходна обвързаност с градската градина и на изток с пространството на площад „Ал. Невски", както и на другите площади с общоградско значение. Софийският римски амфитеатър е археологически паметник, разположен в центъра на град София, на 300 m от Източната порта на древна Сердика и представлява комплекс от антични сгради - римски театър датиран от края на II, началото на III век и амфитеатър датиран от края на III началото на IV век. Амфитеатърът по големина се доближава до Колизеума в Рим. Размерите на овалната арена на Сердикийския амфитеатър са: дължина 60.5 м и ширина 43 м. Съчетанието на римски театър и късноантичен амфитеатър е уникално в световен мащаб. Откритието е направено през април 2004 г. при строежа на хотела, но още през 1919 година е било намерено свидетелство за местонахождението му - каменна плоча с илюстрация на гладиаторски битки.

В заключение може да се твърди, че съществуващите площадни, улични и градински пространства в източната ос на главния градски център на София крият голям потенциал за тяхното обновяване и по-оптимално архитектурно-градоустройствено оформяне, при което да се превърнат в удобни пешеходни зони с големи композиционно-художествени достойнства. В тази част на столичния център са възможни дори и нови градски площадни пространства свързани с важни обществени сгради или паметници на културата (до сградата на Софийската опера, до Римския амфитеатър и др.). Архитектурно-градоустройственото преосмисляне на източната ос на столичния център с акцентиране на обществените пространства, възраждане на съществуващите и оформянето на нови такива пространства се превръща в значително професионално предизвикателство за обновяване на софийския център и за повишаване на архитектурно-художествените му достойнства като Европейска културна столица с достойно минало, настояще и бъдеще.

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ECOURBARCHITECTONIC BRUTALISM IN CITY

Nikola CEKIĆ[1], Miomir VASOV[2]

[1, 2] The Faculty of Civil Engineering and Architecture of the University of Nis SERBIA - 18000 NIS, Aleksandra Medvedeva St. 14/111

Abstract: *Focusing attention on cultural-city building and historical protection of ecourbarchitectonic physical structures in urban environments is a basis of new formation of macroambient entities. By protecting structures in the sphere of complex, cultural, progressively degraded space, this paper emphasizes a new character of approach to the urban design of cultural heritage and stresses the need for the increasing sensibility in creation of nonglobalistic concepts and in their transformation to a strong developmental potential. Historicity of a location and their quality organic remodeling are a primary task in renovation of cities and activation of new ideas about flexible, synthetic planning of buildings in public space. In these ecourbarchitectonic interventions, integrative-rehabilitation processes could be imperatively strictly observed: genius loci and its identity with all the existing building in the ambient entity in a wide range from architectonic-structural, designing-esthetic to cultural historical and social-artistic particularities. Traditionalistic approach is necessary so as to prevent a wrong interculturalism and ineffective formal quality of urban places in reconstructions and constructions. Such options which did not result in a responsible consolidation in renovation and strengthening of historical authenticity of inherited structures, but a cultorological and artistic-esthetic confusion in space, are accented through examples in the paper.*

Key words: *ecourbarchitecture, integration of cultural heritage, conservation and protection, renovation, cultural downfall*

1. Introduction

There are many microambient entities worldwide which feature considerable conceptual city-building deviations from the basic urbarchitectonic and strategical-historical models. The extent of this phenomenon is such that the new cultural-formal patterns in space drastically changed the balance between the old and new physical structures. Simply, a different, hybrid spatial concept has been established, in which we can observe numerous problems: historical-cultural diversity of house appearances, esthetic-artistic imbalance, new geometrical strategic design and an orientation which does not honor the necessary interaction of cultures between the urban design of inherited forms, nor the relations of diverse materialization, plasticity of facade surfaces, their coloration and texture, joints in the contact zones of structures, specific appearance of their physical structures, genius loci and iconology of space. This research shows

[1] Academician, PhD Nikola CEKIĆ, grad. Eng. of Arch., full professor, Aleksandar Medvedev Str. 14/111, 18000 Niš, Republic of Serbia, E-mail: ncekic@yahoo.com
[2] Assist. Prof. PhD Miomir VASOV, Eng. Arch. The Faculty of Civil Engineering and Architecture of the University of Nis. SERBIA - 18000 NIS, Aleksandar Medvedev St. 14/112. E-mail: vasov@medianis.net

unacceptability of diverse, non-synthetic formation adjacent architectonic forms in space. It focuses on the lack of sense for preservation of urbarchitectonic heritage and deviation brought about by inorganic, even violent interpolation of physical structures, brutal urban cultural mixture and imposition of global philosophy of disrespect of preservation of old city localities.

2. Research



Fig. 1. Hilton Budapest - Castle District. Communist era Hilton Hotel, completed in 1976
https://upload.wikimedia.org/wikipedia/commons/1/17/Medieval_Church_Remains_(Dominican_yard)_Monument._Budapest_Hilton_(rear_view)_Buda_Castle_Quarter,_Budapest.JPG
http://www.sixumbrellas.de/?p=601
https://www.google.com/search?tbs=sbi%3Acs&tbnid=Qpw68WIIBBEfdM%3A&docid=vi8aJvr3CcxWMM&bih=770&biw=1536&ved=0ahUKEwih67u1j6fMAhWEtxoKHdGtCN8QiBwICQ&dpr=1.25
http://mw2.google.com/mw-panoramio/photos/medium/54340433.jpg

The Hilton Hotel in Budapest, having 321 accommodation units was built incredibly quickly built, against the strong opposition of professional town planning-architectonic public, on the most attractive historical locality, in the old Buda city. It was constructed in a year and half, on the ruins of renovated Dominican monastery, with a lot of relics, with a splendid panoramic view of the Danube and Pest. It is located next to the Fishing bastion and the St. Matthias church, on top of Buda Castle Hill, in the impressive Palace district, which is a part of the UNESCO world heritage. The foundations for this neo-gothic church date back to 1015. The quick building intervention, the genius loci was disrupted by a severe cultural incident, even though the designers strived to produce the best organic composition of the old, ruined wall remains and new physical structures of the hotel. Dramatic cultural diversity of forms and materials of structures in the environment brought about a new identity of the place, an unrecognizable cultural pattern, mixture of urbanologic,-architectonic relations, cultural-communication and historical deviation from the basic spatial matrix.

Sant Francesc Church, Santpedor, was originally built between 1721 and 1729 by the Franciscans in Spain. After several centuries of usage, the structures was dilapidated to a point when it needed a radical building reconstruction. The reconstruction was performed, at a surprise of many experts, by adding the new and very contemporary architectonic volumes and materials, creating thus a complex and contrasting ecourbarchitectonic spatial hybrid between the old and new stone structures of walls and archisculpturally designed volumes, crosswise-laid structural beams, of acute, geometrical edges.



Fig. 2. Sant Francesc Church, Santpedor, Spain. Amazing contrast between old stone structure and new sharp Spain's Crumbling Sant Francesc Church Gets a Modern Renovation by David Closes
http://acdn.architizer.com/thumbnails-PRODUCTION/c9/89/c9898b062b9fdb9510b9b36aab747666.jpg
https://www.google.com/search?tbs=sbi%3Acs&tbnid=6UQxNrN9uobQiM%3A&docid=9k08ABJNGljDWM&bih=770&biw=1536&ved=0ahUKEwjsj8GAi6fMAhXBOxoKHWnhApAQiBwICQ&dpr=1.25

All this is combined to the glass apertures which make the entire physical structure dynamic but also provocative in historical-cultural terms. The restored church has very specific appearance for the professional public. It has a provocative-polemic and challenging characters. Deviations from the original conceptual urbarchitectonic design of the church were stressed to the extent that they open the complex questions when approaching revitalization and creation of new conceptual values in formal, integrative processes, as well as the limits to which on can go in changing identity of places in the urban space.



Fig. 3. Penthouse on the bunker, Hamm Westfalen, Germany
http://acdn.architizer.com/thumbnails-PRODUCTION/14/d8/14d8041d4247881beac3c2649e8d7e65.jpg
http://architizer.com/projects/penthouse-auf-dem-hochbunker/
http://acdn.architizer.com/thumbnails-PRODUCTION/e6/12/e6127d947886cbecfc068086040fee8e.jpg
http://acdn.architizer.com/thumbnails-PRODUCTION/ad/00/ad00fff80cde8eabd16bc5c804b57e12.jpg

The example of the building constructed on the foundations of a tall bunker in Hamm Westfalen - Germany, also poses the question of ideology of urban design and capacity of old and new architectonic forms for interpolation. In this example as well, it was confirmed that in creation of new ecourbarchitectonic space, designing cultural sensitivity is required as well as observing the complexity of a locality - of natural and artifact structures with which a multidisciplinary intuitive dialogue must be established. Penthouse on the bunker is structured on an orthogonal grid. The newly built section has prismatic volumes. This

resulted in a large discrepancy of cultural-materialization individuality of walls and their historicity - this is a reflection of obvious misunderstanding of characteristics for realized combinations of architectonic elements in a physical structure. A brutalistic intervention resulted in a new, unintelligible concept, radical change in planning, controversial fusion of design and degradation in production of urban space.



Fig. 4. The Porter House by SHoP Architects - Meatpacking District. Porter House with Architect Gregg Pasquarelli of SHoP Architects. Original Building: 1905, Addition: 2003, New York
https://duranvirginia.files.wordpress.com/2013/09/virginia-duran-blog-amazing-buildings-you-shouldnt-miss-around-the-high-line-porter-house-by-shop-architects-day.jpg
https://s-media-cache-ak0.pinimg.com/236x/0d/7e/ca/0d7ecab2a7a823c7e38de1a7209dd42a.jpg
https://c2.staticflickr.com/2/1232/1408962837_f6697837a0_b.jpg

Extension of a New York building built in 1905 shows complexity of interpolation of the new structure and creation of a new spatial urban concept. New urbarchitectonic parallelepiped form, made of diverse materials and façade planes, has a narrative design which in the total transformation brought about a practice with a utilitarian character in newly formed characteristic floor layouts, but not the respect of existing forms in the immediate environment. The focus is on a new introduction and understanding of hybrid artistic and cultural ecourbarchitectonic innovations in the environment, whereby the inherited structures lose their essential, relevant social-historical, artistic-iconological and esthetic traits. What is necessary is an integral approach to urban design, in order to avoid large cultural-ecourbarchitectonic and visual differences and a brutal deviation and loss of the identity of the place. It is necessary to carefully change the value perception for urban environments in which the microambient spaces would be created though scientific research and precise strategic analyses. The example from New York is a part of new ideology in which the pressure of globalization imposes an urbarchitectonic and overall designing diversity of physical structures in public space in which there is no dialogue.

Jayleen Hotel u Singapore is indicative for a very frequent neglect of urbarchitectonic historical values and for a city building action in which strategical urban design permits very liberal promotions of new structures in the public space, without observing the cultural identity of existing physical structures. The structures in the immediate vicinity of Jayleen Hotel are very indicative for disrespect of the spirit of the place and its iconology. Not only the form of adjacent buildings, but materialization and coloration of the facades drastically change the physiognomy of the street by multicultural scenographic collage. They create a conflict of positions at the level of the history of the city and its memory. As if the designers forgot the conservations of cultural traditions and sensibility to different character of locations and easy creation of conflicting situations.



Fig. 5. Jayleen 1918 Hotel, Singapore
http://www.panoramio.com/photo/95025212
http://media.expedia.com/hotels/9000000/8100000/8091200/8091185/8091185_50_b.jpg
http://www.manypathstotread.com/singapore

New "hybrid identities" suggest search for ecourbarchitectonic balance where brutalistic-globalistic creative approaches can forever destroy the inherited structures.



Fig. 6. Budapest - church based on the plans of Johann Georg Pauer. The imposing church building was erected between 1725 and 1732. Szervita Church at Szervita Tér square
http://m.cdn.blog.hu/va/varoskepp/image/2009/70es/szervita4n.jpg
https://upload.wikimedia.org/wikipedia/commons/6/65/Szervita_templom_Budapest.jpg
http://www.ourtravelpics.com/budapest/budapest_123.jpg

Mixing of building cultures and disrespect for the spirit of urban locations can be seen in the example of Szervita Tér square in Budapest. Grotesque, brutalistic contrast can be recognized in the violent urbarchitectonic fusion of a church built according to the design of Johann Georg Pauer in the period 1725 and 1732 and aluminum curtain wall. A part of the structure next to the church, having ground floor and three floors was demolished in order to create town-planning and location conditions for construction of the administrative building. Great cultural and historical diversity, mixing of confusing architectonic-designing styles is evident, as well as the conceptual design of unharmonized materialization of the façade frontal plane, which creates esthetic-visual and artistic problems in public space. This "mix" of the structure of diverse functions, non-cultural

forms and facades obviously indicated the spatial visual-communication, functional conflict and in general the image of the city which had to be imperatively preserved as authentic historical-ecourbarchitectonic heritage. By dramatic accentuation of formal and urbarchitectonic differences, the strange logic established microambient, hybrid, destabilized and undesirable identity of the place.



Fig. 7. Zanderroth architekten: Christburger residential buildings, Berlin
http://afasiaarchzine.com/wp-content/uploads/2015/09/zanderroth-architekten-.-Christburger-residential-buildings-.-Berlin-3.jpg
http://www.zanderroth.de/de/projekte/cb19/
http://www.archilovers.com/projects/164404/gallery?1411178

Lack of harmony between the immediately adjacent ecourbarchitectonic forms can be observed on the Christburger residential buildings in Berlin. Different narratives in architectonic formation of façade planes are clearly evident in conceptual design of façade openings, their size, plastics of elements and the method of solving the contact zone of physical structures in the interface zone. It was necessary to adapt - balance façade appearances of adjacent buildings in order to avoid drastically different forms and preserve the existing, inherited structure of the building having a ground and 4 floors. The designers did not observe the height of the cornice of the inherited building, so the newly designed ecourbarchitectonic form noticeably deviated from the general concept of façade appearance in the street. In addition, the geometrical composition compared to the other buildings remained uncoordinated, which is a further evidence of the globalistic city building philosophy, where, as it seems, everything is allowed for the sake of modernity and creation of a new, hybrid, esthetic, collage identity suited to different criteria - economic ones, primarily. Contrasting forms between the inherited and new architecture can be seen in the center of Dnipropetrovsk city, Ukraine, on a structures whose dominant façade is based on a multicultural identity. The only feature remaining from the inherited, neglected building having ground floor and 2 upper floors is the façade plane with a rich, attractive plastics, while the administrative-office building with strong structural face was built in the background and the upper zone of the old building. The building belongs to different architectonic-historical and cultural groups according to its ecourbarchitectonic and designing properties, emphasizing the iconological memorial spirit of the place in the city center. What has been imposed is a brutal prism form whose verticality disrupts the profile of the entire vertical composition of central city structure.



Fig. 8. It is centre of Dnipropetrovsk, Ukraine. The contrast between old and modern architecture. The modern edifice has been built up instead of the old house. Only facade remains from the old house.
http://media.expedia.com/hotels/9000000/8100000/8091200/8091185/8091185_50_b.jpg17 000 m2
http://www.skyscrapercity.com/showthread.php?t=338754&page=43
http://ink361.com/app/users/ig-1983351144/doodnio/photos/ig-1039979344716489834_1983351144
https://marketplace.500px.com/photos/76588079/modern-architecture-exchanges-old-buildings-by-igor-traven

The inherited architecture was abandoned and pushed to the background, and the new character of identity in the central city space was accentuated. The adjacent physical structures in the immediate environment, which also belong to different architectonic styles were not taken into account. It was necessary, in organic and synthetic terms, to very carefully analyze the wider environment and inherited structures to realize a true city building intervention and preserve the inherited architecture.



Fig. 9. Now images of Bewag house in the Luisenstrasse 35, Berlin
http://fassadenretter.de/objekte/luisenstra%C3%9Fe-35
http://www.abload.de/res/imgs/403.gif
http://www.abload.de/img/luise017rac.jpg

Significant changes on many buildings around the world are observed through addition of thermal insulation material on the facades - Styropor, styrodur etc. which extinguishes the identity of the original physiognomy. The example from Berlin is a striking example of this phenomenon, whereby the adjacent structures with details and fragmented cultural patterns become suppressed in architectonic-esthetic and designing terms. The inherited physical ecourbarchitectonic structures, with innovated facades radically change the physiognomy of the space of streets, squares and plazas, and bring about a cultural diversity of forms by creating different resources in which the significant historicity of the place and its memory identity slowly disappear. .This additionally negates

cultural, urbarchitectonic differences in space. New globalistic concept is emphasized, a design in which standardized elements provide almost the same esthetic value and monotonously created public space. What we see are completely flat façade surfaces with little artistic-designing or visual character, most frequently featureless, devoid of culture or unrecognizable.



Fig. 10. Prague, in Czech Republic, the main boulevard contrast between austere communist and lovely cultural architecture. The Dancing House was built on the plot of a former building that was destroyed when the US bombed Prague in 1945 by accident.
http://oneturkeyrun.blogspot.rs/2015/10/eastern-europeans-teach-communist.html
http://fluper.ru/ffh/15/praga_nochnaya_praga_rassvet_2450x1378.jpg
http://img.radio.cz/pictures/c/rozhlas/praha/narodni_divadlo_nova_scena.jpg

There are several examples from the contemporary architecture of Prague, Czech Republic: from Vaclavske namesti, Dutch cultural center or the New Theater also demonstrate urbarchitectonic estrangement of certain physical structures in space and disregard for the inherited properties of architectonic structures and in particular for the immediately adjacent buildings whose historical value indicate the identity of the place. The globalist approach creates new, intensely emphasized, pretentious physical structures which suppressed the existing architecture and brought about radical changes in space. They brought about a cultural diversity where the houses lost their dialogue, and where they do not poses cultural esthetic, artistic-visual and designing homogeneity. What happened are most often dramatically interpolated conglomerates based on different designing and town-planning criteria which created a new spirit of the place, uniform global cultures in which the inherited architecture is pushed to the background. It is noticeable that architectonic heritage in certain urban environments is disappearing, and that diversity of forms in space with a multitude of new forms introduces a new modernity, ie. that the cities go through very rapid and radical urbanological changes.

3. Conclusion

City building activity on the creative basis of cultural ecourbarchitectonic heritage is nowadays a primary task for preservation of the historical matrix and planning-developmental fabric of cities of the world. The examples of the practice indicate that there were many wrong moves, uninventive attempts to integrate new physical structures in city building, historical and culturological terms with the old structures and establish new identity-significant artistic and recognizable visualization in the public space. There are several places with microambient entities and innovative environment, where the urban-metabolical design of new and old forms produced an irresponsible and low quality formal transformation, an inadequate and unimaginative mixture in space. It is our opinion that the complex process of respect and restoration and adaptation of old buildings, of interpolation of new physical structures, should be viewed as a balancing interactive cultural-scientific tool and not as designing avant-garde experiment. Even though there some opinions that in this challenging transformative activity of integration of old and new structures the best dialogic, formal, geometrical, functional, esthetic and contrasting combinations can be

achieved, utmost caution and the professional understanding is required of the complexity of relations of interior and exterior, diversity and esthetic-historical character of inherited physical structures and the immediate environment. The issue of cultural-original manifestation of realized contemporary interventions and adaptation of inherited ecourbarchitectonic authentic historical structures which need protection, normal continuation of fuctions by employing modern technologies, whereby the spirit of liveliness of the locality and dynamism of the location will not be degraded in cultural-historical and memorial terms. It is our opinion that it is necessary to preserve the identity of cultural traditions which represent differences between communities, their subcultural level as well as mixtures of new ecourbarchitectonic physical structures, spatial forms which significantly deviate from the fundamental city building narration and impact the complex character of the living space.

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МЕЖДУБЛОКОВИТЕ ПРОСТРАНСТВА В ПАНЕЛНИТЕ КОМПЛЕКСИ КАТО СОЦИО-КУЛТУРЕН ФЕНОМЕН ОТ ВТОРАТА ПОЛОВИНА НА 20 ВЕК.

Веселин Рангелов[1], Стефан Аспарухов[2], Веселин Шахънов[3] ,

Лесотехнически университет, Университет по архитектура, строителство, и геодезия

Veselin Rangelov, Stefan Asparuhov, Veselin Shahanov

University of Forestry, University of Architecture, Civil Engineering and Geodesy

***Abstract**: The construction of large residential complexes have as a global trend in the 50s of the last century in the US and Europe after the Second World War. It is the result of rapid urbanization, industrialization, overproduction and concentration of enormous human resources in big cities.*
The emergence, development and decline of housing estates is a phenomenon in the history of 20th century - one of the largest experiments in residential environment - an attempt to cardinally solve the housing problem. Its heyday was in the 60s and 70s and during the 90s already seen the first attempts to seek appropriate practices for upgrading.
The publication analyzes the issues relating to: (1) history of landscaping and public works in spaces between residential blocks and surrounding environment; (2) trends in landscaping and urbanization of the spaces between residential blocks, innovation and development opportunities; (3) the impact of vegetation and park furniture on the sanitary situation and comfort in the spaces between residential blocks, and possible guidelines for the conservation and management of these areas in the context of socio-economic sustainability of the micro-level.

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***Key words**: urban spaces, residential complexes, occupancy, planning*

[1] Веселин Петров Рангелов, главен асистент, д-р, ланд. арх., бул. „Климент Охридски“ №10, ЛТУ – гр. София, e-mail: veskorangelov@abv.bg;
[2] Стефан Валтеров Аспарухов, главен асистент, д-р, арх., бул. „Христо Смирненски“ №1, УАСГ – гр. София, e-mail: asparuhov_stefan@abv.bg
[3] Веселин Малинов Шахънов, ассистент, д-р, ланд. арх., бул. „Климент Охридски“ №10, ЛТУ – гр. София, e-mail: veshaha@abv.bg

1. Въведение

Възникване, развитие и състояние на междублоковите пространства в България в периода до 1990г..

Изграждането на мащабни жилищни комплекси се налага като глобална тенденция първоначално в САЩ, а по-късно и в Европа след Втората световна война. Това е в резултат на бърза урбанизация, индустриализация, свъхпроизводство и съсредоточаване на огромен човешки ресурс в големите градове. Те възникват малко по-късно и в страните на т.н. социалистически лагер поради същите причини. Опитите за постигане на универсални решения на жилищния проблем през този период неизбежно водят и до редица градоустройствени и благоустройствени затруднения, които поставят въпроса за адекватна организация на формираните междублокови пространства.

Възникването, развитието и упадъкът на жилищните комплекси представлява забележителен феномен в историята на 20-ти век като един от най-мащабните експерименти с жилищната среда и опит за кардинално решаване на жилищния проблем в големите индустриални градове.

Началото в развитието на това масово жилищно строителство и формираните в него междублокови пространства е непосредствено след войната. Неговият апогей е през 60-те и 70-те години, като през 80-те и 90-те години вече се забелязват първите опити за търсене на подходящи практики за тяхното обновяване.

У нас, както и в останалите страни от социалистическия блок, тези комплекси възникват в резултат на технологична еуфория и социално инженерство, без отчитане на съществуващите традиции на жилищната и социална среда. Наречени тогава райони и микрорайони, днес те представляват истинско предизвикателство за решаване както по отношение на амортизирания сграден фонд, така и по отношение деградацията и моралното остаряване на получените в миналото междублокови пространства.

Общественият характер на тези свободни територии сам по себе си компрометира идеята за обособяването на района и микрорайона като самостоятелни структури.. Свободният достъп до крайблоковите пространства поощрява самоцелни проекти за абстрактни потребители. Поради това критериите при проектирането им водят най-често до изграждане на „неадресирани" площадки и безсмислени алеи, чието основно качество е красивият рисунък, който може да бъде проследен от високите етажи. Поради еднообразието си, тези пространства задържат едва 5-10% от жителите на околните панелни или ЕПК блокове (Фиг. 1).



фиг. 1 Междублокови пространства в комплекс „Меден рудник", гр. Бургас

В миналото инвеститорите насърчаваха проектирането на по-дълги и по-широки сгради, а в по-късно време реабилитираха периметралната застройка от

началото на тези процеси. Както е известно, това доведе до увеличаването на Кинт (коефициент за интензивност на застрояването). Проектантите работиха с минимално допустимите разстояния между жилищните сгради (1,7÷2H), въпреки че по този начин теоретически е невъзможно да се разположат необходимите паркинги, спортни, детски и други площадки. Нещо повече, разработването на концепцията за „магнетизма", според която сградите задържат обитателите си на разстояние до около 20м. от входовете им, оправда намаляването на разстоянията между сградите, дори позволи да се слезе и под нормата за 3-часовото слънчево огряване за техните фасади.

Всичко това допринесе за общия неугледен вид на междублоковите пространства в новите жилищни комплекси. Те създават представата за „пустиня", за място, в което напразно се влагат средства за поддържане, за голямо недовършено площадно пространство , което би могло да бъде дозастроено. Именно поради това, жилищните комплекси, строени през 60-те и 70-те години, имат значително повече площи с растителност, отколкото реализираните през 80-те, когато зелените площи започват силно да се редуцират.

Общо състояние на междублоковите пространства в България в периода след 1990г..

Общият брой на панелните апартаменти в България днес е около 30% от наличния жилищен фонд. Динамиката в развитието на социално-икономическите отношения през последните 27 години промениха облика на панелните комплекси. Търговските обекти стихийно навлязоха в жилищната среда. Многообразието и самоделните подобрения направиха кварталите интересни и жизнени, но не ги доближиха до съвременната представа за качествено място за живеене. Процесите на социално преструктуриране и разслоение на обществото са все още слабо изразени поради задържащата сила на собствеността върху жилищата и ограничените възможности за финансови инвестиции. Все пак порасналите изисквания към средата за обитаване са причина за напускането на панелните жилищни комплекси от обитатели, които могат да си позволят това. Успоредно с това заможни предприемачи изкупуват и ремонтират апартаменти с цел продажба на значително по-високи цени и, най-вече, с цел отдаване под наем (не бива да се пренебрегва двойното увеличение на населението в столицата през същите тези 27 години). Остават обаче хиляди семейства, и не само в София, натоварени с бремето на собствеността, без средства за нейното поддържане и обновяване.

Проблемите на жилищните квартали, строени по индустриализирани технологии през 60-70-те години на миналия век, имат своите физически, социални, икономически, демографски и екологични аспекти. Материалното и морално остаряване на сградния фонд е лесно забележимо. Демографските промени във възрастовата структура, големината и броят на домакинствата, мащабът на безработицата, както и промяната в начина на живот, налагат различни изисквания към размера, съдържанието и функционалната организация както на жилищните сгради, така и на пространствата между тях. Съществуващите сгради не могат да отговорят на тези изисквания поради сериозни конструктивни затруднения при опити за вътрешни промени. Обновяването на тези жилищни комплекси с добро местоположение и изградена техническа и социална инфраструктура подпомага ограничаването на екстензивното разрастване на градските структури и застрояване върху ценна селскостопанска земя, както и върху просъществували дълги години природни паркове или непокътнати ландшафти около големите градове. В тази връзка е уместно да се потърсят основните пътища за излизане от тази негативна тенденция, предизвикана от ограничените възможности на държавата и нейното население за овладяването на гореизложените процеси.

По отношение на междублоковите пространства можем без никакво съмнение да определим основния въпрос за решаване – собствеността върху земята. Оттам нататък всичко може да бъде решено бързо и ефективно при едно що-годе приемливо спазване на законодателството на страната.

Можем да продължим с отразяването на тази тенденция с примери на демащабирани (преоразмерени или умалени) пространства, занемарени зелени площи без професионално поддържане. Благоустрояването и паркоустрояването в миналото често се изпълняваше на случаен принцип с кампанийни акции от типа на „Ленински съботник", „Седмица на гората", ученически и студентски бригади, 45-дневни бригади на служители и пр. Тези мероприятия бяха задължителни за участниците в тях и в повечето случаи безплатни. Днес те продължават и са много по-разнообразни, но се базират върху напълно дилетантски програми като „Зелена София", „Ариана търси компанията пред блока" и др. Непрекъснато се толерират и финансират непрофесионални и безпринципни устройствени мероприятия в междублоковите пространства от некомпетентни, но много активни субекти. Пълното отсъствие на икономическа целесъобразност при всички благоустройствени и паркоустройствени дейности днес е маскирано под кодови понятия като устойчивост на биоценозите, развитие на екологичния потенциал, пърформънси, инсталации и други урбоекологични ивенти.

Сравнителният анализ на проблемите и състоянието на междублоковите пространства в различни части на Европа показва, че има голямо сходство, но и разлики между тях. Едни и същи дадености на средата се възприемат от обитателите като позитивни или негативни. Главни предимства на тези пространства за едни, са основен недостатък за други. Например свободните площи между блоковете се възприемат неоднозначно – за някои те осигуряват простор, въздух и зеленина, а за други те са потенциален ресурс за уплътняване на застрояването с нови функции.

Основните констатации при внимателен анализ на състоянието на тези свободни територии са следните :

- нееднороден социален статус на обитателите
- тотално неглижиране и незаинтересованост на обитателите от околните жилищни блокове към естетиката на пространствата
- безстопанственост по отношение алейните настилки и занемаряване на градинската мебел
- отсъствие на ефективно осветление, кошчета за смет и други битови архитектурни паркови елементи
- нецелесъобразно и кампанийно поддържане на тревните площи и дървесно-храстовата растителност и цветята
- хаотично и непланирано изникване на търговски обекти
- прояви на антисоциално поведение, престъпност и вандализъм
- усещане за несигурност и санитарно-хигиенна безопасност
- категорично различни виждания на обитателите относно бъдещото развитие на квартала
- силно ограничено използване по предназначение на тези пространства (майки с малки деца в детски колички и по-рядко пенсионери)

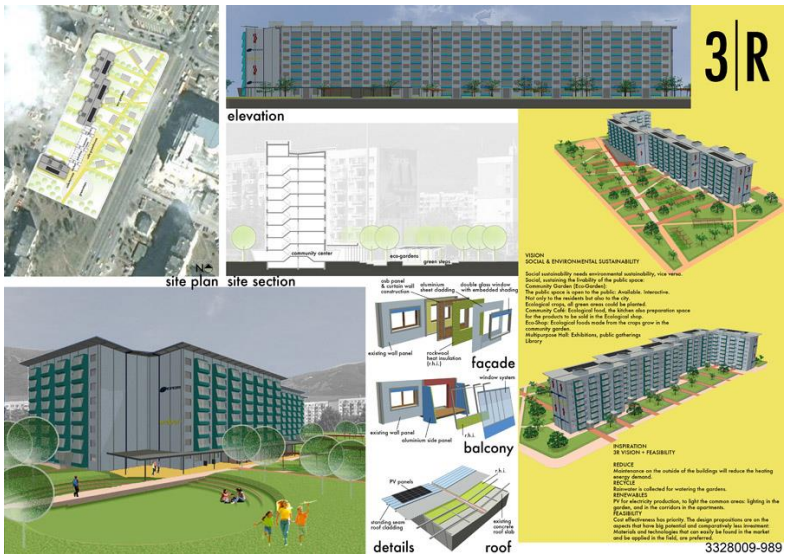
Прилаганите мерки за решаване проблемите на тези пространства са скъпо струващи и неефикасни, защото засягат само самите жилищни сгради и съвсем слабо естетиката на околната среда и нейното функционално използване. Физическите недостатъци на сградите, задълбочаващите се социални проблеми на обитателите, както и липсата на адекватни политики по отношение на тези свободни територии води неминуемо до тяхната естествена деградация.

Съвременни подходи и мерки за благоустрояване и паркоустройство на междублоковите пространства.

Подходите за обновяване на тези територии почиват на общо разбиране за глобалната цел на устойчивото развитие с неговите три основни аспекта: икономически, социален и екологичен, а именно - постигането на балансирана и стабилна жилищна среда. По отношение на междублоковите пространства това означава изграждане и управление на една хармонична и здравословна среда, способна да функционира дълготрайно физически и социално икономически, при минимално отрицателно въздействие върху природата.



а. Положителен пример за реновиране на междублоково пространство с ясна планировъчна структура и интегралност между архитектурното решение, благоустройството и паркоустройството.



б. Отрицателен пример със самоцелна композиция на алейната мрежа, водена от прекалена амбиция за дизайн, задълбочаваща проблемите на съществуващите междублокови пространства

фиг.2: Проекти от конкурс на АРХМОДУЛ „Нов живот за панелните комплекси“

Последствията от промяната в климата, от една страна, налагат да се вземат мерки за съхраняване на околната среда чрез подобряване на енергийната ефективност на сградите и намаляване на замърсяването, а от друга, да бъдат търсени устойчиви съчетания между архитектурните и вегетативните обеми с

подходящ и актуален видов състав, който също би могъл да оказва пряко влияние върху енергийния баланс на околните жилищни сгради (Фиг. 2).

Издигането на растителността във вертикална посока е една от малкото алтернативи за внасяне на растителност в силно урбанизираната среда. Последни проучвания показват зависимост между цената на жилищните сгради и липсата или наличието на зеленина, в частност вертикални озеленени плоскости тип вертикални градини.(Шахънова, М. (2015) Биологични модели за създаване на вертикални градини в интериора. Дисертация, Лесотехнически университет, София, стр.2, 174.)

Променящата се демографска структура и начин на живот, различните финансови перспективи за придобиване на жилища, нуждите на хора с ограничени двигателни способности и много други фактори определят възможностите за избор като едно от най-важните условия в планирането на цялостния комплекс от жилищни сгради, междублокови пространства и комуникации и инфраструктура.

Реабилитирането на идеята за общност е мярка за противодействие на социалните проблеми на кварталите, престъпността и разрушаването на социалните ценности. Осигуряване на приемственост при изграждането и експлоатирането на междублоковите пространства дава възможност да се съчетаят добрите традиции на миналото с изискванията на настоящето и с новите идеи за бъдещето.

Съвременните технологии и строителни материали повишават както естетическата стойност на средата, така и експлоатационната й продължителност. Използването на подобни технологии в обновяването на междублоковите пространства намалява стойността и дава възможност за тяхното по-пълноценно използване.

Негативните резултати от прилаганите през 80-те г. програми затвърждават убеждението, че инвестициите трябва да стимулират устойчиви на времето решения, които могат да бъдат постигнати единствено с комплексен подход към проблемите на жилищните квартали. Мерките за физическото обновяване и модернизиране на сградите и благоустрояването на околната среда са тясно обвързани със средствата за повишаване на енергийната ефективност. Те имат смисъл само в условията на социална и икономическа стабилност, постигането на която е предмет на не по-малки усилия и средства. Отчитането на реалните нужди и приоритети на обитателите и постигането на консенсус между всички участници в процеса насочват ресурсите във вярната посока и правят този подход ефективен.

Макар че проблемите в междублоковите пространства на жилищните комплекси, строени през 60-70-те години, изглеждат еднакви, дейностите за тяхното разрешаване варират в широк спектър. Някои от тях с добър потенциал за развитие биват санирани, други частично преструктурирани, а трети напълно разрушавани заедно с ограждащите ги сгради поради невъзможност да се преодолеят социалните и икономически проблеми.

Подходите могат да бъдат групирани както следва:

• запазване характера на междублоковото пространство, но модернизация на ограждащия сграден фонд.

• частично поетапно преструктуриране на пространството съобразно променената рамка или нужди на обитателите.

• пълно преструктуриране на жилищния комплекс и формиране на нови междублокови пространства.

Независимо от различната степен на интервенция в междублоковите пространства подходите включват целия спектър от мерки, необходим за създаването на устойчива градска среда.

• цялостна реконструкция на паркоустрояването и благоустрояването – нова алейна мрежа с обособяване на нови зелени площи

• изграждане на съвременни детски площадки с комбинирани детски съоръжения

• подмяна на водните площи и парковата мебел

• запазване на ценните декоративни дървета, санитарна сеч и засаждане на нова дървесно-храстова растителност

• оптимизиране на улиците, тротоарите и местата за паркиране, създаване на непрекъсната велосипедна мрежа с безопасно преминаване на кръстовищата

• обособяване на малки дворове или тераси в партерните нива на сградите, които защитават уединеността на жилищата

• изграждане на места за социални контакти, подходящи за различни възрасти

• създаване на оградени и изолирани спортни игрища с ограничителен режим на ползване

• комплексно подобряване неугледния външен вид на ограждащите пространството жилищни сгради

• подобряване сигурността чрез подходящо ограждане и растителни обеми, които ограничават достъпа на външни лица в близост до жилищата

• усъвършенстване на системите за сигурност и видеонаблюдение

• сигуряване на малки архитектурни форми и елементи на достъпна среда

• модернизиране на местата за отпадъци

• дефиниране на границата между частното и публичното пространство

• участие на обитателите в проектирането и управлението на междублоковите пространства

В разглежданите жилищни комплекси, след като се запазят основните пешеходни оси, е възможно да се позволи на обитателите да оградят собствените крайблокови пространства, а дори след време и да им се продадат. По този начин общината ще спести средства от поддържането им и би могла да концентрира усилията си във формирането и интензивното поддържане на „зеления гръбнак” на територията. Общините следва да възложат разработването на единна концепция за реконструкция на тези свободни територии. Формирането на обособено дворно пространство около жилищния блок променя характера, духа и атмосферата на средата. Практически би отпаднала необходимостта от разполагането на неподвижна паркова мебел. Увеличават се възможностите за полифункционалното използване на настланите площи, които от своя страна могат да намалят квадратурата си за сметка на терените, заети от растителност. Ограденото пространство осигурява много по-добри възможности за стопанисване и поддържане на тревните площи, дървесно-храстовата растителност и цветята.

Част от общините в София имат високи подпочвени води, което позволява дори изграждането на собствени кладенци със съответните икономични поливни системи. Възможно е включването на малки постройки – летни кухни, павилиони, навеси, а на

места и малки плувни басейни и декоративни водни площи с ефектно осветление по примера на новоизградените жилищни комплекси от затворен тип (Фиг. 3). Оградения двор представлява предимство за майките, които биха могли да оставят децата си без надзор. Успоредно с това дворът осигурява и по-висока степен на безопасност на жителите от партерните етажи.



а. „Цариградски комплекс“



б. комплекс „Оркид хилс“



в. комплекс „Сите жарден“



г. комплекс „Макси“

фиг. 3: Жилищни комплекси от затворен тип

Изводи

Както беше изтъкнато по-горе, собствеността върху жилищния фонд и земята в кварталите е ключов фактор в програмите за обновяване и модернизиране на тези пространства. Частната собственост върху жилищата в България и липсата на собственост върху земята и прилежащите терени е главна пречка за успешното реализиране на тези програми. Влошаването състоянието на сградите ще принуди собствениците да търсят начин за обединяване на усилията за справяне с проблемите. Създаването на публично-частни партньорства от типа на жилищни фирми или сдружения с широко представителство на собствениците, общините, правителството, неправителствения сектор и други заинтересовани лица, може да бъде съществен фактор при решаването на проблемите на междублоковите пространства.

Съвместната дейност между обществен и частен сектор има редица предимства, тя може да привлече инвестиции в места с определен пазарен потенциал, като осигури баланса между сигурността на капитала, срока на инвестицията и възвръщаемостта й, но изисква приемлива степен на доверие и риск. Реформите, които могат да бъдат осъществени по този начин, следва да стартират чрез разграничаване на публичната собственост върху земята за пътища, площади, паркинги, зелени площи и др. от терените, предназначени за жилища. Подобно на

новоизградените затворени жилищни комплекси, фирмите, които ги стопанисват, придобиват владение върху земята под сградите и прилежащите им зелени площи, включително вътрешните пространства между блоковете, паркингите, кътовете за социални контакти с барбекюта на открито, спортните и детски площадки, местата за съхранение на отпадъци, по-малки алеи и вътрешни обслужващи улици.

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РОЛЯТА НА СГРАДИТЕ НА БАЛНЕОЛОГИЯТА В ГРАД КЮСТЕНДИЛ, ВЪЗМОЖНОСТИ ЗА ОБНОВЯВАНЕ НА СЪВРЕМЕННАТА МУ ГРАДСКА СРЕДА

Димитър Власарев[1], Антон Гороломов[2], Николина Виденова[3], Стефан Александров[4], Стефани Романска[5], Гергана Величнова[6], Любомир Максимов[7]

Висше строително училище „Любен Каравелов“

THE ROLE OF THE BUILDINGS OF BALNEOLOGY IN KYUSTENDIL, POSSIBILITIES FOR RENOVATION OF ITS CENTRAL URBAN ENVIROMENT

Dimitar Vlasarev, Anton Gorolomov, Nikolina Videnova, Stefan Alexandrov, Stefani Romanska, Gergana Velichkova, Lyubomir Maksimov

University of Structural Engineering and Architecture "Luben Karavelov"

***Abstract**: This study examines the role of spas as a factor for the development of the city of Kyustendil. A brief historical summary and analysis of the historical balneological complexes in the city is done. An evaluation of their participation in the modern urban environment is done. Examples and suggestions for improving the impact of these buildings on the whole urban organism are presented.*

***Key words**: buildings of balneology, Kyustendil, possibilities for renovation, central urban enviroment*

1. Увод. Ролята на минералните извори за развитието на град Кюстендил

Кюстендил е един от най-древните български градове. Със своята осемхилядолетна история той има повече от 1900-годишна градска характеристика.

След падането на Тракия под римска власт (45 г. от н.е.) римляните превръщат селището на траките във важен търговски център и известен балнеологичен център с име Пауталия, което се среща за пръв път през I-ви век върху една монета, сечена в

[1] Димитър Власарев, доц. Д-р арх., ВСУ „Любен Каравелов“, гр. София, dvlasarev@abv.bg
[2] Антон Гороломов, студент, ВСУ „Любен Каравелов“, гр. София, tonyngor@gmail.com
[3] Николина Виденова, студент, ВСУ „Любен Каравелов“, гр. София, niki_sweet92@abv.bg
[4] Стефан Александров, студент, ВСУ „Любен Каравелов“, гр. София, tsef7n@abv.bg
[5] Стефани Романска, студент, ВСУ „Любен Каравелов“, гр. София, stefi.romanska@gmail.com
[6] Гергана Величкова, студент, ВСУ „Любен Каравелов“, гр. София, velichkova.gery@gmail.com
[7] Любомир Максимов, студент, ВСУ „Любен Каравелов“, гр. София, lyubomir.maksimov@gmail.com

града. На нейното лице стои образът на Асклепий – бог на медицината, а на обратната страна е изобразена змия – знак на целебни води.

Древна Пауталия създава почитта към градската баня.

С падането на България под турско робство в Кюстендил също се възражда почитта към минералната вода. Турците построили в района около 12 бани, три от които са се запазили и до днес. От тях само Дервиш баня, построена през 1566г., е съхранена в първоначалния си вид. [9]

И до днес минералните извори като природен фактор на Кюстендил за градското развитие оказват изключително важно значение в устройственото му развитие. Съществуват 36 броя минерални иззвори в града, като дебитът им ги нарежда на първо място в България с около 1980-2100 литра на минута и със средна температура около 74 градуса.



а) б)

Фиг.1. а)опорен план на центъра на град Кюстендил с обозначени места на балнеоложки центрове; б) национален културен и археологически резерват Пауталия-Велбъжд-Кюстендил (карта на археологията)

2. Исторически паметници

2.1 Пауталийски асклепион

Пауталийският асклепион не е запазен до наши дни. Представлявал основна сграда с правоъгълен план и двусклонен покрив. На предната страна имал триъгълен фронтон, поддържан от 4 колони с коринтски капители. Строен през 1 и 2 век и имал обща площ (заедно с постройките на допълващото застрояване и римските терми) около 3600 m². Посещаван е от почти всички римски императори. Бил е втори по големина на Балканския полуостров след този в Епидавър. [3]

Банята имала помещения както за групово, така и индивидуално посещение и лечение. В римските терми имало аподитериум (съблекалня), тепидариум (умерено топла зала), калдариум (гореща зала), фригидариум (студена зала), лаконикум (пералня), палестра (гимнастическа зала). Отоплението на баните било по типично римски модел - с хипокауст, който затопля пода, после стените и цялото помещение.

Асклепионът обхващал освен баните и комплекс от антични постройки, предимно храмове на божества от гръко-римския пантеон. Освен храмовете имало парк, гимназион, стадиони, театри, както и други обществени постройки. Архитектурата на асклепиона била типично римска. [4].



а) б) в)

Фиг.2. Пауталийски асклепион: а), б) разкрити римски терми в Пауталийския асклепион; в) монета, от която се съди за архитектурата на асклепиона.

2.2 Дервиш баня

Дервиш баня е средновековна османска обществена баня в центалната част на града. Построена е през 1566 г., видно от цифров надпис от червени тухли на фасадната стена. Банята е изградена от ломени каменни блокове и червени тухли – в традиция на т. нар. „живописен стил", характерен за българските архитектурно-строителни школи. При строежа са използвани материали от стени на средновековековната крепост.[1]

Пространството включва правоъгълно помещение, покрито с масивен цилиндричен купол, съблекалня и подиум. Къпалнята и басейна с лековита гореща минерална вода са осмоъгълни в план, облицовани с мрамор. В ъглите са разположени мраморни чешми – курни. В полусферата на купола от кръгли остъклени отвори прониква дневна светлина. В северната фасада е изградена ритуална ниша, където палели свещи и принасяли в жертва петли – далечен отзвук от култа към древния бог на медицината – Асклепий. Клетъчната зидария, корнизът тип "вълчи зъб", прецизното фугиране, покритието с оловни плочи, светлинните кръгове от лято стъкло на купола над къпалнята и пластичните форми на банята са характерни заархитектурата по българските земи от времето на османското владичество.[2] През 2005 г. е цялостно реставрирана и е обявена за архитектурен паметник на културата.[1]



а) б) в)

Фиг.3. Дервиш баня: а)изглед; б) детайл на зидарията, зъбореза и оформяне на арка над прозорец; в) Дервиш чешма.

2.3 Алай баня

Алай баня (Войнишката баня) е обществена баня, построена върху основите на късносредновековна турска баня. Намира се в централната част на град Кюстендил, на ул. "Хан Крум" № 22.

Първоначалната турска баня е частично разрушена след Освобождението, и е възстановена през 1912-1914г като неголяма двуетажна сграда с едно отделение. Тя има и външна чешма с минерална вода. През 1928 година е преустроена в настоящия си вид.



а) б) в)

Фиг.4. Алай баня, сегашен вид

2.4 Чифте баня

Чифте баня се намира се в централната градкса част, между улиците Христо Смирненски и Стефан Караджа, до джамията "Ахмед бей". Първоначалната турска баня е построена през 1489г. от Сюлейман паша върху основите на Пауталийския асклепион. [10]

През 1910г. късносредновековната "Чифте хамам" е частично разрушена и върху основите и е изградена нова модерна градска баня, със самобитна архитектура, по проект на архитект Христо Ковачевски (1860-1949) от град Кюстендил. Преустройството и реконструкцията на банята завършват през септември 1913г. [10] Оттогава насам Чифте баня се използва и днес, като в настоящия момент тя е предназначена най-вече за балнеология. Около Чифте бяна е изграден парк, наречен Банската градина, който е паметник на парковото изкуство в Кюстендил. [9]

Банската градина е създадена през 1912г. по проект на архитект Христо Ковачевски. Първите дървесни видове са чинарите пред централния вход на банята. През 1974г. са засадени иглолистни видове: туя и обикновен смърч, а през 1935г. градинарят при Кюстендилската община Ал. Балабанов засажда пауловния, плачеща черница и декоративни храсти.



а) б) в)

Фиг. 5. Банската градина: а) Паметникът на Пейо Яворов; б) Пластична композиция в градината; в) Банската градина

Под плачещата черница е разположен бюст - паметник на Пейо Яворов. Паметникът е копие на паметника на поета в Парка на свободата в София. Автор на паметника е Гр. Петрович Агаронян, открит е през 1929г.

През 1960г. след археологическо проучване са експонирани руините на римските терми и лапидариум.

3. Предложения за развитие на балнеоложка рекреативна ос на града

Понастоящем баните не се вписват добре в селищния организъм, те са откъснати, не са в система и пешеходният достъп до повечето не е добре решен. Желателно всяка от тях да стане чат от по-голяма благоустроена зона под формата

на балнеоложка рекреативна ос. Подобна зона, макар и със сравнително малки размери и без връзка с други зони, има само около Чифте баня – банската градина.

Предложението за балнеоложка рекреативна ос включва продължение на зелената система пред Чифте баня с комплкса на римските терми и създаване на композиционна връзка с централния площад и градската градина пред общината, както и композиционна връзка на Дервиш баня с оста.

Около Дервиш Баня понастоящем е решено кръгово движение. В близост е направен голям паркинг. Предложението е да се направи подходящ пешеходен доцтъп до Дервиш баня, да се премахне паркинга като банята се включи в композиционно единство с прилежащата зелена площ, елемент на рекреационната ос. Алай баня се намира южно от река Банщица като реплика от същесвтуващата рекреационна ос на реката. Банята може да бъде включена като елемент от балнеоложкия комплкс в бъдещо развитие на парковата зона по реката.



Фиг. 6. Предложение за балнеоложка рекреативна ос

Фиг. 7. Предложение за балнеоложка рекреативна ос по река Банщица



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ЛАНДШАФТНО-АРХИТЕКТУРНИ МЕТОДИ ЗА ОФОРМЛЕНИЕ НА ПРИРОДНАТА СРЕДА НА НЕДВИЖИМИ КУЛТУРНИ ЦЕННОСТИ

Мария Гуркова

Лесотехнически университет

***Резюме**: Неразделна част от опазването на недвижимите културни ценности е съхраняването на автентичния облик и културна значимост на естествения природен ландшафт, в който са формирани и съществуват. Динамичното развитие на естествените ландшафтни компоненти във времето води до изменение и на автентичната природна среда. Избраните методи на опазване определят степените на намеса и свързаните с тях елементи, необходими за представянето на обекти на КИН в природна среда и предполагат подходяща функционална организация на пространствата и благоустрояване при запазване на естествеността и екологичната им устойчивост. Изследването се насочва към методите на ландшафтната архитектура, които синхронизирани с някои ландшафтноустройствени и лесоустройствени практики, спомагат пълноценно защитата на недвижимите културни ценности и представянето им в природна среда в зависимост от избрания метод на опазване.*

***Ключови думи**: недвижими културни ценности, природна среда, методи на опазване, степени на намеса, благоустрояване*

Въведение

Недвижимите културни ценности и природната им среда представляват защитени територии за опазване на културното наследство. Те са фактор, който има значение за регионалното развитие, затова опазването и представянето им като туристически обекти са от първостепенно значение. Оформлението на природната среда в тези територии трябва да отговаря на комплекс от изисквания, сред които възможност за защита и представяне на ценностите, създаване на комфортна в естетическо и функционално отношение среда за отдих, опазване на ценни насаждения с културна значимост. Затова отговорната задача на ландшафтно-архитектурното проектиране е да спомогне съхраняването и експонирането на културната значимост на целия природен комплекс.

Поради установено разминаване в смисъла и съдържанието на понятието *място*, както между български и международни документи, така и в националното законодателство, в изследването по това наименование се имат предвид забележителни обекти и територии с културна значимост – историческа, научна, художествена или друга стойност.

Кратък исторически преглед установява, че още през 20-те, 30-те години на XX век природната среда на старините става обект на специално отношение и фактор за опазване [1, 2], а за природата на България са поставени ясни правила и режими за

защита. Разработената на по-късен етап нормативна база за специалното стопанисване на горите около забележителните места има за задача да съвмести културната с природната им стойност. От 1954 г. в дружеството за проучване и проектиране на горски територии Агролеспроект работи отдел „Защитени природни територии, парково и ландшафтно проектиране", който стои зад стотици мащабни разработки на исторически места и територии за опазване на паметниците на културата. Създадената в отдела специализирана методика включва: *предварително проучване, функционално зониране на територията, обемно-пространствено изграждане на растителността, включване на подходящи архитектурни елемент и провеждане на целесъобразна алейна мрежа.* Основните принципи на проектиране са подчинени на *взаимодействието на природата и обществото* и съвместяват опазването на *биологичното и ландшафтното разнообразие*, *научно-познавателната дейност* и *рекреационното туристическо ползване* [3].

Днес с бързи темпове се създават туристически атракции въз основа на съществуващи недвижими културни ценности в природна среда. Те са и една от отличителните черти на съвременния период в областта на опазването и представянето пред обществото, както и фактор за *устойчивото развитие на регионите*. Интересен анализ на териториалната организация на средата на някои културни ценности в последните години показва периодично предпочитание към точкови обекти, линейни обекти, площно-ареални обекти [4].

Материали и методи

В изследването е извършена съпоставка на:

- *Принципите на ландшафтната архитектура, компонентите и елементите на ландшафтната композиция* и приложението им в условията на природна среда с цел формиране и съхраняване на естествения ландшафт в исторически контекст или при композиционното оформление на средата като експозиционно пространство
- Степента на съхраненост, автентичният облик и културната значимост на естественият природен ландшафт, запазен или създаден чрез установени ландшафтноустройствени и лесоустройствени практики, определящи *методите на намеса*

Направен е опит да се изяснят някои съпътстващи естетически и функционални особености и какви са теоретичните възможности за тяхното решаване със средствата на ландшафтната архитектура в природна среда, но при съобразяване с изискванията за представяне на историческите места. Това би спомогнало спазването на основните постановки на международните документи в областта и в частност на Хартата на ИКОМОС за интерпретация и представяне на историческите места, която обръща специално внимание на околния ландшафт, природата и географските характеристики като неразделна част от историческото и културно значение на мястото [5].

Основните закономерности и принципи на ландшафтната архитектура, водещи до постигане на цялостна и единна композиция са установени отдавна в теоретичен аспект. Изясняването на целесъобразността, разнообразието, повторението, колоритът, мащабността и пропорционалността, равновесието, категоричността, контрастът, нюансът и равенството, перспективата и значението им при формиране на природната среда на паметниците на културата се нуждае от конкретизиране в теоретичен аспект. Това се налага най-вече поради *изискванията* при представянето – респект към ценността, съхраняване на автентичността и цялостта, ясно разграничаване на новата намеса от автентичните елементи. Постигането на визуално единство в природната среда в известна степен е улеснено

от синхронизираното развитие на природните елементи във времето под въздействието на различни фактори – физическо взаимодействие между горска растителност и скални масиви, развитие на мъхова и лишейна растителност едновременно и върху природните и върху антропогенните елементи. Търсенето на функционално единство между недвижимата културна ценност и новата благоустройствена намеса обаче се явява сложно предизвикателство и изисква сериозно предварително проучване. Богатото разнообразие от различни по категория, класификация, обхват и предназначение недвижими културни ценности предполага и съответствие с предлаганите ландшафтно-архитектурни намеси. Особено значение имат те и при комплексни ценности като археологическите резервати [6].

Целесъобразността при представянето на разглежданите обекти е водещ принцип пряко определящ основното предназначение на защитената територия. Прилагането на принципа изисква предварително да се установи необходимостта от намеса, и последващата синхронизация с качествата на ценността, културната й значимост и потребностите на социализацията във всички аспекти на представянето.

Разнообразието в природна среда предполага горските насаждения да са с висока естетическа и функционална стойност, а в рекреационнно отношение – да формират разнообразни пространства и подобряване комфорта на туриста. Умереното прилагане на принципа предпазва от опасността от пренасищане с чужди природни и антропогенни елементи и отвличане на фокуса от културната значимост на местата. Еднообразието на насажденията в непосредствената среда на паметниците на културата не може да се разглежда непременно в негативен аспект, особено когато насажденията са носител на автентичност.

Повторението спомага за подчертаване на връзката обект с културна значимост-среда при представянето им. Повтарянето на едни и същи елементи и детайли при благоустрояването на местата създава единство и синхрон на намесата и спомага визуалното и функционално възприемане на ценността и „разчитането" на ново и старо.

Мащабът в природната културна среда има съществено психологическо въздействие, поради значимостта му за правилното възприемане и „разчитане" на културните ценности. Доброто пропорциониране създава усещане за стабилност, здравина и устойчивост във времето. Безспорно освен във визуален аспект принципът следва да служи и за преценка на баланса между автентични и нови елементи и в този смисъл се явява критерий за оценка на допустимостта и правилността на вече извършените намеси. От най-съществено значение е мярката на мащаба, обратно на урбанизираната среда, тук мащабът често се определя от природните ландшафтни компоненти, а основно предизвикателство е съобразяването с тяхната изменчивост във времето.

Категоричността при представянето на недвижимите културни ценности в природна среда се свързва с яснотата и убедителността на благоустройствените решения. Минимализмът, многофункционалността и обратимостта на намесата гарантират категоричната изява на ценностите и съхранението на природния им контекст.

Контрастът, нюансът и равенството, симетрията и асиметрията придобиват водещо значение при представянето на ценностите, когато насажденията сами по себе си нямат водеща културна значимост. По отношение на благоустройствените елементи и съоръжения прилагането на принципите за контраст, нюанс, равенство, симетрия, асиметрия придобиват съвсем различно значение. Сложността идва от едновременното изискване намесата да е достоверна, разпознаваема, но и ненатрапчива и функционална.

Специфична е ролята на колорита. Докато в парковото изкуство е предмет на специално проектиране, при местата с културна значимост в природна среда колоритът следва да допълва усещането за естественост и хармония с околния ландшафт. По този начин той става изразител на *съхраненото единство на мястото* в по-широк контекст. Колоритът в горските насаждения се създава чрез горскостопанските методи и следва да е резултат от специално горско стопанисване.

Избраният метод на опазване определя и *степента на намеса* в средата. Популярните днес методи на опазване консервация, реставрация, реконструкция, адаптация и тяхната приложимост при опазването и представянето на недвижимите културни ценности в природната им среда имат специфична конкретика, която се определя не само от състоянието на средата, наличето на достоверна информация, степента на съхраненост, автентичният облик, културната значимост и от целите на намесата. От най-съществено значение е фактът, че културният ландшафт е динамично развиваща се система, чиито променлив елемент са горските насаждения – основен фактор на средата, определящ обемно-пространствената характеристика. В този смисъл подходящи за целите на настоящото изследване са методите на опазване на исторически ландшафти, изведени от Боговая и Фурсова [7]:

- Научна реставрация, при която възстановяването е пълно и научно обосновано, което налага изнасянето на съвременните функции на активния отдих извън територията
- Реставрация с приспособяване на някои елементи към съвременните изисквания
- Благоустрояване с елементи на реставрация, при която се реставрират само участъците, съхранили първоначалния замисъл
- Пресъздаване при загуба на първоначалната идея

Резултати и дискусии

От съпоставянето на закономерностите и принципите на ландшафтната архитектура, установените в дългогодишната практика ландшафтноустройствени и лесоустройствени мероприятия и дейности и известните методи на опазване могат да се изведат някои теоретични аспекти при ландшафтно-архитектурното оформление на природната културна среда:

Научната реставрация, при която възстановяването е пълно и научно обосновано, налага изнасянето на съвременните функции извън територията. В границите на културната ценност следва да се извърши преценка на културната значимост на насажденията. В зависимост от резултатите от оценката трябва да се планира тяхната консервация или реконструкция със средствата на лесоустройственото планиране – ландшафтни формировъчни сечи и ландшафтни залесявания. Водещ следва да е принципът на целесъобразността. В случай, че насажденията не притежават доказана културна значимост, то при оформлението им може да нарасне ролята на принципи като мащабност, пропорционалност, колорит. Целта на намесата в този случай ще е подпомагане на визуалната и функционалната изява на останалите елементи на културната среда чрез естественото проявление на принципите контраст, нюанс, равенство, симетрия и асиметрия. Изнасянето на съвременните функции в охранителната територия позволява в по-голяма степен и творческо, но непременно целесъобразно решение на паркоустройствената и благоустройствената намеса.

Реставрацията с приспособяване на някои елементи към съвременните изисквания е метод, който днес има широка приложимост основно в урбанизираната среда, поради ограничените възможности за разнообразно функционално използване в природни условия. Често в последните години се използват понятия като

ревитализация, обновяване, реконструкция и други, които се свързват единствено с подмяна на физически и морално остарели благоустройствени обекти и съоръжения. Съвсем ясно е, че тази намеса не трябва да се свързва с намесата с цел адаптация, каквато е приспособяването на някои елементи към съвременните изисквания.

Благоустрояването с елементи на реставрация, при която се реставрират само участъците, съхранили първоначалния замисъл се очертава методът с най-широка приложимост при днешното състояние на недвижимите културни ценности в природна среда. Безспорно да се говори за автентичност по отношение на най-динамично развиващият се елемент – растителността, е възможно само по отношение на *образа*, но не и на материята, и то само при положение че е доказана с исторически факти и документи. Разглежданият метод на опазване е приложим за недвижими културни ценности, чиято автентична материална субстанция е съхранена, а широкия им природен контекст придобива мултифункционалност. Тя се изразява на първо място в осигуряване на физическата защита на ценностите, визуалната им изява и доколкото е възможно изявата на автентичната им функция. Най-привлекателните в културно-историческо отношение обекти и елементи са и най-атрактивни за посетителите. Това съвсем естествено води до по-висок антропогенен натиск в някои участъци, за сметка на други. Правилното решаване на територията с второстепенна значимост позволява разпределение на туристическите потоци. Дългогодишната практика показва, че изграждането на тематични лесопаркове около недвижимите културни ценности в природна среда илюстрира отлично пълноценното прилагане на разглеждания метод на опазване и неговата устойчивост във времето.

Пресъздаването при загуба на първоначалната идея води до загуба на автентична материя и цялост. Поради това категорично не можем да приемем, че пресъздаването може да бъде определено като метод на опазване, а по-скоро като крайна мярка за съхраняване на *духа на мястото*. В този случай, при липса на съхранена автентична материя, *мястото* може да бъде определено като носител на историческа информация, но чрез косвеното значение на съхранените ландшафтни компоненти и условната информация, предоставена от възстановките. Пресъздаването обаче, именно поради допустимата условност на илюстриращата стойност на композиционнните елементи, позволява широка творческа интерпретация със средствата и методите на ландшафтната архитектура при прилагане на широк набор от принципи.

Изводи

Основна цел при ландшафтно-архитектурното оформление на природната среда на недвижимите културни ценности трябва да бъде съхраняването на автентичността и цялостта на комплекса. Балансирането на туристическите потоци, разнообразяването на средата с допустими дейности и елементи трябва да е в пълен синхрон с целта и избрания метод на опазване.

Колкото по-строг е избраният метод на опазване и по-минимална допустимата степен на намеса, толкова нараства значението на принципите целесъобразност и категоричност при ландшафтно-архитектурната намеса. Обратно, ниската степен на съхраненост и липсата на материална автентичност позволяват творческа интерпретация в много по-голяма степен.

Обективната оценка и респектът към естествената природна среда, в която са формирани и съхранени паметниците на културата, независимо от избрания метод на опазване, трябва да води до създаването на качествено и отговорно ландшафтно-архитектурно оформление, което да спомага изявата на отделните ценности, да

подчертава културната значимост на ландшафта и да позволява гъвкава обратимост на намесата при евентуална нова научна интерпретация на местата.

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arch_art89@abv.bg или partov@vsu.bg

НАПРАВЛЕНИЕ 2

Документиране, интерпретиране, презентиране и публикуване на културно-историческото наследство; Увреждане на недвижимите културни ценности в обкръжаващата го околна среда; Предпазване от промени във вътрешния климат и ефекти от туристическата инвазия; Биодеградация на културно-историческото наследство.

TOPIC 2

Documentation, interpretation, presentation and publication of culture heritage; Degradation of culture heritage in surrounding environment; Indoor climate and tourism effects; Biodegradation of culture heritage.

FUNCTIONAL MODEL OF RESIDENTIAL AND DEFENSIVE TOWERS DURING THE OTTOMAN PERIOD ON THE BALKANS

Radosveta Kirova[1]

Institute of Art Studies

Abstract:

Functional characteristics of residential and defensive towers during the Ottoman period in the Balkans are based on their long lifespan and quality of construction, as well as the initial concept of multipurpose usage such as passive and active defense; inhabitation on permanent or temporary basis, including as hideouts; observation and spatial control; storage and safe-keeping; other specific functions connected with religious cults, production, administration, etc. Primordial functional model of the archaic architectural type of the residential and defensive towers which used to focus several different usages, coalesced under the aegis of defense and protection. On the other hand importance on urban level the independently fortified tower were predetermined by their functional model where observation and spatial control guaranteed by the dominance of height among the geometric characteristics used to have a special role as well as storage functions especially in Initial convergence of functions into one archaic determined by cold weaponry architectural type in the border age of Ottoman conquest used to persist sustained by specific social models for spatial control in private properties; later on by the end of the Ottoman period comparable mono-functional types with similar architectural features as sentinel posts, clock towers were differentiated.

Key words: *residential and defensive towers, functionality, inhabitation on permanent or temporary basis*

1. Introduction

Specific social models of distribution of residential and defensive towers and of the residential and defensive towers determine the vitality of predefined by the cold weaponry architectural type after the gunpowder revolution during the Ottoman period on the Balkans and underlay the functional analysis of these buildings, exemplars of both residential and fortification architecture. Mapping of residence and defensive towers concerning the social models reveals their presence in the Ottoman periphery marked by certain specific semi-authonomous status or hereditary property rights – these buildings feature the cultural landscape in border territories such as Bosnia, Albania or Mani,

[1] Arch. Radosveta Kirova, PhD candidate, rkirova@abv.bg

Peloponese, also feature the opposite of timar system chiftliks and because of the adequate scale rather serving for private than for public safety.

The aim of the paper is to investigate and summarize the functional model of residence and defensive towers on the Balkans during the Ottoman period including the various usages in the course of operation, different adaptations, etc. with a stress on the problem of the cahracter of inhabitance.

Hybrid typology of the residential and defensive towers due to the crossbreeding between residential and defense architecture defines their primordial functional characteristics - living and defense that are accompanied by two auxiliary functions – storage, surveillance and control and various specific functions such as religious cults, production, administration, etc. that sometimes became even prevailing in the course of time form altogether a complex and intricate functional model.

2. Problem of the character of inhabitation. Inhabitation on permanent basis.

Paucity of historical data along with the loss of authentic interior features in result of the repeated changes in functional aspect as well as the multiple reconstructions in the course of operation are the major obstacles for ascertaining the concrete functions of residential and defensive towers even in case of architectural integrity. The basic idea of residential and defensive tower was to provide security and protection of a family or in other specific cases of a single functional military unit "odzhak" or group of seasonal workers or part of the population of an area therefore serving as permanent or seasonal dwelling. While the presence of interior elements such as hearths for preparing food and heating in wintertime, toilets and sinks, as well as ventilation, water supply and sewer installations implies inhabitation, the problem of temporary or permanent basis of occupancy is of determinative character. Of key importance for the discussion of the character of inhabitance is the long lifespan and therefore operational period that resulted in multiple and various usages of the buildings and therefore evoking of mutations in the initial functional concept.

Historical data for the concrete occupants of some residential and defensive towers reveal that residential function used to be leading at least at particular moment in the course of maintenance. Historical sources of Month Athos testify that the nowadays ruined residential and defensive tower in the village Dafni near Serres known as the "tower of Kyra Maro" (fig.1) the primary dwelling inhabited on a permanent base during the first half of the XV century by the widow of Murad I and respected stepmother of Mehmet II the Conqueror Mara Brankovic or Despina Hatun. [1] [11] [15] It is curious that Serbian narratives testify that after her return form Edrine after her husband's death in 1451 Mara Brankovic lived in the residential and defensive tower in Kursumlija. [18]Another historically proved example of inhabitance on permanent basis is the the renowned theologian and religious author and leader of the Nakşibendi order Haji Mahmud Efendi or Hırka Baba in the middle of XVII century who lived with his family in a tower situated in his chiftlik in the outskirts of Bitola later known as ”Zandan Kule”. [8]

Inhabited on permanent basis were also the residential and defensive towers in arsanas of Mount Athos, homes of the border lords ”kapetans” in Bosnia – for example Rustempasica, Sulejmanpasica and the ruined nowadays Gaziahmedpasica tower in Gornji Odzak, Bugojno, Surkovic tower in Bjelimci, etc., a number of objects – homes of influential local families in Mani peninsula on Peloponnese. [7] [13] [14]

In other cases towers served as nucleuses of fortified residential complexes – for instance of the influential border lords' family Mihaloğlu in Pleven from XV century[30] [33], of Rustem Bey in Belashtitsa near Plovdiv (fig.2) or Cemalovic residential complex

in Buna, Bosnia [10], which consisted also of a lower horizontally developed residential unit, other auxiliary buildings, and water supply surrounded by a tall masonry wall – in that case towers served as hideouts in case of attack, but assumably in some cases like Pleven towers had served as primary dwelling before construction of the rest of the fortified residential complex.



1)



2)

Fig. 1. Residential and defensive tower of Maro, Dafni, Serres, Greece – photo R. Kirova

Fig. 2. Residential and defensive tower in Belastica, Plovdiv, Bulgaria– photo R. Kirova

3. Residential and defensive towers in chiftliks. Leading storage and surveillance functions

Partial time occupancy proved for some residential and defensive towers used as hideouts, watchtowers and checkpoints, but also for various additional and specific types of functions reveals the multi functionality of one and the same architectural form which features durability, stability, fire resistance, dominant height and adequate scale for displacing issues of security from public to private sphere.

Due to the abundant historical data presence and functionality of residential and defensive towers in agrarian estates in Northern Greece could be traced back in Antiquity. Safety of lives of family members but predominantly of servants or slaves - for by rule they were not occupied by the owners but served as seasonal dwellings for slaves or mercenaries - as well as safety of property and agricultural production. A speech attributed to Demosthenes describes the attempt of creditors to retrieve their debts if the absence of the indebted citizen by attacking his tower in Attica, where his woman slaves used to live and locked safe. [9] [16]

The protection of agricultural estates by residential and defensive tower continued to be used in the middle ages by the athonites in Halkidiki. The mutual interest in the exploitation of natural resources by religious owners of agricultural estates in Northern and Central Greece in medieval times decreed protection of property through residential and defensive towers that served as hideouts and points for monitoring and transmitting messages within the fortification network, storage of agricultural tools and products, but also for protection of the claims of other owners. [6] Towers of Mount Athos as a rule were part of a larger complexes as monidrion, kelion or arsanta and certainly were occupied - sometimes permanently, and in other cases only temporarily as a last refuge for the monks of the brotherhood in case of pirate attacks. [14]

The proximity of the towers Alekspirgos, Pispirgos located in agricultural property owned by the monastery of Great Lavra, Kontovrakina Iviron, Mudros owned by Vatoped and Skala owned by Koutloumousiou monastery on the island of Limnos, suggests their role as posts for monitoring and messaging as well as guard property against intruders and thieves. [3]

The ubiquitous and approved model for protection of agricultural property from ancient and medieval times was utilized later by the Ottoman provincial elites as part of their strategy to impose their authority in inheritable private chiftlik property after the decline of timar system - evidence is provided by the numerous residential and defensive towers in chiftliks on the Balkan Peninsula – some of them preserved until today, other possible to trace bask only by historical records - in Ledenik near Veliko Tarnovo, in Razhena near Kazanluk, in Kunino and Rayanovtsi near Vidin, in Stip (fig.3), the tower of Ahmed Bey near Ruse, in Vassiliki near Thessaloniki, in village Goranxi, the regions of Matt and Tet in Albania, etc. [4] [19] [20] [21] [22] [23] [24] [29] [35]

The two-storey stone building "tower" from the the second half of XIX century located in the chiftlik in Brianovstitsa area near village Boykovo, Plovdiv could be added to the group of objects with prevailably monitoring and control functions serving as observation post of the chiftlik, later as a border customs for the so-called "Tamrash republic", forest post guerrilla shelter and a tourist hut. [17]

The reviewed examples of towers inhabited on temporary basis reveals the leading role of storage functions for protection of property and paraphernalia rather than lives - storage agricultural production, various types of instruments, weapons or ammunition. Residential and defensive towers possessed by wealthy individuals who need protection of their property, functioned as storage for valuables or as a kind of "bank safes". Besides the discussed above examples of towers in agricultural estates, towers in mining centers such as Kratovo probably had similar functions of a storages for coins, various iron, silver or gold products, metal tools and instruments, valuable construction materials for buildings and ships - nails, tensioners, lead sheets for roofing, etc.

Towers of the monasteries on Month Athos also served as storages (skevofilakia) for various religious valuable relics, icons and manuscripts. For example Koutloumousiou tower (1508) serves a repository for the collection of icons of the monastery until today like the towers of the in Great Lavara, Zograph monastery, monastery near Serres, etc. [14] [31]

2. Specific administrative, religious and production functions of residential and defensive towers on the Balkans.

Besides the often equipped with chapels monastery towers that store valuable objects associated with religious rituals, possibly another group of towers could be associated with Dervish order – together these examples form an interesting cross-religious and cross-cultural group of objects which usage is dedicated to specific religious functions.

One of the few precisely dated towers from the first half of XVII century by identifying its its contractor and inhabitant is Zandan Kule in Bitola of Haji Mahmud Efendi is preserved until today. Hırka Baba used the tower as a primary dwelling with his family, but also for spiritual seclusion. After his legendary death the tower used to serve as

library for his rich collection of religious literature and reliquary for his belongings venerated by both Muslims and Christians until the middle of XX century. [8] Hırka Baba's usage of the tower for religious retreat resembles the traditional Christian practices of hermitage - for example St. Sava's solitude and prayer cell in the tower belfry of the church in the Žiča monastery. These inter-cultural elements may have had intervened in as early as late antiquity in Syria, where occurred Christian tradition of living in attached to the walls of the monastery or church pillars of monks hermits and later the also sometimes inhabited by hermits idiosyncratic Islamic minarets. [2]

To the group of objects related with Dervish orders practices could be amplified after further detailed researches by probably the towers in Florina, Etropole, Kjustendil etc.

Depending on the social profile of their owners and occupants, residential and defensive towers combine along with the two main functions – dwelling and defense- other specific functions in different periods of occupation and exploitation, including usage for administrative or military duties, usage as hideouts related with the traditional local law and blood feuds or later -the national liberation struggles of the peoples on the Balkans.

For example, according to the memoirs of J. Hadzhikonstantinov-Dzhinot in the residential and defense tower in Kavadarci resided not only the local ayan (owner of a large land property) but also the kadi, therefore the tower served a kind of administrative function. [34]

In analogy to the existing tower in Protaton in Karyes built to serve the Ottoman administrator on Mount Athos and the tower Stagira in the semi-dependent region Mademochoria on Halkidiki it can be assumed that residential and defensive towers in mining centers such as Kratovo, village of Teshovo near Gotse Delchev, Etropole, etc. also served as places for temporary habitation for the multiple regulated by the special mining law which - naibs, kadis, emins, etc. [14] [15]

According to H. Kresevliakovic residential and defense towers in Bosnia used to serve in some cases for permanent or seasonal housing to the wealthy and influential kapetans' families, in other cases - for military administrative headquarters - for example the tower in Old Maidan, Bosnia used in later time as a gendarmerie barracks, and in third cases - for observation posts for guarding important roads. [7]

Number of towers in the Ottoman border areas of specific, semi-dependent status as Mani or Albania, used to serve as hideouts and shelter not only in case of armed pirate attacks, but also in case of clan feuds and blood vendettas. [13]

The tower of Nenadovic in Valjevo, Serbia was built by Jacob and his son Ephraim Nenadovic in the spring of 1813with the stone material and probably following the elder architectural model of the two earlier Vitkovic towers in order to preserve ammunition and shelter rebels during the Serbian liberation struggles. From the end of 1813 until 1815 the tower was converted into a prison by the Turks, then after the re-conquest of Valjevo Serbs had burned it while later in 1836 it was recovered by M. Obrenovic. Today the tower is adapted as a local museum, alike many other residential and defensive towers - Kurtpashovata tower in Vratsa, Simichevata tower in Kratovo, Beiskata tower in Skopje, the two towers in Kumanovo, etc. Museum and exhibition function are the most popular contemporary adaptations of residential and defensive towers.

Historical data and local narratives reveals that some of the residential and defensive towers were used to host production activities, mostly connected with mining and metal production testified by the specific facilities installed with or without additional later alterations of the ubiquitous open plan premises on each storey - for example the towers in Kazanlak, arsantata of Zographou probably the tower in Teshovo, Gotse Delchev, part of the towers in Kratovo, tower of Meshchiite in Vratsa and others.

The massive domed second single premise floor the residential and defensive towers on Mount Athos in the arsant of Iviron (1625) was later divided into two separate

rooms with low ceilings – a small vaulted chapel and an auxiliary work space with lower ceiling and ramshackle walls occupied by lathe for carpentry operations. [14]

The water supply provided sink on the beletage of the residential and defensive tower in Teshovo, Goce Delchev similar to those of the towers of arsana of Zographou and one of the towers in Siderokasia assumes that it served for metal operations orspecific kind of production. One of the metal processing yards in Samokov also included two-storey tower with no evidences whether it hosted production or storage activities. [14] [20] [26]

Although the information for the building history of the demolished tower in Kazanlak is contradictory, local narratives reveals its later usage for the production needs of the tanners guild, as well as an element in the defense system of the town during the Kardzhali period. [23] According to the reports of the local researcher A.Tacov the residential and defensive tower in Etropole also served as an observation point and hideout for the Muslim population during the Kardzhali period, sheltered traveling Jewish merchants and Muslim religious gatherings. [27]

4. Typology differentiation.

Characteristic dominant height underlay the later adaptation of the residential and defensive towers into clock towers frequently by adding a wooden turret on the top and clock gear – such as the towers in Stip, Vratsa (fig.4), Kumanovo, Kratovo and etc.



3)



4)

Fig. 3. Residential and defensive tower in Stip, Macedonia adapted for a clock tower – photo R. Kirova
Fig. 4. Residential and defensive tower of Mesciite in Vratsa, Bulgaria adapted for a clock tower – photo R. Kirova

After the end of the age of inner insecurity in the Ottoman empire at the end of XVIII and beginning of XIX century known as Kardjali period beklemes (sentinel or look-out posts) were implemented for surveillance activities and security of the roads engaging mostly Albanian mercenaries to replace the earlier in charge for inner order and security derventdzi and sipahi. [32] Apart for the preceding hybrid multifunctional residential and defensive towers mono functional beklemes and clock towers which however shared similar structural tectonics and architectural features, especially dominant height with the

residential and defensive towers were a logical result of the changed social and economic conditions in the Ottoman Empire that required much precise differentiation within the architectural typology. Massive masonry construction and fire resistant qualities [25] of residential and defensive towers proved their appropriateness for storages - the XIX century two-storey stone maazas could also be considered as an architectural type derived from the prior residential and defensive towers but lacking the most prominent feature – the dominant height. Tower houses which possessed an architectural scheme of both vertical but also horizontal development could be assessed as a transitory architectural type much closer to the residential architecture lacking such prominent defensive features such as the protected elevated entrance, machicolations, etc. – for example objects in Morea or Rhodope mountains. [5] [28]

The versatility of residential and defensive towers during the Ottoman period in the Balkans was not an isolated phenomenon. Similar functional scheme have the medieval and late medieval towers across the Iberian-Caucasian region, including in the Caucasus, the Balkans, Italy and Spain - for example the defensive and residential towers in Tuscany from XV century, two of which served in agricultural estates, three were later incorporated into later buildings, eight were occupied by the earthquake in 1971; and the tower Podesta served as clock tower before its collapse. [12]

5. Conclusion

The scale of residential and defensive towers ensured security and protection for private properties – fortified residences, agricultural properties, monasteries and arsanas, involving besides the fundamental inhabitance and defense also monitoring and control of the nearest vicinity, storage, production, administrative functions, etc.

Intricate multi functionality is a key feature of residential and defensive towers during the Ottoman period on the Balkans encoded in their genesis as a result of the complex interplay of housing and defensive architecture, as well due to the complex overlapping of functions in the course of time due to their high quality and structural durability. The basic functions of dwelling and defense were complemented or even prevailed sometimes by storage, monitoring, surveillance and control functions, but also completed by specific industrial, religious or administrative functions, proving that the same universal architectural form could serve in various ways. Along with the social and economic changes differentiation of architectural differentiation reflected the universal hybrid multifunctional type of the residential and defensive towers producing similar in architectural features mono functional types that served the changed overall situation better.

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IS THE MISTERY OF PYRAMIDS FINELY REVEALED?

Arch. Theodore Gyurovsky[1]

Abstract: *There are half a dozen of theories pretending pyramids were built by the aid of water-locks. The conclusion is based on the presence of salt deposit on the walls of all the interior passages and chambers. The fact that the thickness of the deposit is different, denies the theory of the supposed highest level (about 60 m more than the actual) of the Mediterranean Sea at that times, being the cause of the deposit. The authors of these theories are mostly interested by the way water was carried up, in order to feed water locks. There are quite phantasmagorical theories, like this affirming, that the interior of the Cheops's pyramid is a big ram water pump. There is a French architect, claiming that there is an internal squared spiral passage (near to the surface of the pyramid), where were drawn wooden sliders, carrying the limestone blocks up to the apex – about 3 km!!! And all France is supporting this nonsense!!*

An additional fact supporting the hydraulic theories is the presence of three big steps (3 x 6 m) carved in the ground near the pyramid, now buried under the road, passing nearby.

Key words: *Cheops's pyramid, hydraulic built pyramids, Theodore Gyurovsky*

My theory is based on two assumptions: 1. – the pyramids were built at the same time with the Sphinx – at least 8500 years ago, at the end of the last mini ice age, when the weather was very rainy. And 2 – pyramids were built with the help of rainwater, which fed lockage (1 – 2m deep), where wooden barges with the stone blocks were lifted up. (Fig. 1)

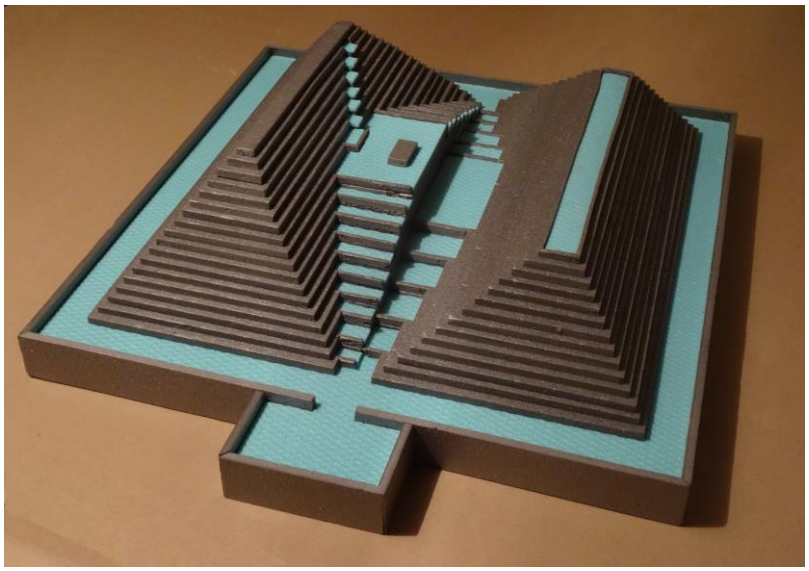


Fig. 1 On the model are represented two stages of the construction of the pyramid: on the right side (the lower) the cells of the lock-way (nearly 12 m width) are reaching the level

[1] "Kapitan Andreev" 11 str., Sofia 1421, Bulgaria, theodorgyurovsky@ymail.com

of the floor of the king's chamber. The left side lock-way (nearly 7 m width) reaches the level of the last relieving chamber (on the picture above represented by the little dark rectangle in the top lock sell). From this level up to the apex of the left semi-pyramid there is a lock-way (with cells measuring 6 x 6 m). This is an example of a possible variation of the lock-way.

The authors of "hydraulic built pyramids" (particularly the Cheops's one), probably guided by the presence of salt layer on the walls, but no one had imagined the simplest source of water – the rain. And the reason is the imposed point by ancient Greeks, that pyramids are tombs of the Pharaohs. By consequence comes the next mistake – the presumption of a dry weather existing since the Pharaohs's days ahead till now. But these authors don't underestimate the skills of the builders of pyramids, like are doing in contrary those, which theories are sheer insult to the builders – they were not such a fool as people make out, to pull the blocks up the hill, like would do it ants! So, it's my duty to require the du respect to the ingenuity and smartness of our ancestors! But why did they do pyramids? The eternal question! There are quite amazing answers and suppositions, I would not comment, but one of these sheer fabrications pushed me to find my own explanation of things! Then I made an important deduction – we are all waiting someone else to explain things and events! Instead, we must ask ourselves questions, and try to find out the answer! Enough waiting in front of TV displays to hear somebody else telling us the truth!

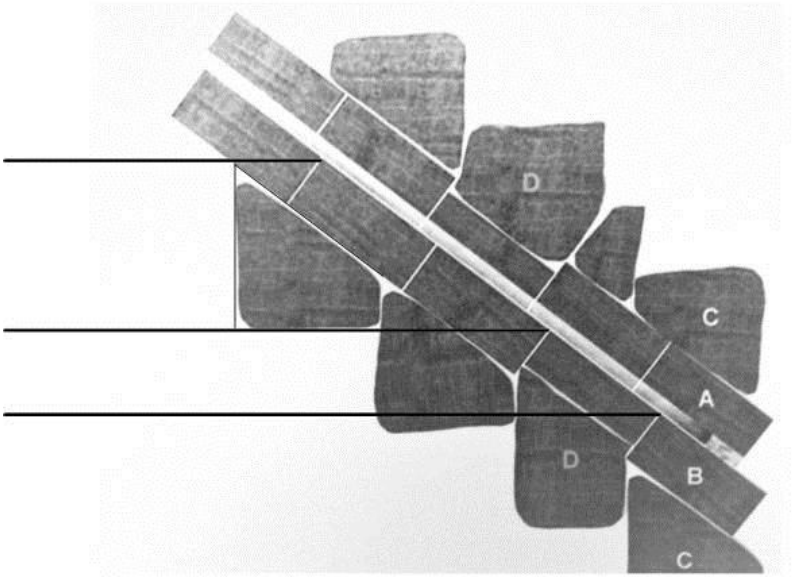


Fig. 2 This picture from the "upuau project" proves that the upper edge of the underlying block is leveling with the rows of the pyramid.

But, let's go back to the eternal question – why did they build pyramids: from a while I had noticed that mounts have pyramidal shape, which let me make a correlation between the mounts and pyramids. And one day I saw a picture of three mounts taken in the Alps (Fig. 3) – they had an astonishing likeness with the Giza pyramids!

Then I was sure, that pyramids are a copy of the mounts (in modern speaking "copy – paste")! Additional support of this thesis is the presence of small pyramids, existing around the three pyramids, and with a casual disposition. Why did they make such a labor-consuming construction? The only explanation is that they needed a place where their Gods to inhabit!



Fig. 3

But why on top of the mounts – because ancient people believed that their Gods were living there; I shall quote two examples: the ancient Hindu believed that their supreme God inhabited the mythical mount Mehru, and so did ancient Greeks about their Gods, living on the top of the mount Olympus. The most probable cause obliging indigenes to leave their native lands and go elsewhere is the last mini ice age, which affected the upper part of the northern hemisphere about 12 000 years ago, forcing them to go back to the warmer south, from which their ancestors came thousand years ago.

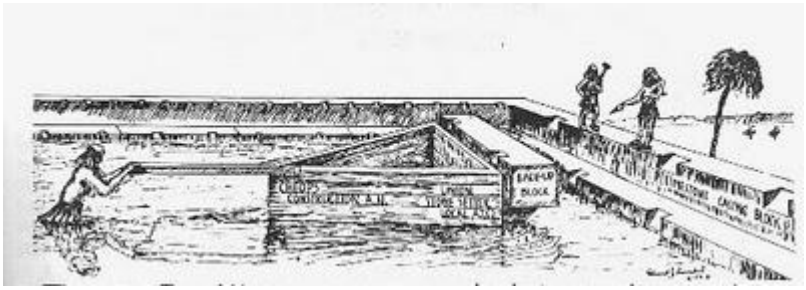


Fig. 4 On the drawing is represented a method of construction of fencing, used in pharaohs times to build temple's fencing.

Now is time to go to the point: after the leveling of the bed of the future pyramid, was build the lock-way from the Nile to the spot, having a connecting channels with the local quarry. Then started the construction of the pyramid by laying down the first row of the enclosure stone fence – forming big squared lakes, surrounding the pyramid. This artificial lake will have multiple functions. Let's list them: 1. For accelerating the speed of construction, because the presence of the surrounding lake permitted to have a second entry to the pyramid – from the western side. 2. Another function is to receive and evacuate the lowered down by the sides of the pyramid empty barges. 3. This is the biggest recipient of water, supplying the water-lift on the eastern side of the pyramid (called today – mortuary temple), which were able to deliver in a few hours a multitude of barges up to the construction (about 20 m). Let's say it now – the hardest work was to open and to close the gates of the locks – probably by the aide of sacks of sand. The same ring lake is a kind of a water-lift: when fulfilled with barges, after rainy period it can lift up them several meters. 4. In a less rainy periods it could function like storage area. 5. Most probably the blocks of the fencing wall were used to build the upper part of the pyramid. After the first enclosure row was laid down the first row casing white limestone (white – to have a resemblance wit the covered with snow mounts). So, the first about 20 meters were built relatively easy – using the water-lift system. But, raising a higher fence is not convenient

because of the enlargement of the base of the wall and the geometrical progression of the material needed for it.

Then, from the 20th meter up the pyramid was divided in to elongated parallel pyramids – northern and southern. What is the benefit of this bifurcating: the water-locks are less sloppy, and there is a gain of water and time. Probably this unique method of construction permitted to the Cheops's pyramid to be the biggest. Some words about the Grand gallery: this is the largest recipient of water – his volume is about 500 m3. It is divided in 18 cages (the evidence for this are the square holes carved in the stone), each one containing about 20 m3 (this volume is an indication for the dimensions of a lock-cell). At the end – how the megaliths were putted on place (this is the more exciting point – some of them are weighing about 45 tons!)? The answer is in their broken ends! The question is: why they didn't cut the extremities of the megaliths in the quarry? If one needs a 7 m long block, he will cut it in the quarry?! Here's the explanation: to put one megalith on the king's chamber's walls, it was carried by its extremities on two barges (Fig. 5).

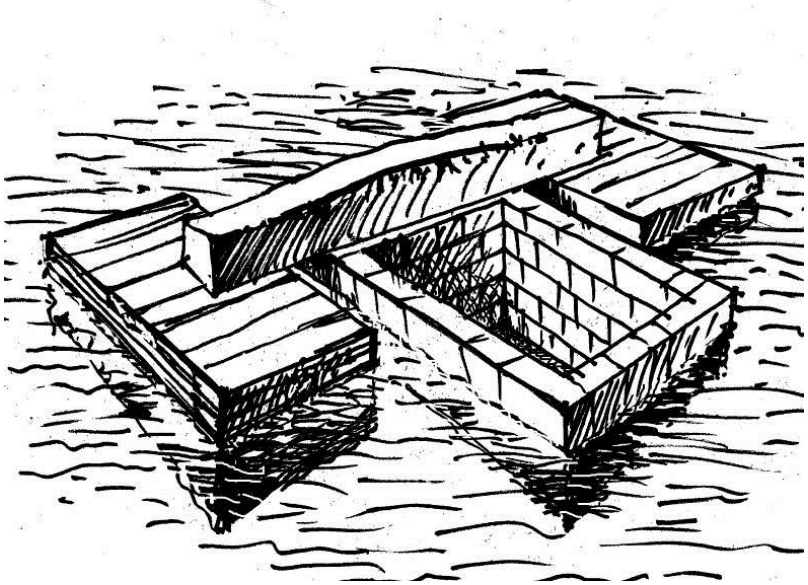


Fig. 5

Then the protruding parts are cut off by the aid of a big hammer, and then were used for the supporting row of the next range of megaliths. The supposed length of the megaliths is about 11 – 12 m. After a detailed examination of the supporting blocks and their comparison with the megaliths, the theory will be proven! So long dear friends.

THE CHALLENGES OF RECONSTRUCTION AND MAINTENANCE OF THE BUILT CULTURAL AND HISTORICAL HERITAGE OF BOSNIA AND HERZEGOVINA

Adnan Ibrahimović[1], Damir Zenunović[2], Kenan Mandžić[3], Enver Mandžić[4]

Faculty of Mining, Geology and Civil Engineering, University of Tuzla
Faculty of Mining, Geology and Civil Engineering, University of Tuzla
Faculty of Mining, Geology and Civil Engineering, University of Tuzla
Academy of Sciences and Art of Bosnia and Herzegovina

***Abstract**: Reconstruction and maintenance of the built cultural and historical heritage has always been a challenge for engineers. The challenge is in need of a sort "reconciliation" of the old construction method and the fulfillment of demands posed by modern standards of construction. In addition, the specificity makes the fact of diversity of types of these objects, as well as the facts related to the scope of their destruction due to war activities. War destruction of these buildings is a particular engineering challenge and experience.*
The paper describes the methodological bases and practical approaches to the reconstruction and maintenance of these buildings, which have been developed based on challenges and experiences of engineers in Bosnia and Herzegovina.

***Key words**: Reconstruction, Maintenance, Architectural Heritage, Bosnia and Herzegovina*

1. Introduction

The territory of the modern state of Bosnia and Herzegovina has always been a suitable place for settlement of human communities, so the archaeological remains found in the area are dated even to the periods of thousands of years before Christ. In such circumstances, it is quite understandable that the architectural as well as cultural and historic heritage of Bosnia and Herzegovina has been rich and diverse. Its diversity is multidimensional: in terms of historical periods, the typology of architectural heritage, the cultural and civilizational as well as architectural and stylistic features of architectural heritage.

A special part of this heritage is consisted of buildings of various types and purposes, which have originated from the Middle Ages to the present times and have witnessed all

[1] Adnan Ibrahimović, Dr sc.-Dipl.ing., Associate Professor, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, adnan.ibrahimovic@untz.ba
[2] Damir Zenunović, Dr sc.-Dipl.ing., Associate Professor, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, damir.zenunovic@untz.ba
[3] Kenan Mandžić, Dr sc.-Dipl.ing., Associate Professor, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, kenan.mandzic@untz.ba
[4] Enver Mandžić, Academician, Dr sc.-Dipl.ing., Professor Emeritus

the variety of cultural and historic periods of human life and human creation on the territory of Bosnia and Herzegovina. On the basis of this architectural heritage the development of architecture in Bosnia and Herzegovina can be traced, especially in terms of the impact of the close and wider environment on its development, both in the architectural style and the technological and technical aspects of this heritage. The general assessment, in this respect, has been recognition of the presence of general architectural and construction norms of a particular period in the history, both in the architectural style and the technological or technical segment. It is necessary to emphasize that those building, in almost all cases, have been made out of stone. All the above mentioned represents understandable facts related to the geographical position of Bosnia and Herzegovina and the importance of such position in geopolitical terms. Also, one of the most important facts is that in the 14th and 15th centuries the medieval kingdom of Bosnia was an economically and militarily developed country, according to the social standards of the period, with abundance of natural resources and well-developed commercial activities. All types of connections and contacts with Central European states of the period were present, which left its mark on the architectural heritage of Bosnia and Herzegovina.

Such favorable circumstances for the development of the construction continued to exist in the period of the Ottoman Empire, particularly at a time when Bosnia and Herzegovina became the most western part of the Empire to the rest of Europe. At the same time, it also became a division and buckle between the western and eastern civilization, which is reflected in its architectural tradition and heritage.

Today, the remains of such heritage, which represent a mirror of development of a society and a true cultural and historical treasure and, in some cases, the monuments of the world heritage[5], are unable to resist the challenge of their destruction through time. Therefore, it is necessary to conserve them and to undertake their proper reconstruction and conservation. This paper aims to present experience that Bosnia and Herzegovina has in the architectural preservation of cultural and historical heritage, as well as ways to manage them properly. This will be done through presentation of the state of this heritage and the impact on its condition, regulatory requirements that the restorers and conservators meet, as well as the approach to solving this problem in terms of surveying, analysis and assessment of the state and condition of these buildings in order to develop restoration projects.

2. State Of Architectural Heritage In Bosnia And Herzegovina

However, such geostrategic position of Bosnia and Herzegovina brought about the frequent invasions and devastations that the wars always bring. They have not spared structures. Relatively frequent armed conflicts did not allow to undertake the reconstruction of the destroyed constructions, partly because of economic powerlessness of society to do so but also because of the fact that their frequency has created a sense of meaninglessness of such procedures. Therefore, such circumstances have created a specific awareness and relationship to the structures from earlier historical periods that we can qualify as a complete negligence of such objects.

It is not rare that the old historic structures or their remains serve more to local people as a source of free building materials, in such a way that the parts of these buildings have been built into their personal houses and other auxiliary facilities.

[5] On July 15, 2016 thirty necropolises of medieval tombstones (Stećak) were inscribed on UNESCO's World Heritage List.



a) b)

Fig. 1. a) Parts of the doorpost beams and columns from the Jajce town fortress built in a private residential building nearby; b) The demolished part of a rampart walls of Jajce town fortress, left unprotected due to negligence or financial inability to undertake a proper reconstruction (Photo: A. Ibrahimovic, 2009, 2010)

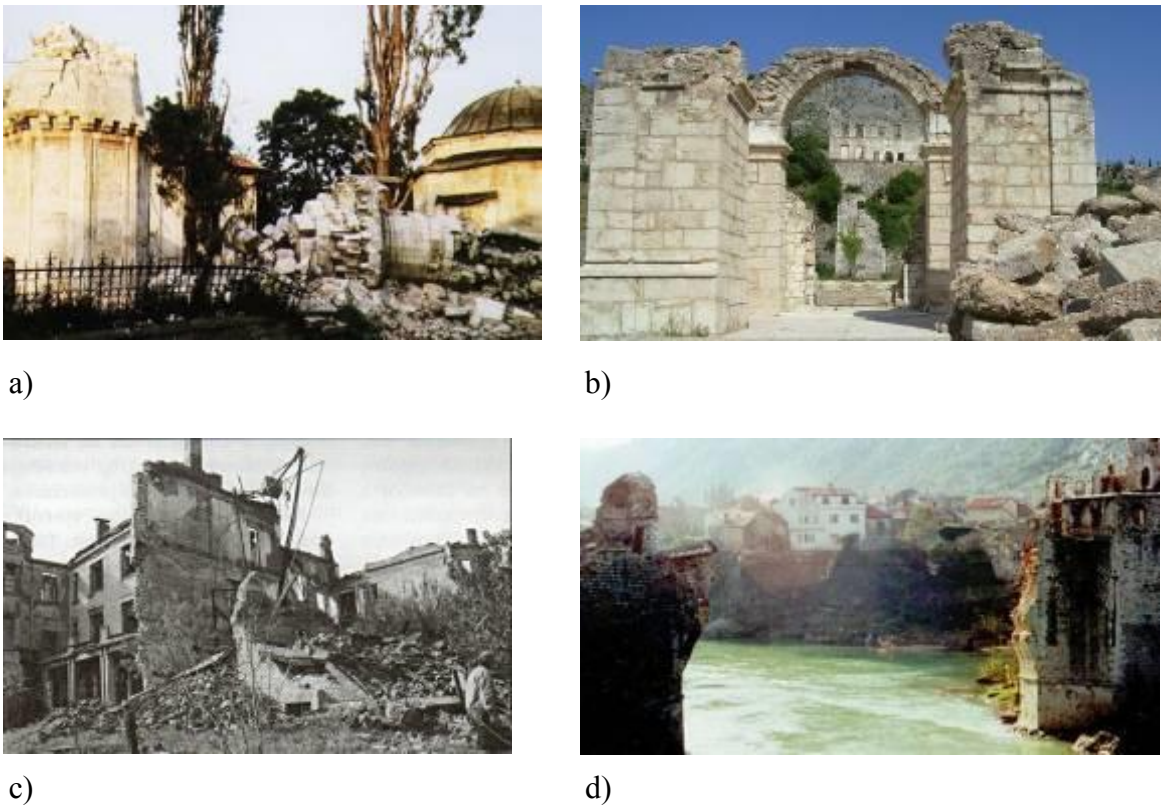
Therefore, it is not rare that in some case only toponyms survived today to witness the existence of the old structures in the past, and that there is no material evidence at all or, if still existing, they would be available only in archaeological excavations[6]. It is usual in Bosnia and Herzegovina that the toponym "Gradina" refers to a location that, according to the oral tradition, used to be the site of the medieval town, fortress and watchtower.

However, a special form of architectural destruction of cultural and historic heritage took place in the latest aggression on Bosnia and Herzegovina, when a massive, and in some cases systematical, destruction of religious and sacral buildings took place, some of which were older than several centuries and had a high cultural and historical value[7]. According to official data kept by churches and religious communities, as well as other institutions that take care of architectural cultural and historical heritage, during the aggression on Bosnia and Herzegovina from 1992 to 1995, the following buildings were completely destroyed:

- 614 mosques and 218 masjids,
- 65 Catholic parish churches,
- 125 Orthodox churches.

The number of damaged religious sites is much bigger. It should be emphasized that some of the buildings were national monuments and examples of exceptional constructional and architectural value. Many other structures of the architectural heritage have not been spared, with the Old Bridge in Mostar being the most famous of them.

[6] In such cases, we usually deal with the foundations of structural constructions that represent the basis for doing an assessment and reconstruction of its dimensions, structure and purpose.
[7] Many of them represent valuable national monuments of cultural heritage.



a) b)

c) d)

Fig. 2. a) The ruins of Ferhadija mosque in Banja Luka; b) The ruins of Episcopal Orthodox Church in Mostar; c) The ruins of Franciscan monastery in Plehan, d) The Old Bridge in Mostar after its demolition

Moreover, there are many significant architectural and constructional sites in Bosnia and Herzegovina that require proper reconstruction and management in the process of their full preservation. Their number is not small. In the river Una valley alone, there are about a few dozens of sites with the remains of architectural, cultural and historic heritage from the Middle Ages and later periods, such as fortified castles, towers, chapels and other religious building as well as many other structures. The same situation prevails in other parts of Bosnia and Herzegovina, too. Valuable necropolises of the medieval tombstones (Stećak) represent a special issue.



a) b)

Fig. 3. Cultural and historic architectural and constructional sites: a) Medieval town of Tesanj; b) Medieval town of Srebrenik (photo: A. Ibrahimovic, 2014, 2016)

3. Restoration and conservation requirements and challenges that result from standards and regulations

When it comes to the reconstruction of the architectural and constructional heritage we face the problem of staying in the domain of authentic construction, in terms of the constructional techniques and the use of materials (assembly and material), and application of normative demands related to the structures that are made out of stone. We would say that the engineers who are engaged in this business face certain paradox, contradiction that they need to reconcile in order to assure a high quality of reconstruction and avoid obviousness and visibility of the subsequent reconstruction works. This fact alone is listed at the very beginning of the ICOMOS Charter, in terms of restrictions on the application of construction standards in diagnosis and restoration processes.

It is worth noting that the first of the general criteria, within the principles of analysis, restoration and conservation, is a necessity of multidisciplinary approach. In addition, it is important to emphasize that the value of the architectural heritage is not only reflected in its appearance, but also in the integration of all its components into a single product of the specific construction technology at a particular time. It is clear that the restoration of a structure of the architectural heritage is not an ultimate end itself, but a means to an end, which represents the structure as a whole.

What is important are the specificity and design of constructional heritage sites and buildings, which include their historical complexity, require a precise algorithm of actions in the process of studying and proposing all necessary procedures. Compliance with this order of actions allows achieving the following:

- Obtaining relevant data and information,
- Identification of the individual causes of damage,
- Selection of the rehabilitation measures and efficiency control interventions.

Any activity undertaken as a part of the restoration must be assessed in terms of its negative consequences for the architectural and constructional heritage. The emergency security measures can be exempted from this rule[8].

Research and diagnosis includes nine steps.

1. Multidisciplinary team begins with work from the very beginning, for example the initial site reconnaissance and developing a research program,
2. Preliminary data and information processing in order to form a more comprehensive plan of activities in connection with the actual problem,
3. Complete understanding of the structure and Applied Materials (original and all subsequent conditions of the construction, construction techniques, changes and their consequences, past impacts on the construction, the current state of construction)
4. Emergent constructive solutions at the archaeological sites, which are undertaken to stabilize the structure during excavation that must not jeopardize the form and the way the building is used,
5. Diagnosis is based on historical, qualitative and quantitative approaches[9],
6. Identification of the causes of damage and decay, structural safety assessment, making decision about the type and mode of intervention on the structure,
7. Safety assessment must be harmonized with the quantitative and qualitative analysis,
8. Special analyzes and considerations justify different approaches to safety assessment in order to avoid excessive and impossible safety measures if the same level of security is applied as in the case of designing of new buildings,

[8] In the case of earthquake and taking measures to prevent the collapse of the structure, and even then with maximum possibility of avoiding permanent and irreversible changes in the material.

[9] The qualitative approach: direct access to and insight into structural damage and deterioration of materials, historical and archaeological research; quantitative approach: testing of materials and structures, monitoring, analysis of the structure.

9. Technical report, as a mandatory part of the documentation, must include all aspects related to the existing information, diagnosis with safety assessment and the decision to intervene on the construction of the architectural and constructional heritage.

Compliance with the above stated enables the achievement of the objectives of the recovery and controlling measures, which are contained in 22 defined requirements of the ICOMOS Charter. When it comes to contemporary normative requirements, they are related to the compliance of works with these regulations, especially the standards that have to be met by walls made out of natural stone. In this sense, it is necessary to meet regulatory requirements related to:

- the degree of stone processing,
- application of a binder,
- the building method and degree of the joint processing,
- the type of bond and building method.



a) b) c)

Fig. 4. Different level of stone processing, building method, the degree of the processing of the joints and the bond types: a) Retaining wall of the mosque plateau in Pocitelj; b) The old people's school of Franciscan monastery in Livno; c) Different types of walls in the old town in Srebrenik, indicating expansion in different historical periods or lack of knowledge in the process of reconstruction (Photo: A. Ibrahimovic, 2010, 2015, 2016)

In addition, it is necessary to do a proper wall classification, which is clearly defined in the standards (DIN 1053-1, EC6, DIN EN 1996-1). DIN 1053-1 includes classes from N1 to N4, and they are in function of:

- ratio between joint thickness (h) and the stone block thickness (l), h / l,
- inclination of joint (tan α),
- transmission factor of (η).

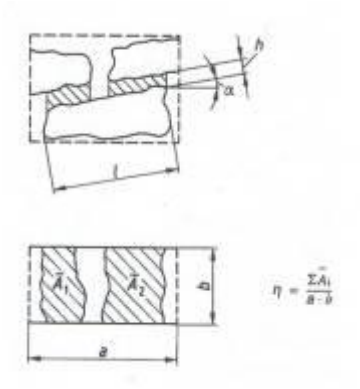


Fig. 5. The starting value for the determination of the class wall

Also, it should be noted that the classification in accordance with EC6 has been slightly amended compared to DIN 1053-1, so this should be taken into consideration.

When it comes to standard tests, a proper care should be given to the choice of test methods, which means paying particular attention and consideration to the test conditions and the factors affecting the testing. In Bosnia and Herzegovina, the standard tests of the strength of natural stone are defined in the standard BAS.B.B8.012, which clearly stipulates the following: equipment and accessories, the sampling process, preparation of samples (tube) as well as their numbers, the experiment process, calculation method, the test results interpretation method.

In the case of modern, semi-probabilistic safety concepts, a short statistical analysis is also made, for example in accordance with the standard EN 1926: 2006.

Testing stone wall includes the following tests:

- Permissible wall stress: compressive stress and shear stress, based on DIN 1053: 1996 (deterministic safety concept)
- Characteristic wall strength: compressive and shear strength, based on EN 1996-1-1: 2005 and DIN EN 1996-1-1: 2012 (EC6) (semi-probabilistic safety concept)
- Assessment of multilayer wall capacity by the Egermann.

It is suggested to apply identification of the wall compactness coefficients, which represents the level of fulfillment of the wall volume with the rock material and the binder between the two outer surfaces of the wall.

4. Methodological approach for different cases

4.1. Methodological approach to the restoration of the stone bridges

Works on the restoration of the stone bridges, as well as all other cultural and historical buildings, begins with the collection of data and information. In addition to general data, special importance must be given to obtaining full and detailed information on the previous conservation and restoration works.

The next stage, regardless of the quantity and quality of the previous data and information, is the creation of the action plan, which allows for a complete preparation of the rehabilitation and protection project, and includes:

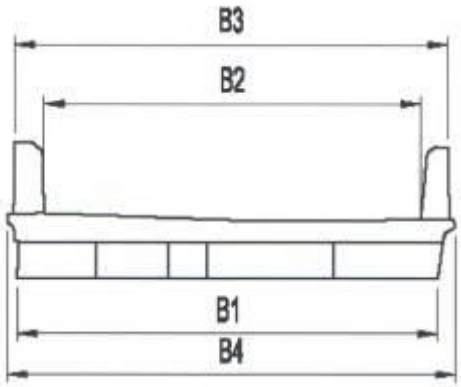
- program of the preliminary research works,
- current situation project,
- monitoring and supervision of the research works,
- preliminary static analysis of the bridge,
- defining conclusions and making recommendations for rehabilitation project.

A well-designed project of the current situation involves the following:

- necessary documentation of the Commission to Preserve National Monuments (a decision to designate a building ie. a bridge as a national monument),
- geodetic survey of the bridge, the river bed and banks,
- architectural and construction plan of the current situation: the design, details and description of the visible damage, technical description, photo documentation of the current situation,
- designs from all earlier rehabilitation projects documentation and
- records of manual measurement, which is done on both upstream and downstream side.

Description of the bridge structure must be precise and detailed. In addition to the bridge construction, it also includes the bridge ramp. Representation of details or longitudinal and transversal dimensions can be displayed in tables (Fig. 6). Details that must be included in the description of a structure are:

- the total length of the bridge with its arches and river pillars,
- the length of the bridge fence and its height,
- the length of the ramp, with its detailed description, and the length of the bridge and ramp,
- the height of the bridge measured from the riverbed to the bridge fence top,
- the number of arches with their light range dimensions,
- the number of river pillars with their ground layout dimensions,
- the way of reliance on the bridge pillars on its foundations and of the foundation types (description of the foundations, with its characteristic details of the upstream and downstream sides - icebreakers and counterforts, and other characteristics related to the foundation method),
- the thickness and width of the bridge arches,
- the gabarit and tread width of the bridge,
- the type and size of the longitudinal slope of the bridge with all the characteristics of the longitudinal bridge profile.



	Gabaritne širine			
	Svod	Hodna površina	Vrh ograde	Vijenac
	B1	B2	B3	B4
	[m]	[m]	[m]	[m]
OD		3,85	4,42	4,54
L1	4,18	3,82	4,37	4,54
S1		3,82	4,36	4,54
L2	4,27	3,87	4,40	4,55
S2		3,90	4,47	4,56
L3	4,26	3,89	4,45	4,57
S3		3,85	4,40	4,55
L4	4,25	3,87	4,42	4,56
S4		3,86	4,47	4,59
L5	4,31	3,86	4,44	4,59
S5		3,84	4,40	4,56
L6	4,28	3,80	4,36	4,55
S6		3,78	4,33	4,54
L7	4,30	3,78	4,35	4,53
OL		3,84	4,39	4,58

Fig. 6. A typical cross section of the bridge with table transverse dimensions and outline width

While collecting these data, a special care should be given to precise and clear labelling of the individual segments, whose data and information are being measured and described.

The design documentation should include all observed damage or deformation, with a special emphasis on those that can be defined as specific and that have special significance. This damage and all deformations should also be photo-documented.

The analyses of the state of these buildings for the purpose of developing rehabilitation projects require determination of certain parameters through which we can assess the condition of the structure and suggest the optimal measures of the restoration and protection. Therefore, it is necessary to perform the research and testing to identify these parameters. In the cases of rehabilitation of old stone bridges, the goal of such research and testing is:

- to define the requirements of the bridge foundations: geological composition, engineering and geological characteristics of the ground for each pillar of the bridge, the depth of the pillars' foundations, the thickness of the foundational stone blocks, material properties in the foundations, the characteristics of the foundational material in the influence zone of foundation in depth,
- to define mineralogical and petrographic structure of the stone material,
- to define physical and mechanical characteristics of the stone, for each of the structural elements of the bridge (especially the stone strength),
- to define characteristics of mortar through its chemical composition.

All the mentioned data and information can be obtained through a precisely made research program. A part of this program are clearly defined field investigations and laboratory testing. The field investigations include:

- Geotechnical drillings,
- Exploratory excavations,
- The Standard Penetration Test (SPT),
- The Schmidt Hammer Testing.

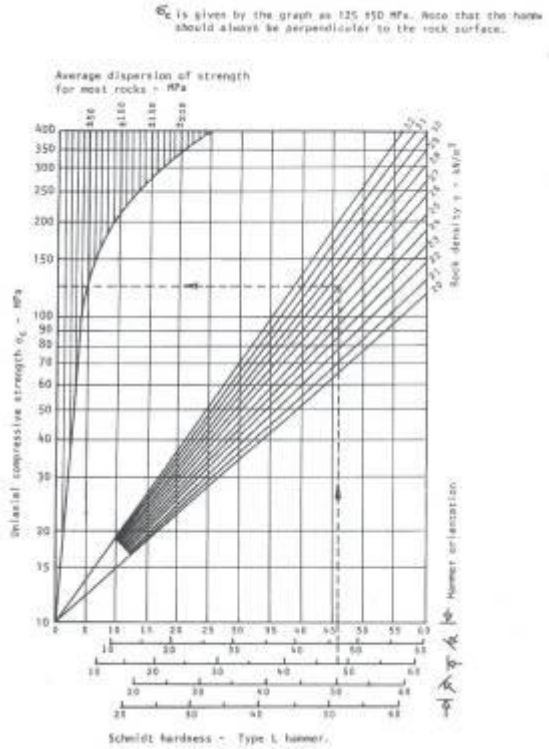


Fig. 7. The relationship between the hardness obtained Schmidt hammer and uniaxial strength of rock (by Deere dealer and Muller)

Laboratory testing include:

- Geomechanical testing of the soil,
- Geomechanical testing of the stone,

- Mineralogical and petrographic examination of stone,
- Mineralogical, petrographic and chemical analyzes of the original mortar,
- Assessment of the cementation index (hydraulic module) of the original mortar.

The performed investigations and tests enable the implementation of a preliminary static analysis, which involves determining the capacity of the construction in terms of:

- Stability of its arch construction,
- Bearing capacity of the foundations.

These analyzes consider the limit states of the bearing capacity, in accordance with the partial concept of safety coefficients of the load and resistance.

Based on all these researches, testing and analyses, the assessment of the state of the structure is performed and the recommendations of optimal rehabilitation measures are given, all of which makes the project of the rehabilitation and protection of the bridge as a cultural and historic construction.

4.2. Methodological approach to the restoration of the stone towers and fortresses

Considering the stone towers and fortresses, there is no substantial differences in methodological approach compared to the one for the stone bridges that we have already described. There are, however, certain specific features, extensions or modifications, which will be listed and described.

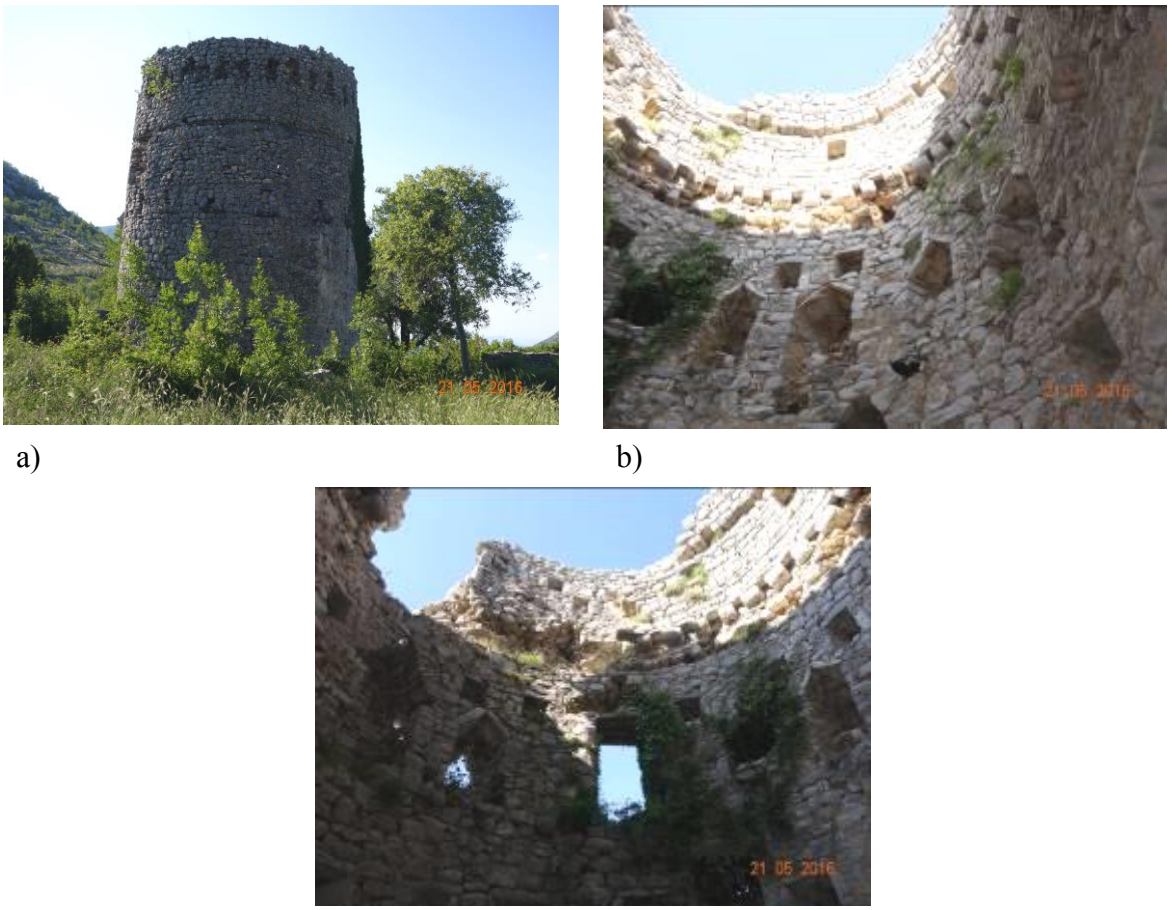
When the stone towers and fortresses are considered, in the phase of collection general information about the building, it is important to collect information about the stages in the construction of the building. This means that each stage is defined according to the historical period in which it was executed, the scope of the works done, characteristic details in this particular phase of the construction as well as other relevant notes and facts (for example, who ruled in that period, which may indicate to the technical and technological characteristics of the construction in this phase or to the type of material used). Other basic data are as follows: type of tower (fortress), construction method, the subsequent construction procedures and detailed information on dimensions, as well as all available or new design plans.

When describing the current situation, a special attention should be paid to the damages and to making their typology and registration. Damage types related to cracks, weaknesses in the wall in the form of washed binder, falling out of the stone blocks (Fig. 1. b)), the wall deformations.

The research works aim at obtaining information on the foundation soil and masonry construction and consist of:

- Geodetic surveying,
- Geotechnical testing of the soil,
- Architectural surveying of the current situation,
- Initial conservation and restoration works,
- Recording damages,
- Analysis of the structural components stability,
- Investigating the walls including all its components (a nondestructive testing methods are carried out here).

When it comes to examining the stone out of which the wall is made, then, in addition to the above mentioned testing, the calcimetry measurements are done as well as the velocity of longitudinal waves in the wall stone is measured. Here, the macroscopic description of the mortar is also provided. Nondestructive testing methods include geophysical surveying of the terrain and the wall.



a) b)

c)

Fig. 8. Hadzibey's tower near Stolac: a) the state of the outside wall of the tower, with visible defects and deformations; b) and c) the state of the inside wall of the tower (photo. A. Ibrahimovic, 2016)

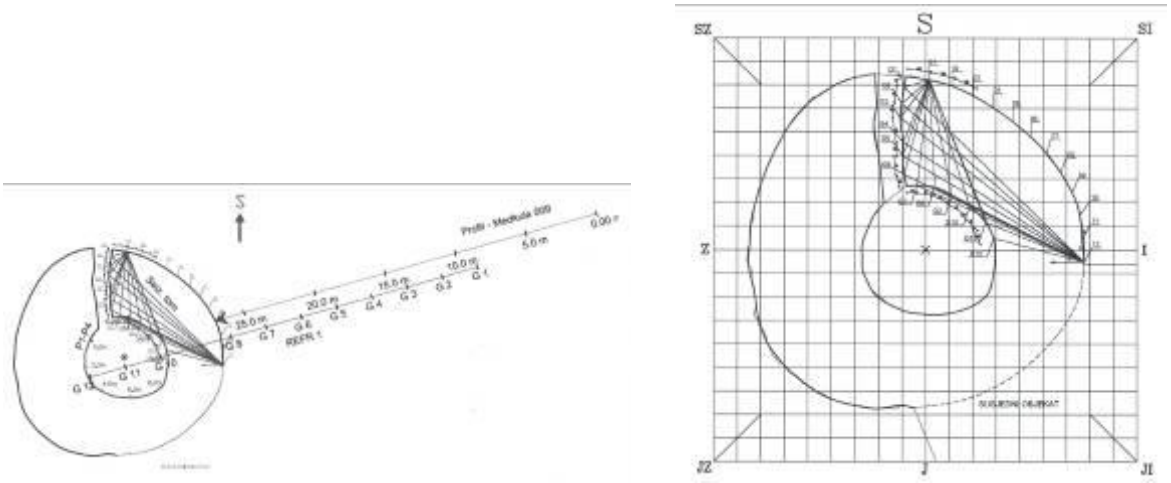


Fig. 9. a) Disposition of geophysical measurements; b) seismic tomography walls of the tower with the disposition of geophones and point of initiation

In the wider area of the construction (measurements in the soil), the seismic and georadar measurements are done. However, measuring methods of seismic tomography and georadar are used on the construction wall, (in order to estimate the wall compactness) (Fig. 9.).

The rehabilitation project defines optimal rehabilitation and protection measures, all on the basis of the investigations and analysis, separately for all damage types and for all the individual parts of the stone building, tower and fortress.

4.3. Methodological approach to the restoration of the religious buildings

The restoration of the sacred objects poses a particular challenge when it comes to reconstruction and preservation of the architectural, cultural and historic heritage. First of all, those are the buildings that still have their operational function. Regardless of their age, these buildings are mostly active in terms of their daily operation, for the purposes they have originally been constructed for. In addition, a considerable number of those buildings represent both a type of museum spaces and buildings in the service of tourism. Their twofold purpose is the reason for the most direct interconnection, and, to say it, the conflict between the desire to preserve the authenticity and the application of modern norms of construction of the structure that must meet all the safety and operational standards in terms of its reliability. Finally, their nature is significantly richer in architectural elements and details that require a certain artistic approach and a significant level of conservation in the context of projects and works that we define as the reconstruction or restoration and conservation project of architectural, cultural and historic heritage.

Based on these assumptions, each of the aforementioned steps, within the overall algorithm of the successfully implemented reconstruction and protection of the historic building, is characterized by its numerous details. It begins with the general information about the description of the current state of the facility until investigations and measurements[10].

Testing of the mortar is done on samples of the mortar used for masonry, the mortar used on the facade and the mortar used on the inside walls. When the strength of the mortar can be crucial for the load capacity of the wall, it is recommended to do the testing in accordance with EN 1855-9, procedure III[11].

In the case of geophysical surveying and testing, due to the possibility of the poor condition of the walls, it is recommended to use geoeletric surveying method (Vertical Electric Sounding - VES). The results are presented in the form of graphs and tables and their interpretation is performed in order to precisely determine the condition of the walls of the building. The same method of geophysical surveying can be performed to survey the surrounding soil.

For Islamic sacral buildings, it is important to emphasize one more specificity concerning the need to create the research program that applies only to the minaret as a part of the mosque separated from the rest of the building. These research programs are integral parts of the overall research on this type of objects, so that recommendations or rehabilitation projects of the minaret are integral parts of the overall rehabilitation of the mosque. Of course, this also applies to other religious buildings, such as churches, if they have parts that are more or less separated from the basic footprint of the building (e.g. separate towers or bell towers).

5. Instead of a conclusion

Reconstruction, restoration, conservation and management of the cultural and historic architectural heritage represent a very special engineering challenge. Its multidisciplinary nature talks about the specificity of engineering problems.

[10] In a study of the wall stone, we should do a detailed geological interpretation of the stone, its mineralogical and petrological determination, and geomechanical properties include bulk density and volume as the level of water absorption, which allows us to use the deterministic safety concept for calculations, in the absence of data that allow us to estimate the characteristic strength of the stone according to EN 1996: 2006.

[11] Testing of mortar in the joint.



a) b)

Fig. 10. The reconstruction works on the mosques destroyed in the war: a) military mosque at Kuslat near Zvornik; b) Ferhadija mosque in Banja Luka (Photo: A. Ibrahimovic, 2012, 2013)

Seemingly paradoxical and irreconcilable requirement to preserve the authenticity and the fulfillment of the requirements of technical standards and regulations may discourage engineers to take the challenge.



a) b)

Fig. 11. Reconstructed and ongoing reconstruction of architectural heritage: a) Ferhadija mosque in Banja Luka; b) the Orthodox Cathedral Church in Mostar c) the Old Bridge in Mostar;

However, the correct approach with clear methodology framework for works in this area make it possible to do the task successfully, satisfying both aspects of the aforementioned requirement. Positive experience in Bosnia and Herzegovina speaks in favor of it. What we have presented in the introduction to this article, as a result of destructive activities that, in the case of Bosnia and Herzegovina, have become known worldwide and termed urbicide, after completed and ongoing works on the restoration and reconstruction are now seen as successfully completed projects (Fig. 11., Fig. 12.).



Fig. 12. Reconstructed The Old Bridge in Mostar;

It must also be emphasized that ignorance and lack of awareness of the importance of architectural, cultural and historic heritage can lead to tragic cases where national treasure is being lost forever. For example, this happened to the Turhan Emin Bey's mosque in Ustikolina where the construction of an entirely new structure on the site of the old mosques destroyed in the war has resulted in irrevocable loss of a national monument of exceptional value. Unfortunately, this is only one of many such examples.



a) b)

Fig. 13. Turhan Emin Bey's mosque in Ustikolina: a) the earlier design (15th century) before demolition; b) current design after restoration

The new challenges for multidisciplinary teams of engineers working on reconstruction and restoration of these objects, include testing of the rocks at which these building are situated, especially in cases related to the rock cliffs, analysis and assessment of their stability conditions, which, as a result of the loss of the rock mass, can also be the cause of the damage or the destruction of such old buildings. Such is the case with the old town Srebrenik. However, it is not the only case because there is a significant number of similar buildings.

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DESTRUCTION OF OLD BUILDINGS IN TUZLA CITY CENTER DUE TO SUBSIDENCE OF TERRAIN IN THE ZONE OF SALT EXPLOITATION

Kenan Mandžić[1], Adnan Ibrahimović[2], Damir Zenunović[3], Enver Mandžić[4]

Faculty of Mining, Geology and Civil Engineering, University of Tuzla
Faculty of Mining, Geology and Civil Engineering, University of Tuzla
Faculty of Mining, Geology and Civil Engineering, University of Tuzla
Academy of Sciences and Art of Bosnia and Herzegovina

***Abstract**: The city of Tuzla is located on the salt deposit which was for many years exploited for the needs of the population and industry. The significant increase in salt water exploitation began in the last 60 years. Exploitation of salt, under the city, created great spaces which is reason why there has been a ground subsidence in the area of the city. Maximum subsidence in parts of the city is 18m. Over time, the strain that appeared on the surface of the ground led to the demolition of many buildings of cultural and historical heritage of the city. In this paper, the reasons and process itself that lead to loss of cultural and historical center and the gradual demolition of a large number of important historical buildings in the city of Tuzla is presented.*

***Key words**: Subsidence, Salt deposit, Destruction*

1. Introduction

The documentary evidence of settlement in what is now the town of Tuzla, date from the Neolithic period and is related to the sources of salt water that existed in that area. From X century there is a document that states that this settlement is called Salines, which in Latin means salt. With the arrival of the Turks area of the village is called Memle Hatein, Memleha-Zir, Memeleha Bala, which in Arabic means they salt. Turkish name Tuzlai-zi and Tuzlai Bala, also means salt, as well as the present name Tuzla.

In the Turkish time since the end of the fifteenth century until 1987, when Bosnia and Herzegovina comes under Austro-Hungarian rule, salt was produced by pumping salt water from hand-dug wells in the city. People were boiling salted water to produce salt. From 1885 begins industrial exploitation of salt water by drilled wells. Salt water is

[1] Kenan Mandžić, Dr sc.-Dipl.ing., Associate Professor, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, kenan.mandzic@untz.ba
[2] Adnan Ibrahimović, Dr sc.-Dipl.ing., Associate Professor, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, adnan.ibrahimovic@untz.ba
[3] Damir Zenunović, Dr sc.-Dipl.ing., Associate Professor, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, damir.zenunovic@untz.ba
[4] Enver Mandžić, Academician, Dr sc.-Dipl.ing., Professor Emeritus

pumped from greater depths and locations for the wells were in the metropolitan area. Two salt factories were built, in which salt water was cocked to produce salt.

At the time of Yugoslavia, since 1945, exploitation of salt by salt wells continued, since it was the only deposit of salt in Yugoslavia.

From the earliest times to 1885 from the underground by salt water about 4,000,000 tons of salt was removed. From 1885 to 1939, also from salt water it was produced approximately 4,000,000 tons of salt. From 1939 to 2000 and from the underworld about 32 million tons salt has been exploited. In underground, in the area where salt was dissolved and taken out to the surface of the ground by the salt water the large empty space of 9.5 million m³ was created. This area, where the water dissolved salt, was filled by subsidence of the terrain above this space. Deformations in the massif with the time came to the surface of the ground. As the result subsidence of the ground surface, on which the urban complex of the city of Tuzla existed, began.

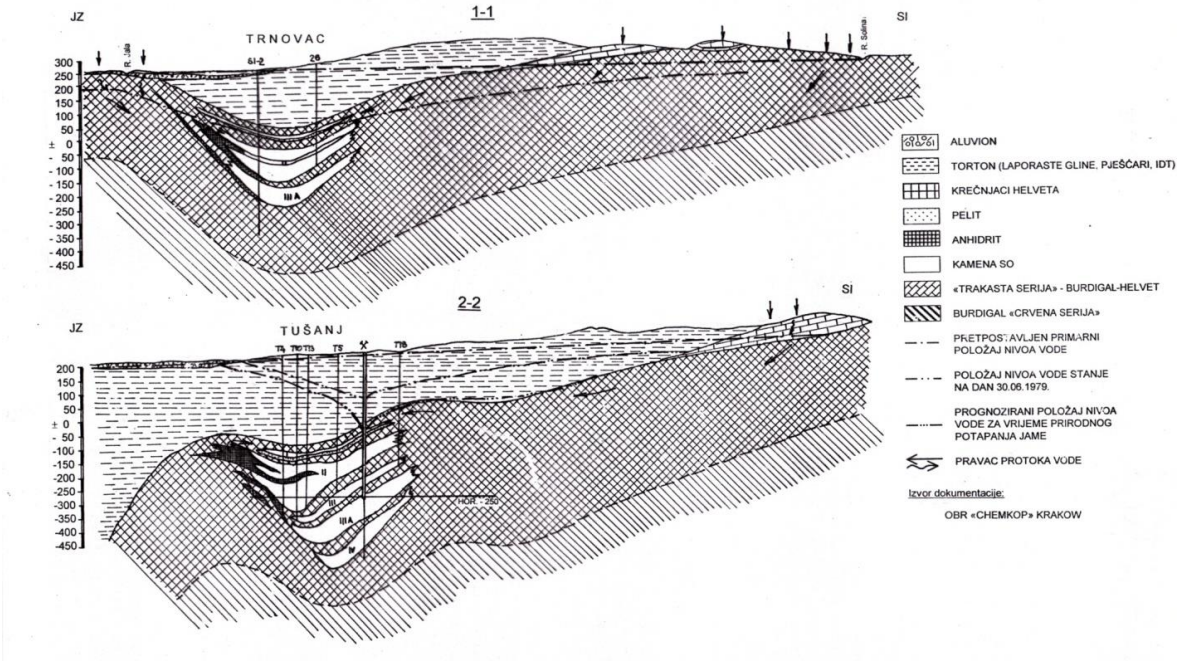


Fig. 1. Profile of salt deposit under the city centre

2. Problems as the result of the city of Tuzla subsidence

Industrial exploitation of salt water by underground wells lasted for 120 years. During this time 180 wells, that pumped salt water from underground, were drilled. Dissolving salt and salt water pumping from the underground created a degradation of the massif in the area of salt exploitation by salt water, which resulted in subsidence with reflection on the surface of the terrain. The process of sinking metropolitan area is followed by geodetic measurements since 1956. Until 1992, geodetic measurements are performed annually in the month of July. This made it possible to establish that the area of 6.3 km² had subsidence of more than 1 cm per year. The volume of space that was affected by subsidence from 1956 to 2000 amounts to about 7.5 km³. Vertical subsidence in the city area, in some places, reaches the value of about 18 m.

As a result of subsidence 2,700 apartments, 67,000 m² of office space and 130,000 m² of objects space that served as administrative, educational or Health had to be demolished. From downtown Tuzla about 15,000 people were displaced. Damaged by subsidence, all the buildings built during the period of the Turks and Austria Empire, in the center of the city, had to be destroyed. By demolition of buildings in certain parts of the

city, the whole streets vanished, and the city had to change the organizational and functional structure. With today's population, the consequences of the sinking, which took place at the time of the existence of Yugoslavia, had the scale of the environmental disaster. It is important to note that the very intensive construction of important structures in Tuzla took place in the period Austrian rule from 1879 to 1914. Buildings that were built, for that time were, modern hotels, large gymnasium, post office, civil and military administration, court, spa, swimming pool and many architecturally significant housing facilities.

The paper is intended to show some characteristics of the sinking and catastrophic consequences caused by subsidence on the surface.

3. Geodetic measurements of subsidence in the city of Tuzla

In 1910 cracks on some buildings were observed. During the Kingdom of Yugoslavia 1918 to 1945 the problem of the sinking was not given any special attention. From 1945 industrial exploitation of salt water is significantly increased due to the importance of salt in the chemical industry. In 1952 and 1953, the problem of subsidence in the metropolitan area was becoming very significant, because on the facilities which have been built since 1945 cracks were observed and on the objects from Austria period (1879-1918) the cracks become so large that some facilities have to be demolished. In 1955 a network of geodetic points was set up for monitoring subsidence of the city and baseline measurement was done. The first results in 1956 show that there are areas in the city where the annual subsidence is over 30 cm. Geodetic measurements up to 1992 showed that the subsidence of the certain parts of the city took place very intensively.

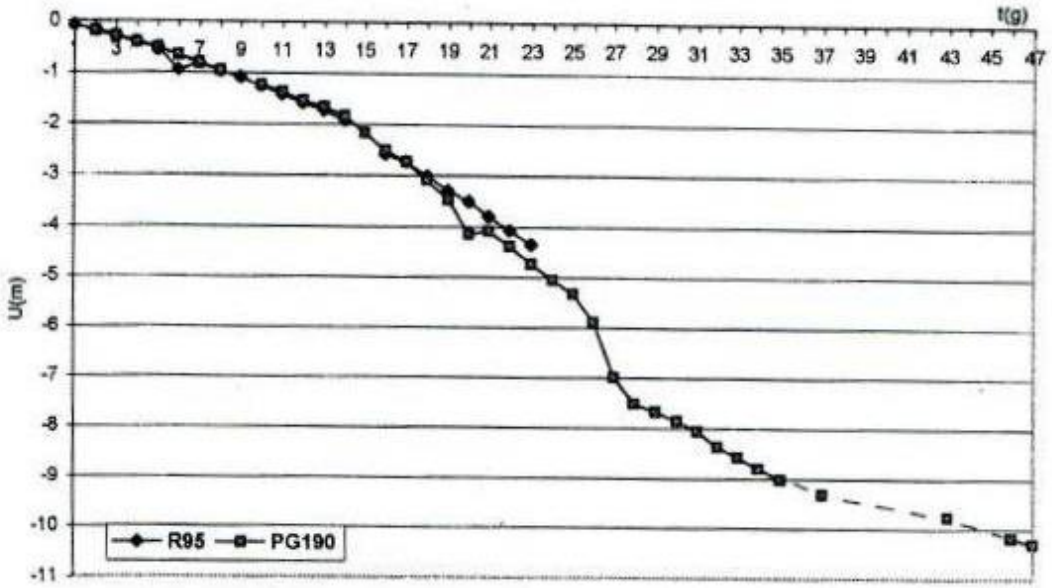


Fig. 2. Cumulative flow of sinking polygon point PG in last 15 years, until 2003-the flow is interpreted by polynomial of the third degree, with high coefficient of correlation. Terrain located on the PG 190 point subsided 10.3 m.

3. The characteristic deformation of the ground surface

In time, on the ground surface the characteristic deformations appear, and can easily be registered on the site, as the product of subsidence. These deformities occur in only a few years after the construction of certain parts of the stairs, asphalt paths or curbs.

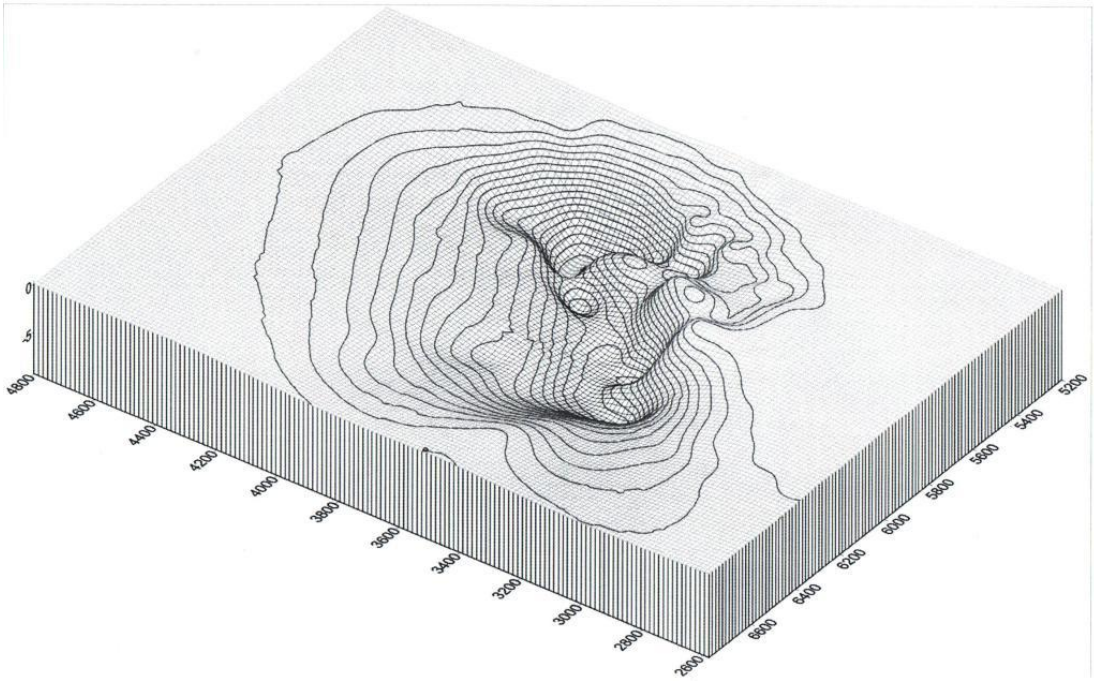


Fig. 3. Regional overview of subsidence field in city area, with contours hatching equidistance of 0.5m. Volume of subsidence is around 7.500.000 m³.



Fig. 4. Typical deformation on the surface (photo: K. Mandžić 2008-2013)

The destructive effect of the sinking has been shown in several examples of important structures and parts of the screening picture how it was and how it is today. From the presented examples one can presume the extent of the disaster, to which the city of Tuzla has been exposed.



Fig. 5. Typical deformation on the surface (photo: K. Mandžić 2005)



a) b)

Fig. 6. High school built in 1898 (a- photo: old postcard of Tuzla). Area were high school use to be (b-photo: K. Mandžić 2016)



a) b)

Fig. 7. The old post office building, built in Austrian period (a-photo: old postcard of Tuzla). Area were old post office building use to be (b- photo: K. Mandžić 2016).



a) b)

Fig. 8. The street in city center with buildings built in Ottoman and Austrian period (a- old postcard of Tuzla). Area were street use to be (b- photo: K. Mandžić 2011).



a) b)

Fig. 9. The street in city center from 1900(a- old postcard of Tuzla). Area were street use to be (b- photo: K. Mandžić 2016).



a) b)

Figure 10. The street in city center from 1950 (a- unknown author). Area of the street with clear view of street subsidence, in relation to surrounding terrain (b- photo: K. Mandžić 2016).

3. Conclusion

The destructive effect of subsidence as the result of salt water exploitation by wells drilled in Tuzla has been ongoing for more than 120 years. Industrial exploitation of salt water for chemical industry from 1945 to 2000 was the direct cause of the sinking, which is why 2,700 apartments, 67,000 m2 of office space and 130,000 m2 for administration, education, health it had to be demolished and about 15,000 people displaced from the city center. This problem presents the specific

The emergence of subsidence in Tuzla represents a very specific phenomenon and a problem that is very rare in the world. Solving this problem is a difficult task. The paper presents some unique features on the surface due to subsidence and destroyed buildings and facilities along the street, which would now be part of the cultural and historical heritage. All of this happened in a country where it was important to have salt exploitation of the regardless to the catastrophic consequences that this exploitation produced. Many years of neglecting this problem led to the destruction of important structures that could today represented the significant cultural and historical legacy of the city of Tuzla. According to research carried out for the purpose of spatial plan of Tuzla, is determined that in certain parts of the city, subsidence will not stop not till 2026. These results indicate that some parts of the city are useless for the construction of buildings for long period of time and therefore for the eventual rebuilding of the destroyed buildings of cultural heritage.

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WOODEN BEAMS BUILT-IN VAULTS AND DOMES OF THE CHURCHES IN MEDIEVAL SERBIA FROM THE SECOND HALF OF 12th TO THE MID OF 14th CENTURY

Igor Bjelić[1], Nađa Kurtović-Folić[2], Radomir Folić[3]

University of Niš, Faculty of Civil Engineering and Architecture
University of Novi Sad, Faculty of Technical Sciences

Abstract: *The paper analyzes the behaviour of built-in wooden elements of medieval construction of arches, vaults and domes of Orthodox churches built in the area of Medieval Serbia in the period from the second half of 12th to the middle of 14th century. Their role in these structures is significant, because it is a seismically active area, and, in addition to historical knowledge could be useful as lessons for contemporary practice. Solutions in the whole Balkan Peninsula indicate the strong influence of Byzantine construction techniques, which have many variations depending on local traditions. In the literature, wooden structural elements in these circuits are commonly referred to only as ties, rarely was analyzed their other functions. Based on the number of examples this paper defines other purposes of wood elements on vaults and arches depending on different positions they held. Discussion of the results gives basic typology of positions, ways of creating links and form of elements in arches, vaults and domes of Orthodox churches in the medieval Serbia in the period from the second half of 12th to the middle of the 14th century.*

Key words: *Vaults and domes, wooden beams, wooden grid, Masonry, Stress analysis*

1. Opening remarks

Studying medieval sacral architecture contributes to understanding the use of local materials to improve the properties of built structures. However, the stability and durability of masonry structures from this period has passed the test of time over hundreds of years. The stability of masonry structures is largely dependent on their supports, particularly in structures with arches, vaults and domes. The most common problem with these structures is the horizontal thrusts which must be accommodated using specific engineering solutions. This is especially important in structures built in regions with high seismic activities inherent to the territory of the Balkans.

[1] Dr Igor Bjelić, researcher at the Project TR 36042, University of Niš, Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18000 Niš, Serbia, igor_bjelic@yahoo.com.
[2] Dr Nađa Kurtović-Folić, Full Professor, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Trg D. Obradovića 6, nfolic@gmail.com.
[3] Dr Radomir Folić, Professor Emeritus, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Trg D. Obradovića 6, r.folic@gmail.com.

The specific design concept of Byzantine - Orthodox churches resulted in the introduction of adequate structural elements in order to obtain stable, durable and aesthetically valuable objects. Orthodox sacral buildings are characterized by distinctive architectural structures with specific position and spatial relationship between arches, vaults and domes. In sacral Orthodox structures located in seismically active areas of the Byzantine Empire, in zones of supports of arches, vaults and domes, thrust was accommodated using wooden beams - ties. Timer beams occupy certain positions, and can form specific solutions in the form of wooden grillwork. This paper analyzes the wooden beams whose position indicates that they can be defined as ties. In some cases, the position of wooden beams can be different, so that they could not be ties, which is also analyzed in the paper and their possible function indicated.

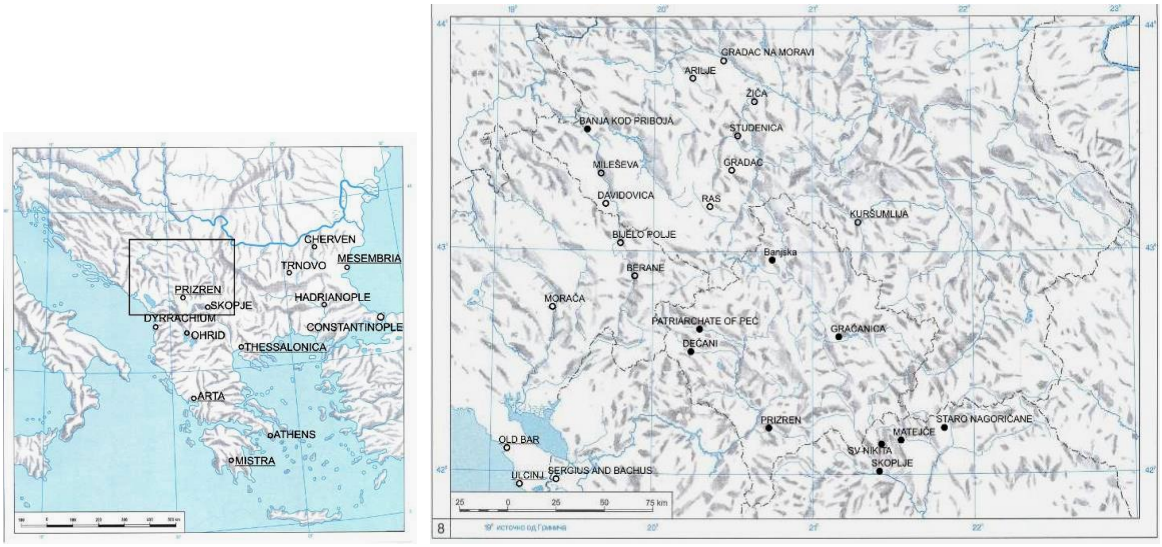
The specific use of certain structural elements in medieval structures was a subject analyzed by several scientists. Unavoidable in older literature regarding the function of medieval structural elements are works of Viollet-le-Duc E. [24], Choisi A. [3] and Fitchen J. [5]. In the second half of the 20th century the theory of limit capacity was actualized again in the domain of arch, vault and dome structures mostly thanks to the works of Heyman J. [8,9], as well as his followers Block P. [1] and Ochsendorf J. [19]. From the aspect of development of these structures also important were the works of Huerta S. [10,11] and Mainstone R. [17]. In Eastern Europe, the most endangered structures of this type are also present on medieval churches, whose architecture is significantly different compared to modern solutions in the west. The problem of stability of structures applied in this architecture was in the focus of the works of Osterhout R. [20], Vintzileou E. [23], Penelis G. [21], Gavrilović P. [7], and Folić R. [6]. A broad overview of monumental heritage of Byzantine-Orthodox medieval architecture was provided by Mango C. [16], Kreutheimer R. [14] and Ćurčić S. [4]. The issue of wooden beams in medieval Orthodox churches was also the subject of the works of Koumantos A. [13] and Karydis N. [12]. They viewed these structural elements as ties, neglecting their other functions in monuments in the region of the Balkans.

This paper analyzes the role of wooden beams depending of their possible specific positions in arch, vault and dome structures made of bricks in the architecture of Orthodox churches on the territory of medieval Serbia. It presents and analyzes a wider range of use of horizontal wooden elements made of materials which are good in tolerating tensile forces in structural systems whose material (masonry) is non-resistant to tension, but tolerant to pressure forces. The paper covers the period from the 12th to 14th century when specific design solutions were applied in the area of medieval Serbia by using structural elements typical of the architecture of the Catholic West and the Orthodox East.

2. Material and methods

Data for this study were obtained by studying the structures of Orthodox Church architecture whose appearance is monitored on the territory of medieval Serbia, where the wooden elements were frequently used as ties in arches, vaults and domes. The considered structures were built during the rule of the Serbian Nemanjić dynasty (1166-1372.). This is the period of greatest prosperity of the Serbian state. By their architectural framework, these structures belong to Orthodox churches of Byzantine style. As a rule of thumb, wooden beam grillwork appear on monuments in a wide area of the Balkan Peninsula, that is not only on structures built in medieval Serbia, but also on Orthodox churches in other countries of this period in Southeast Europe (Fig. 1). Structural solutions and the stylistic expression of church buildings in the area of medieval Serbia often reflect the Western influence of Romanesque and the transitional Romanesque-Gothic style. This influence is primarily coming from the Adriatic coastline (today's Montenegrin and Dalmatian coast).

The majority of examples of sacral architecture on the territory of Old Serbia are the result of creative solutions in the process of construction, ways of designing arch, vault and dome structures, and the use of wooden beam systems in order to stabilize them.



a) b)

Fig. 1: Urban hotspots of Byzantine-Orthodox architecture: a) hotspots in the eastern part of the Balkans between 12th and 14th century; b) highlighted detail – the map to the right shows the frequency of structures of sacral architecture with a pronounced influence of Byzantine architecture on Serbian monuments marked with dark circles (arranged by I.B.).

The application of wooden elements in supports of masonry arches, vaults and domes is particularly common during 13th and 14th century, when Western Europe is largely oriented towards the Gothic architecture. While horizontal thrusts coming from arches and vaults in Gothic architecture were suppressed using buttresses, Byzantine architecture resolves this problem using wooden ties.

This paper applies the method of comparative analysis from the aspect of the constructive role of elements (assemblies of masonry arches, vaults and domes), aesthetic values in the overall assembly, and the history of their manifestations. The analysis includes certain monuments of Byzantine architectural style of constructing sacral buildings on the Balkans. The analysis is focused on the specific positions of wooden beams and their role.

3.2 Analysis of wooden beams functioning as wooden ties

The position of wooden beams depended on the concept of designing the general frameworks of Orthodox sacral structures. In his "Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle" [24], Viollet-le-Duc E. indicates the position of wooden beams in supports of Romanesque buildings (Fig. 2a, beams C on the left side and in the lower right corner).

If the beam shown in the drawing is properly anchored at its ends, it contributes to suppressing the unequal shear of supports in individual supporting arches of the barrel vault.

There are monuments of Byzantine architecture where stepped forms arches and vaults were little or not used at all. Constructing regular barrel vaults, which develop stronger thrust forces than the stepped vaults, has led to the use of wooden shutters. Visual

inspection of old masonry arch and vault structures led to the concluded that during the construction of upper arches buckling occurred in shutters at the level of supports.

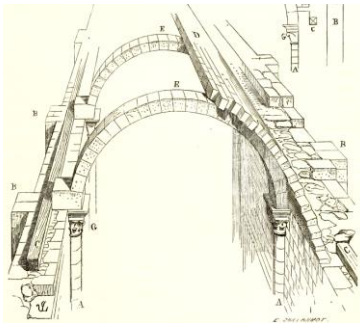


Fig. 2. Location of the wooden beam C with abutments of transverse arches of the longitudinal barrel vault.

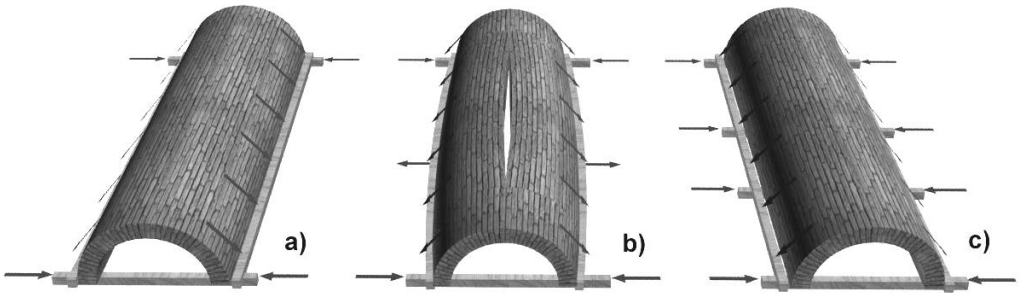


Fig. 3. Position of wooden beams with supports of the barrel vault: a) Effects of lateral thrust on supports of the barrel vault and the longitudinal beams on the outside of the vault; b) Lateral bending of the long longitudinal beams and crack at the top of the vault as a result of the pronounced effect of lateral thrusts exercised by the vault; c) Suppressing the possibilities of beam buckling and vault cracking in the case b) using traverse, equally spaced wooden ties (3D model by I.B.)

As a result, supports were displaced sideways. One of the reasons to place the heavy longitudinal beams to the outside of supports of barrel vaults was obviously to suppress the uneven shear of supports in the process of constructing. However, due to the length of longitudinal wooden beams it is realistic to expect their longitudinal lateral buckling compared to their anchored ends. According to Fig. 3b, cracking of the barrel vault is expected to occur along its central longitudinal zone. Thus, in Middle Ages, wooden ties were installed along the beams in specific time intervals (Fig. 3c). The transverse beams functioning as wooden ties are pronounced in the church of St. Nicholas in Prilep (Macedonia), but their application in this role is characteristic of the church of St. Petka in the village Staničenje in Eastern Serbia. This small church is the endowment of the Bulgarian nobleman Arsenije from the era of Bulgarian emperor Jovan Aleksandar Asen (1331-1371). The ties were fastened with wooden wedges, and this method is also shown in the work of Viollet-le-Duc [24] (comparative drawings in Fig. 4). In some cases wooden scantlings have had the function of ties, especially when it comes to separate arched openings or single-aisle small churches, topped by a longitudinal barrel vault. The effectiveness of their action as ties depended on the ways they were anchored in the arch supports. Penelis G. says about this: "It is characteristic that in the most Byzantine arches existed wooden-anchored ties with metallic junctions and the masonry constructions of the supports" [21]. Wooden beams in Byzantine architecture were anchored through wooden and metal elements.



a) b) c)

Fig. 4. Anchoring with wooden elements: a) in Western Europe in the Middle Ages (drawing [24]); b) in church of St. Petka in Staničenje (drawing by I.B.); c) the position of wooden ties in the church under the vault (according to Popović M.)

The Greek word for wooden beams used in buildings is "imas", while the system itself is called "imandosis", which means "ties" [23]. Therefore, their main role in single-room structures can be equated with the role of wooden ties. Today, ties organized in this way are a typical example of ecological engineering.

Here however, the question is: are they always beam-ties or beams under the force of thrust (struts)? In a system of vaults of churches of Byzantine architecture in the Balkans these beams are the most often considered ties because they are running through the supports of arches. If ties are applied for each arch individually, then it is sufficient for the length of support in the depth of the arch mass to be 20-40cm. The problem of interpretation of their role as ties occurs in vaults and domes, because then they cannot be seen as ties in the spatial framework of Byzantine sacral structures whose masses are dispersed in all levels.

3.3 Beams in the formation of the grillwork functioning as horizontal tying

In many Byzantine churches of the 14th century the exposed wooden beams in vault supports are treated as ties, especially those in barrel vaults, which are common in Byzantine architecture. However, the beam as a line element of a small cross-section which is set in one direction cannot have the function of a tie for the vault which is of larger depth and extends perpendicular to the beam direction, as shown in Fig. 5a. These beam and vault positions are characteristic to the central parts of Orthodox temples.

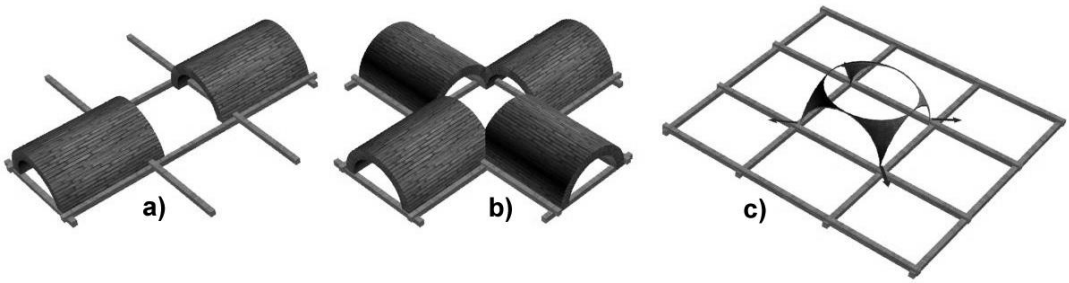
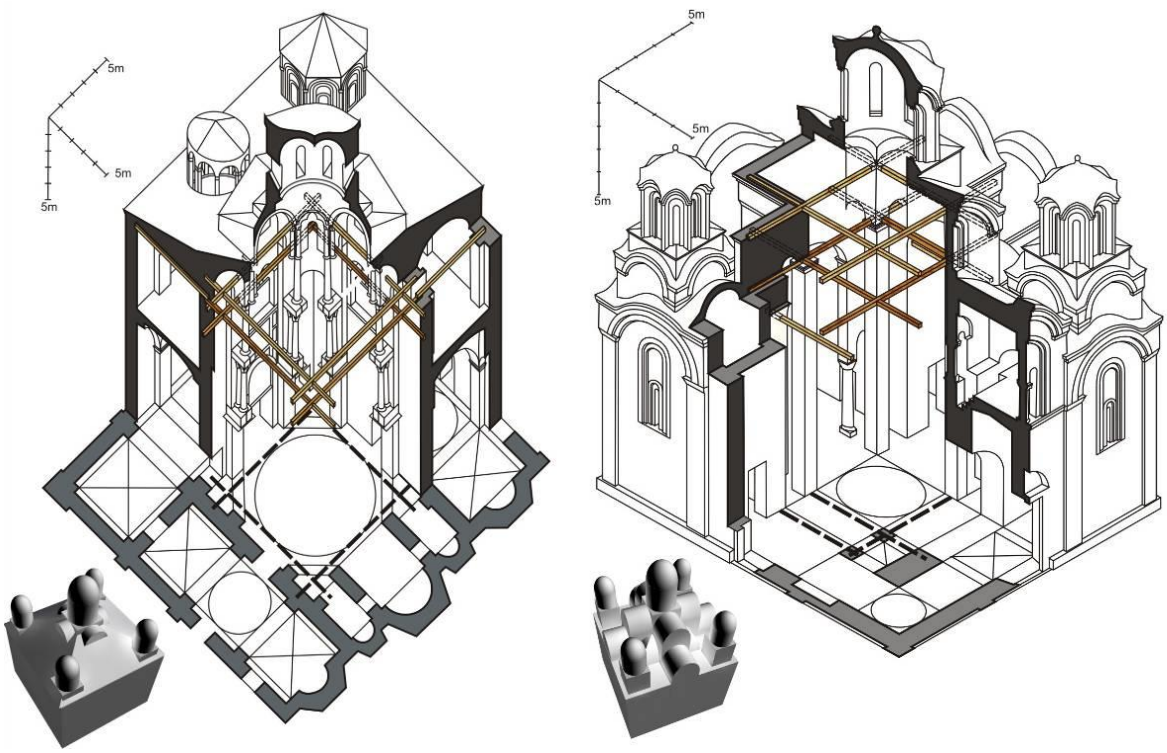


Fig. 5. Positions of wooden beams in the grillwork of vault supports in structures of central plan (I.B.).

Transverse beam position in relation to the vault (Fig. 3.) indicates that the beams were necessary for a longitudinally oriented vault reinforced with longitudinal beams along the supports. By crossing these beams with beams transverse direction longitudinal beams are somewhat prevented from buckling [21,22]. This is applied to a relatively small vault

spans in Byzantine architecture. A typical cruciform shape created by extending the transverse beams (Fig. 5a), creating conditions for the formation of vaults perpendicular to longitudinal vaults (Fig. 5b). Crossing these beams results in a grillwork which prevents them from pronounced lateral buckling which is also presented in basic barrel vaults (Fig. 3.). This stabilized the supports of vaults against horizontal shear.

The grillwork described in Byzantine architecture was very important considering that churches in late Middle Ages were of central plan. The supporting structure of the dome was located at the intersection of vaults and was formed through squinches, but more often pendentives. In supports of pendentives horizontal lateral pressures occur as a result of the own and additional load of the pendentive. The additional load is particularly pronounced in pendentives which carry domes without drums. Due to strong lateral thrusts in the lower part of the dome shear can occur in supports of the pendentive. The use of a wooden grillwork stabilizes the supports of the pendentive and the perpendicular barrel vaults. This is why the wooden grillwork in the structure of arches and domes is very important in the design of churches of Byzantine architecture. In addition, the beam grillwork enabled the formation of more complex assemblies of five-dome churches such as the Church of the Virgin Peragoritise in Arta and the Church of our Lady in Gračanica (Fig. 6. and Fig. 7.). The specificity of their assemblies is that such beam grillworks were applied at several different levels due to changes in geometry of these structures at certain elevations.



a) b)

Fig. 6. Axonometric views of five-dome churches with the positions of wooden beam systems: a) Arta; b) Gračanica (drawing by I.B.).

As the medieval Serbia was the westernmost Orthodox country of Middle Ages, it was an area where Western and Eastern construction technology were mingled.



a) b)

Fig. 7. Detail from the crossing of beams: a) in the zone of the lower cross in Arta; b) continuously crossed beams in the zone of the lower cross in Gračanica

3.4 Wooden ties in cross-vaults in Dečani

The most characteristic example of this is the Church of Christ Pantocrator in Visoki Dečani, where arch and vault structures were applied. The interior of the church is covered with cross-ribbed vaults whose elements were derived with spherical shape, and the whole structure is strengthened with wooden ties. The choice of shape can be associated with the customary form of vaults in churches on the territory of Central European medieval states. Installing wooden ties aimed at stabilizing the vaults indicates Byzantine influence.

Wooden beams in the vault system of the church in Dečani are usually interpreted as having the function of ties, but here the support structure of vaults is similar to assemblies in Italian cathedrals [2]. Despite the similarities to Western models in the choice of structure, the mutual relationship between the position of vaults had to fit the needs of covering an Orthodox temple. Due to the specific position of vaults in this church, the purpose of the wooden beams is also somewhat different.

S. Huerta and A. Ruiz [10] highlight the specific role of wooden beams in medieval cathedrals, and the creation of conditions for the construction of vaults in central aisles. This is confirmed by the fact that in the construction of the Cathedral of Toledo several conclusions were drawn that can be applied also in the analysis of the structure of the church in Dečani. The height of some of the monolithic marble columns exceeds 6 m, while the width of a single bay is less than 5 m, which indicates that the pillars were built before the end side walls of the aisles, after which the columns of internal aisles were erected. As a result, there is no doubt that the construction of the vaults on the side aisles of the naos should have somehow been ensured. The reason for this is that due to the lateral thrusts coming from the side vaults over the side aisles their reliance on free-standing columns endangered the stability of the structure. Therefore, before the construction of vaults in the side and the central aisle, the stability of columns should have been ensured, because they carried the vaults of both the side and the central aisles. Their stability has been achieved by placing a horizontal beam *F* between the tops of columns of the naos. The conclusion is that wooden beams in this case do not have the role of ties but of struts that prevent in a different way the vault supports in the central aisle (which is yet to be built, after the stabilization of vaults above the side aisles) from shear (Fig. 8.a and Fig. 8.b). The same can be concluded also for the *J* beam in the central aisle (Fig. 8.c). Its slightly higher position is dictated by the fact that if the foundation lines of the groin vault segments evoke its spherical shape, the vault induces thrusts also in crowns of supporting arches of groin vaults. In order to prevent the arches of the church of the monastery of Dečani from lateral tilting, the installed beams played a role of a strut in the height of the crown of longitudinal supporting arches [10].

The more complex functions of wooden beams can be seen in the narthex of the same church, which has a form of a basil hall (Fig. 8.b and Fig. 8.d). Under the arches of longitudinal arcades which separate the central aisle from the side aisles there are wooden

beams installed. Up to half the height of their cross-section transverse beams are grooved. During recovering the roofs of side aisles large arches were found in the wall mass along the entire length of longitudinal walls. The span of a single arch is equal to the sum of spans of three individual arcades which carry a single longitudinal wall. In each side wall, the span of this arch is equal to the span of whole arcades that carry these side walls. At the height of supports of these two embedded walls a continuous wooden beam is installed which also serves as a support of the arches of arcades. This beam plays a dual role: in the same time, it carries three small arches in the arcades and serves as a tie for large arches. This significantly reduces the effects of cracks whose presence would otherwise create separate mechanisms. At the same time, these two continuous beams prevent the shear of supports of the transverse arches of side aisles that rest on them. The role of these wooden elements is obviously very important in the complex mechanism of distribution of vaults and arches (Fig. 8.d).

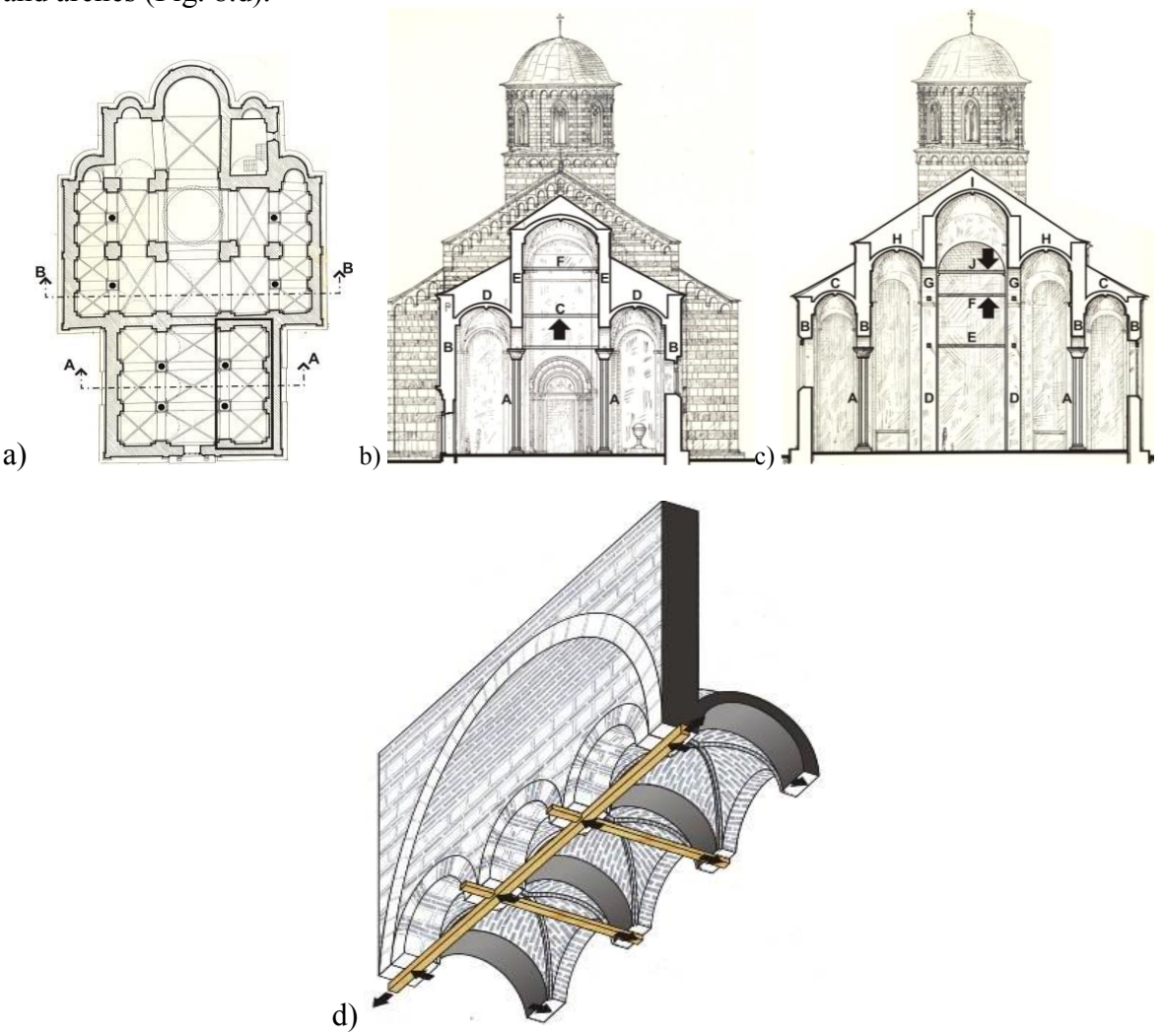


Fig. 8. Dečani – Church of Christ Pantocrator: a) plan of the church with the marked position of cross-section; b) section A-A through the narthex with the marked order of construction; c) section B-B through the western bay of the naos with the marked order of construction – the arrows mark the strut beams (drawing by Boskovic Đ., supplemented by I.B.); d) axonometric section through the southern aisle of narthex (drawing by I.B.).

3.5 The role of wooden beams in the dome

In Byzantine architecture, batch boxes were the most often installed in the middle of the drum, connecting the columns and pillars that carried them. The reason for this is that columns of the drum, due to the action of horizontal thrusts coming from the dome are the

most bent in the middle of their height which can lead to their fracture (Fig. 9.a). That is what happened to one of the columns under the dome of the Church of our Lady in Studenica (beginning of the thirteenth century) during the earthquake that occurred before 1629 [17,18], because the drum contained only radial while lacking horizontal batch boxes. The technique of installing wooden batch boxes in drum columns is often applied in the 14th century (Fig. 9.). In Middle Ages, horizontal wooden beams were installed at certain altitudes in order to prevent the damage, dividing thereby the drum of the dome to several horizontal planes. In Serbian medieval churches, wooden beams were usually installed in the mid height, while in other churches of Byzantine architecture they were installed also in other heights, and were usually not visible from the outside.

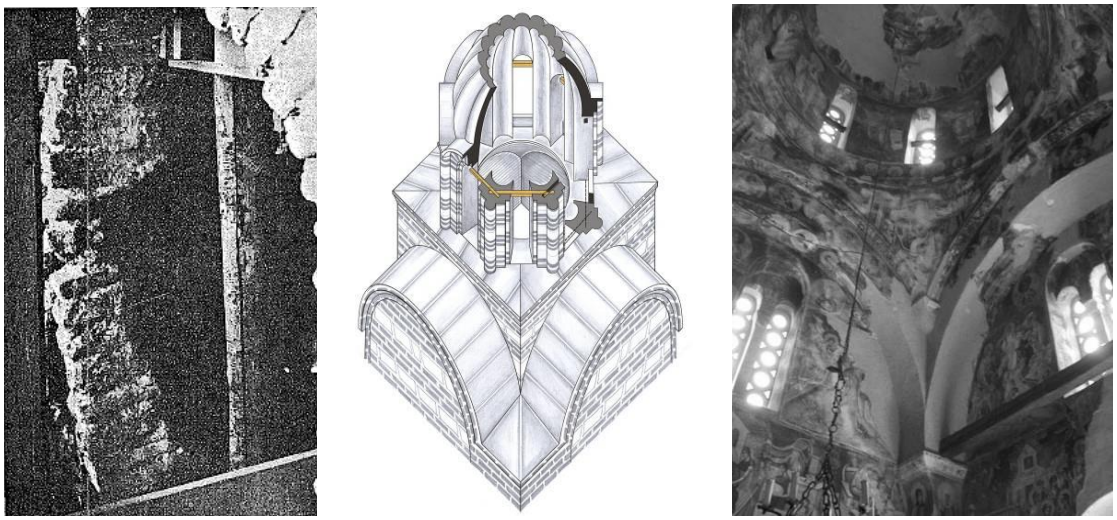


Fig. 9. Wooden beams in the dome structures: a) Fracture of the drum column on the dome of the church of the Studenica monastery (photo [18]); b) Axonometric section through the dome of the Hilandar monastery church with the marked position of wooden beams (drawing by I.B.); c) Position of wooden beams in along the middle of the drum height in the church of St. Joachim and Anne in the monastery of Studenica (photo by I.B.)

The role of wooden beams under the domes is also explained by the example of masonry arches of the under-dome structure in the church of the monastery of the Patriarchate of Peć, on the territory of medieval Serbia (Fig. 10.). Here, wooden beams were also used to prevent the supports of arches from shearing. The structure of this church, which combines several interconnected domed churches, is characterized by the crowns of all arches which are fixed in a single plane. This structure is formed by crossing the wooden beams which are fixed perpendicular to their crowns.



Fig. 10. Wooden beams in the dome structures: a) Model (drawing by I.B.) and b) the *in-situ* position of wooden beams in crowns of under-dome arches in the churches of monastery of the Patriarchate of Peć

4. Closing remarks and conclusions

Bearing in mind that the masonry structures are good in tolerating only pressure, while at the same time they are non-resistant to tensile actions, the construction of medieval sacral temples of complex spatial organization also required using elements made of materials capable of suppressing or at least reducing the adverse effects of tensile forces. The knowledge and skills of Byzantine architects relied on traditional architecture. Based on the presentation and analysis of the examples, this paper has shown that the main role of wooden ties was tying the sacral structures at certain heights. This particularly applies to the horizontal planes in which changes in the structure's geometry occur.

In these structures wooden beams prevented the supports from shearing to some extent. They were not acting locally on individual arches and vaults, as it was perceived previously, but on the system of arches and vaults at a certain height by forming a grid of their crossings and connections. The effects of lateral thrusts in individual arches and vaults in Orthodox churches with diverse spaces can lead to the appearance of cracks. Therefore, in horizontal levels where the spatial geometry changes and structures of different shapes appear, the building was tied, as confirmed by the meaning of the Greek word "imas" and "imandosis" for the system of ties.

A variety of characteristic examples of this architecture can be found in the central part of the Balkans, i.e. on the territory of medieval Serbia. In their arches, vaults and domes, certain types of beams and beam grids can be distinguished based on their function:

- In single-space structures wooden beams with the corresponding anchoring elements (metal or wood) mostly played the role of beam ties.
- More complex assemblies in the architecture of Orthodox structures require the use of a system of wooden beams, the role of which, in certain horizontal levels, is to stabilize the supports of arches, vaults and domes, i.e. accommodate the horizontal forces and neutralize the thrusts acting on abutments. The beams also affect the uniformity of settlement in structures of variable geometry and masses, so that wooden grids played the role of horizontal tie beams. There are two basic types of church structures: single-dome and multi-dome. Specifically, on the territory of medieval Serbia there are a small number of churches with a double-cross plan in the central plan, which requires a system of beams in multiple levels to be used.
- The complex adaptation of western technology of building the arches on Orthodox temples in the central Balkans has led to the use of wooden beams as elements subjected to the force of pressure, instead of tension. Such beams having this role in Serbian churches usually appear in the central aisle, more precisely, in the area of the central aisle at the height of vault supports of the opposing side aisles. In this way, buckling of supporting elements of vaults of the central aisle due to thrusts coming from vaults of side aisles on the still unfinished structure was avoided.
- By installing a grillwork of wooden beams in the height of the dome arch the crown was prevented from displacement. In seismically active areas, such as the Balkans, this is an important function because cracks in the event of stronger earthquakes are expected to occur in the zone of the arch crown. The adverse effects of cracks in the arch and its displacement to the whole dome support system can be mitigated to some extent.

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SEISMIC ASSESSMENT OF A COMPLEX HISTORICAL BUILDING: THE CATHEDRAL OF ICA IN PERU

Maria Pia Ciocci[1], Satyadhrik Sharma[2], Paulo B. Lourenço[3]

ISISE, Department of Civil Engineering, University of Minho

***Abstract**: This paper presents the challenging study carried out on Ica Cathedral within the Seismic Retrofitting Project (SRP), initiative of the Getty Conservation Institute (GCI). On the basis of the information available in literature and the results obtained from experimental campaigns, several numerical models were developed to investigate the structural behaviour of this complex historical building. The timber structure was modelled by adopting isotropic homogeneous and linear behaviour and appropriate assumptions on the connections. The nonlinear behaviour of masonry was described in the numerical models by using the Total Strain Rotating Crack model, based on fracture energy concepts. Advanced structural analyses – including nonlinear static and dynamic analyses – were carried out to validate the numerical models by reproducing the structural damage observed in-situ. Moreover, the structural performance was evaluated through these analyses and the main vulnerabilities were identified to propose an adequate strengthening for this important symbol of cultural heritage in Peru.*

***Key words**: Half-timber constructions, quincha technique, numerical modelling, nonlinear analysis, seismic assessment*

1. Introduction

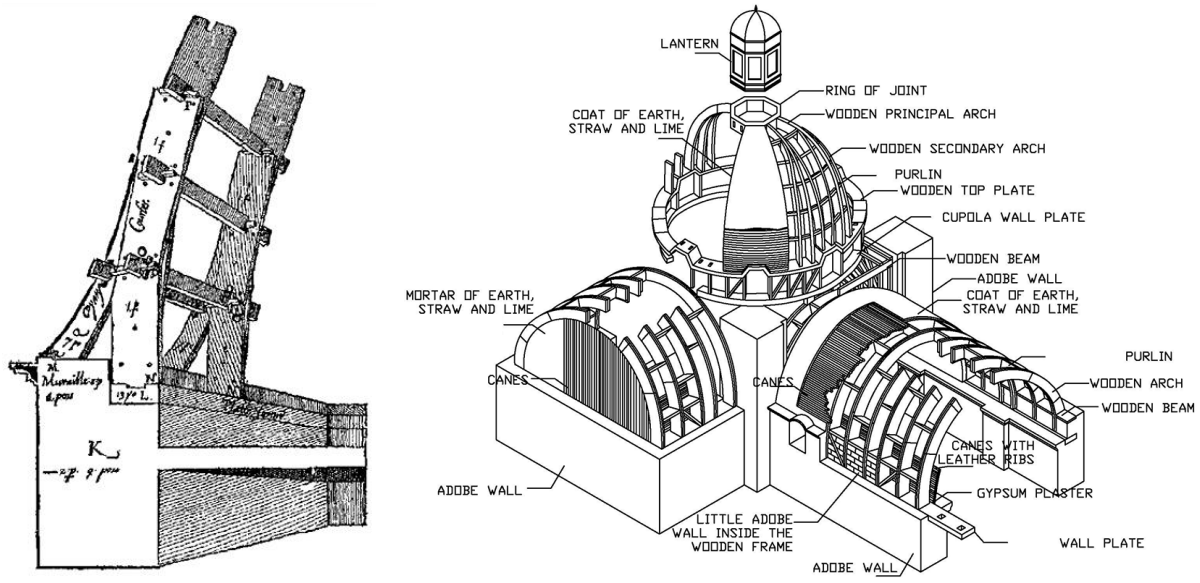
Declared as a national monument since 1982, the Cathedral of Ica is representative of ecclesiastic buildings along the Peruvian coast during the Hispanic Viceroyalty and the early Republic periods (16^{th}-19^{th} century) [1].

The first coastal colonial churches were constructed by Spanish with stone or brick vaults and domes. However, destructive earthquakes that occurred in the 17^{th} century in Peru proved the incompatibility of these heavy structures with such high seismic activity of the Peruvian coast. Since then, half-timber constructions, composed of an external masonry envelope and an inner vaulted roofing system, were used to erect ecclesiastical buildings in order to provide modest weight, better seismic performance and more flexibility of formal and spatial design. Although comparable structures were built in Europe from the 16^{th} century onwards, such as those illustrated by Philibert De l' Orme, a particular construction method known as *quincha* characterized these half–timber structures in Peru, as shown in (Fig. 1) [7], [12].

[1] PhD student, ISISE, Department of Civil Engineering, University of Minho, Campus de Azurém, Guimarães, Portugal, mariapiaciocci@gmail.com
[2] Project Officer, NCSHS, Structural Engineering Laboratory, Indian Institute of Technology Madras, Chennai, India, satyadhriksharma@gmail.com
[3] Full Professor, ISISE, Department of Civil Engineering, University of Minho, Campus de Azurém, Guimarães, Portugal, pbl.@civil.uminho.pt

Used even before the Incan empire, the technique of *quincha*, or *bahareque*, was originally used in Peru to construct primitive huts with frames made of branches and trunks of small trees, which were tied together with vegetal fibres and covered with mud. After the Spanish conquest of the Incas, the *quincha* technique was technologically developed in all its different forms and widely diffused in Peru. The Church of San Francisco constructed by Constantino de Vasconcelos and Manuel de Escobar in 1657-1674 represented the first notable application of the *quincha* technique to construct ecclesiastical buildings, becoming the universally solution to rebuild damaged churches and to construct new ones [12]. These churches were built with vaulted roofing systems which were constructed with several timber elements connected to each other by means of various timber joints and covered by canes, mud layers and lime plasters. Moreover, the timber vaulted roofing systems were supported by hollow pillars, built with the same *quincha* technique [4].

Since their construction, these half-timber constructions have been subjected to inadequate maintenance and inappropriate repair and additions. As a result, these structures, which are typically classified as unreinforced masonry structures, are extremely vulnerable to earthquakes and subject to sudden collapse during seismic events, such as those which occurred in 2007 and 2009. Consequently, the call for preserving them by investigating their structural response, carrying out their safety assessment and, when needed, proposing adequate strengthening techniques has become increasingly louder. Using the Cathedral of Ica as a case study, this paper aims to present a methodology that can be applied to the study of the seismic vulnerability of similar half-timber constructions.



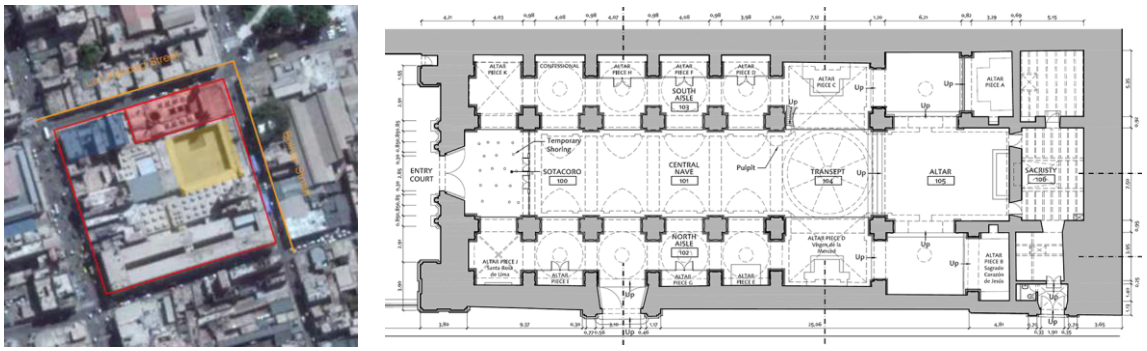
a) b)

Fig. 1. Timber vaulted roofing systems: a) detail illustrated by Philibert De l' Orme [12]; b) typical construction method used in Peru in the 17th century [7]

2. Geometrical and structural description

The Cathedral was originally built in 1759 by the Society of Jesus with a rectangular plan following the Jesuit typology established by the Church of the Gesù in Rome: an atrium, a main nave, two side aisles, a transept and an altar flanked by two chapels on its lateral sides. A series of spaces is present at the back of the Cathedral, including a sacristy, a reception and offices. The Cathedral is adjacent to a three-story modern concrete

structure and a fired brick structure to the west, while a concrete portico and a square cloister are located towards its southern side (Fig. 2).



a) b)

Fig. 2. Ica Cathedral: a) urban context – Cathedral (red), concrete portico and square cloister (yellow), and concrete and fired brick structures (blue); b) schematic of the plan

The Cathedral can be divided structurally into two main sub-structures: an external masonry envelope and an internal timber frame. The masonry structure consists mainly of the front façade, two bell towers, the lateral longitudinal walls and the back façade. In particular, the front façade is made of fired brick masonry with lime mortar. Each bell tower is composed of a timber structure that sits on a fired brick base. The lateral longitudinal walls consist of three different layers of masonry: rubble stone, fired brick and adobe, sequentially from the base upwards. The internal space of Ica Cathedral is divided by a series of pillars, pilasters – i.e. engaged pillars – and piers which support a system of longitudinal and transversal beams, that in turn carry a complex vaulted roofing system. The pillars and the pilasters are composed of numerous posts, which are braced by means of horizontal and diagonal elements and are wrapped with flattened cane reeds (c*aña chancada*). The complex vaulted roofing system includes a main umbrella dome, barrel vaults and small domes. The domes are composed of several ribs with two ring beams located at the top and at the bottom, while the barrel vaults consist of principal and secondary arches. At the central nave, the barrel vaults are characterized by lunettes corresponding to the location of the windows in the upper nave walls. *Caña chancada* and cane reeds finished with layers of mud plaster (*caña brava)* are used to cover the intrados and the extrados of the vaulted roofing system, respectively. The timber members, which are connected by means of different types of timber joints including mortice and tenon and half–lap connections, are made of cedar (*Cedrelaodorata*), sapele (*Entandrophagmasp*) and huarango (*Prosopissp*), used for different purposes throughout the structure according to their characteristics.

3. Damage

The Nazca and South American tectonic plates meet near the Peruvian coast and earthquakes due to thrust faulting make Peru one of the most active seismic areas of the world. Ica Cathedral is currently located in the highest seismic level classified by the Peruvian Building Code [9], [11].

Although the Cathedral has been occupied, renamed, repaired and altered throughout its history, the main sources of historical damage were related to the destructive seismic events that occurred in 1813, 1868 and 1942. In 2007 the MW 7.9-8.0 Pisco earthquake caused widespread damage to the Cathedral, that suffered partial collapse of the vaults and the main dome, as well as extensive loss to its adobe walls. A later seismic event in 2009

aggravated the already damaged conditions with the total collapse of the main dome. As a result, the Cathedral today is heavily damaged and lies in a state of disuse (Fig. 3) [1].

The severe damage caused by these recent earthquakes demonstrated the influence of material decay upon seismic response. The construction materials of the Cathedral had been subjected to significant decay that had increased its seismic vulnerability. Moisture problems had led to plaster detachment, disintegration of the masonry and degradation of the stone foundations. Heavy termite damage, corrosion of the nailed connections, rot due to rising damp and detachment of the plaster had affected the timber structure. Moreover, the damage that is currently present in the Cathedral after the recent earthquakes has exposed the materials to further deterioration [1], [4].



a) b) c)

Fig. 3. Ica Cathedral after the earthquakes in 2007 and 2009: a) front facade; b) main dome; c) barrel vaults with lunettes

4. Combined model

5.1. Overview

Due to the complexity of this historical structure and the numerous unknowns on the morphology and material properties, safety assessment was first carried out on the two sub–structures, independently. In this section, the main outcomes of this challenging study are presented. For further details, refer to [8].

A single representative bay was initially studied by performing linear elastic analysis under different loading conditions. The compliance with the various criteria specified by Eurocode 5 [3] was carried out by means of global and local verifications for the timber members composing the representative bay. The verifications were mostly satisfied for the ultimate limit state and for the serviceability limit state under vertical loading. Under the seismic combination, the beams at the top of the lunettes and the posts close to the masonry walls were not verified for the ultimate limit state. Moreover, the structural performance of the whole timber structure was investigated by performing linear elastic analysis under vertical and horizontal actions and the transept was identified as the most vulnerable part.

Afterwards, the structural behaviour of the masonry envelope was investigated by performing advanced structural analysis. Model updating was initially carried out by adjusting the modulus of elasticity of the different types of masonry so that the dominant modes of the structure predicted by the model of the masonry envelope matched the results obtained from the dynamic identification tests performed by the University of Minho [8]. The results obtained from pushover analyses of the only masonry envelope pointed out that the most relevant failure mechanisms occurred when the lateral loading was applied in the XX– and YY– directions. The lower bound lateral load-carrying capacity of 0.22g was calculated in the YY– direction, much lower than the peak ground acceleration (PGA) recommended for this area. The most vulnerable part of the structure was identified as the

north-western corner of the masonry structure, as also confirmed by the results obtained from time history analysis.

Correlation was observed between the results obtained from the models of the independent structures and the damage observed in-situ, validating the used numerical approach. However, a crucial factor that could have had significant influence on the structural behaviour of the Cathedral was yet to be taken into account: the interaction of the two sub-structures. For this reason, the structural behaviour of the entire structure of Ica Cathedral was investigated creating a combined model holding true the assumptions made on the masonry envelope and timber frame.

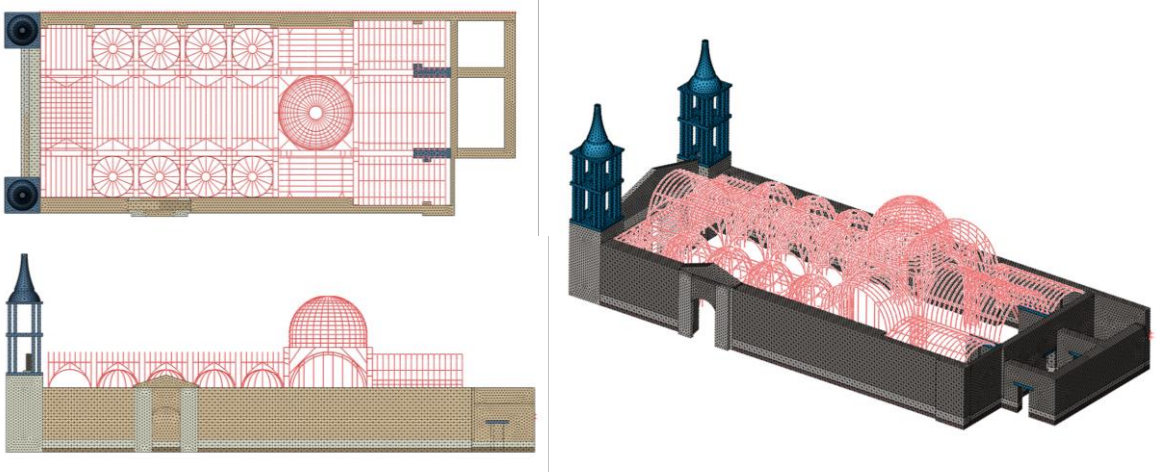
5.2. Definition of the numerical model

On the basis of the information available in literature [1], [5], the experimental campaign performed by the University of Minho [6] and the geometrical assumptions presented in [8], the model of the entire structure of Ica Cathedral was created in Midas FX+ for DIANA [13], as shown in (Fig. 4).

The masonry envelope of the Cathedral was included in the numerical model by using *3D isoparametric solid linear* elements, except for the sacristy, reception and offices on the western side, which being modern lightweight constructions are likely to exhibit an independent behaviour. The cloister on the southern side was included by simulating its buttressing effect in the numerical model by using *one-noded translation spring dashpot* elements. Full connectivity was assumed between intersecting walls, horizontal layers of different masonries and the elements composing the bell towers. Timber lintels were located in correspondence to all the openings of the structure to avoid damage concentrations in the numerical model which were not surveyed in-situ.

As regards the inner timber frame, all the structural parts described in Section 2 were modelled by using c*lass–I beam* elements with shear deformation and assuming rigid connection for all the timber joints. Given the limited information available, some simplifications were made for the model regarding the roofing system covering the main entrance, the transept, the chapels and the altar.

Connections between the two sub-structures were assumed to exist between: (1) the wooden beams in the upper part of the main entrance and the fired brick façade and the lateral longitudinal masonry walls; (2) the transversal wooden beams of the bays and the lateral longitudinal masonry walls; and (3) the wooden beams supporting the barrel vaults of the chapels and altar and the masonry walls. These connections were modelled by merging the nodes of *class–I beam* elements with those of *3D isoparametric solid linear* elements and restraining their torsional rotation degree of freedom to avoid compatibility problems.



a) b)

Fig. 4. Combined model: a) plan and elevation; b) 3D view

5.2. Material Properties

The nonlinear behaviour of the different types of masonry was described in the numerical model by using the *Total Strain Rotating Crack* material model, which allows to specify compressive and tensile softening behaviour depending on the corresponding strengths and fracture energies [13]. The material properties of rubble stone, fired brick and adobe were derived from the experimental campaign carried out by the Pontificia Universidad Católica del Perú (PUCP) [10] and the assumptions presented in [8]. The moduli of elasticity that were obtained from the model updating considering the masonry envelope only (Section 5.1.) were assumed in the numerical model (Tabl. 1).

Table 1 Material properties of the different types of masonry

Properties	Rubble Stone	Fired Brick	Adobe
Modulus of elasticity [MPa]	720*	850*	220*
Poisson's ratio [–]	0.20	0.20	0.20
Compressive strength [MPa]	0.60	1.70	0.46
Tensile strength [MPa]	0.06	0.10	0.05
Fracture energy (compression) [N/mm]	1.50	3.50	1.00
Fracture energy (tension) [N/mm]	0.01	0.01	0.01
Specific Weight [kN/m^3]	19	19	19

Note: ** Modulus of elasticity derived from the model updating*

Isotropic homogeneous and linear behaviour was assumed for the timber elements and the upper part of the bell towers in the numerical model. The density and the modulus of elasticity of the different wood species present in the timber structure were assumed on the basis of the results obtained from the experimental campaign carried out by the Universidad Nacional Agraria La Molina (UNALM), as shown in Tabl. 2. [2]. However, the density value assigned to many elements in the numerical model was not equal to the value corresponding to the wood species in which the timber element is constructed. The weight of the covering layers of the timber structure was taken into account by assigning an equivalent specific weight to the timber elements constructed by applying the *quincha* technique. It should be mentioned that no increase in the stiffness due to the confinement effect of these covering layers was considered for these timber members and the modulus of elasticity corresponding to their wood species was adopted in the numerical model [8].

Table 2 Material properties of the different wood species

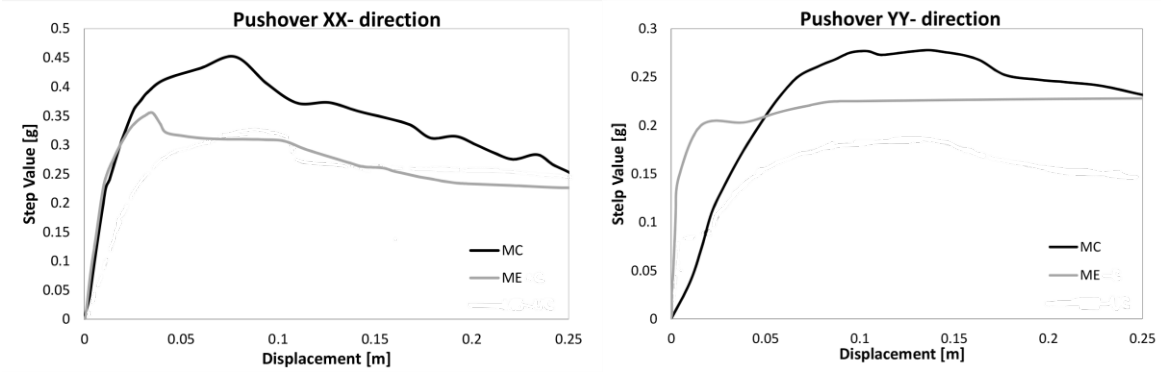
Properties	Cedar	Sapele	Huarango
Density [g/cm3]	0.38	0.49	1.04
Mean modulus of elasticity in flexure [MPa]	9380	8610	16900
Poisson's ratio [–]	0.3	0.3	0.3

5.3. Structural Analysis

The structural behaviour of the combined model was studied by performing several analyses, including eigenvalue, nonlinear static (pushover) under self-weight and lateral loading and nonlinear dynamic (time history) analyses. The results obtained from the eigenvalue analysis, which provided a better correlation between numerical and observed dynamic response, identified the main dome and the upper part of the barrel vaults as the most likely vulnerable regions of the structure. These parts correspond to the regions where significant damage was observed after the earthquakes.

According to the results obtained from the nonlinear static analysis under self-weight, the highest values of displacements were observed for the barrel vaults and the

main dome, ranging from 1.0 cm to 2.0 cm, and no cracking was observed throughout the masonry envelope. Since the most critical failure mechanisms in the model of the masonry envelope were identified in the XX– and YY– directions, the lateral loads were subsequently applied in the XX– (longitudinal) and YY– (transversal) directions of the combined model. Under the lateral loading in the longitudinal direction, the failure mechanism in the masonry envelope consisted of the out-of-plane failure of both the front façade and the bell towers, while the out-of-plane failure of the northern lateral longitudinal wall was observed when the lateral loading was applied in the transversal direction. The lateral load-carrying capacities which were calculated for the combined model were 0.45g in the XX– direction and 0.28g in the YY– direction, about 25% higher than those obtained for the model of only the masonry envelope (Fig. 5). The obtained results pointed out that the interaction between the two sub-structures significantly influence the seismic behaviour of the entire structure of Ica Cathedral.



a) b)

Fig. 5. Load displacement diagrams obtained for the combined model (MC) and the model of only the masonry envelope (ME): a) XX– direction; b) YY– direction

A time history analysis was performed on the combined model considering Rayleigh viscous damping and using explicit time integration with the Hilber-Hughes-Taylor method. The Rayleigh damping parameters for the combined structure were calculated by considering all the natural modes of vibration until 80% mass participation was reached. A single earthquake was simulated by means of two artificial accelerograms, applied in two orthogonal directions to each other (X and Y). These accelerograms, generated on the basis of the elastic response spectrum provided by the Peruvian Code for the region of Ica [9], [11], were uncorrelated, i.e peaks in acceleration do not occur at the same time with respect to each other. Loss of its loading-unloading capacity and severe damage were observed from the loading-unloading diagrams plotted for the masonry of the combined model in the two orthogonal directions in which the accelerograms were applied. It should be mentioned that a better correlation was observed between the damage existing currently in the structure and the results obtained from the nonlinear dynamic analysis when compared to those observed for the nonlinear static analyses (Fig. 6).

5. Conclusions

The methodology used to assess the seismic safety of Ica Cathedral, a complex historical building constructed during the Viceroyalty period in Peru by applying the *quincha* technique, was presented in this paper. Advanced structural analysis was performed on several numerical models, created on the basis of the information available in literature, experimental campaigns and experimental tests.

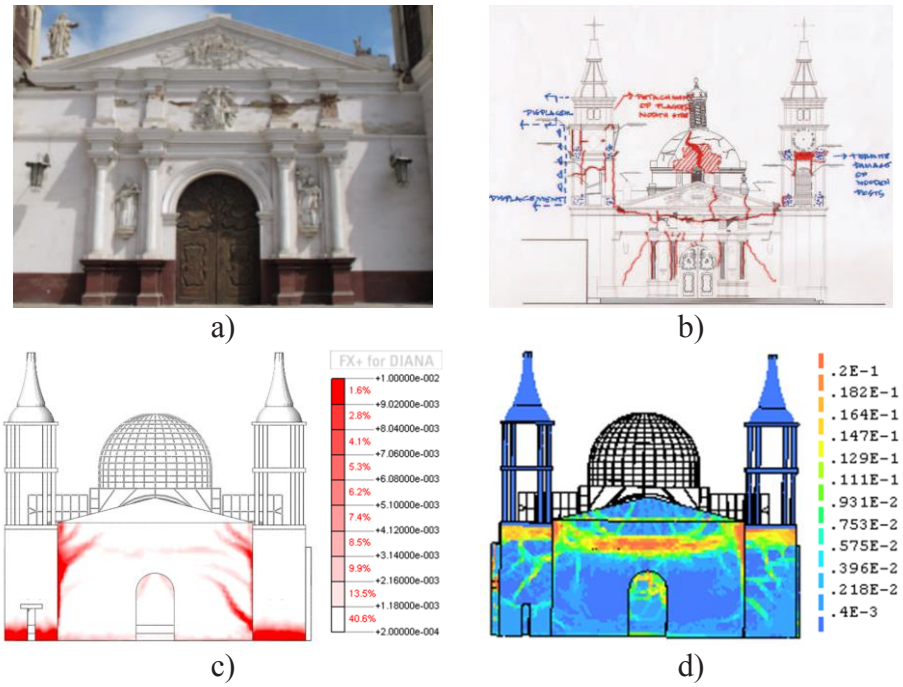


Fig. 6. Correlation of damage observed in-situ and the results obtained for the numerical model: a) detail of the damaged front façade [1], b) crack survey [1], c) crack pattern from pushover analysis in the longitudinal direction and d) crack pattern from nonlinear dynamic analysis

The structural behaviour of the two sub-structures composing the Cathedral – i.e. an inner timber frame and an external masonry envelope – were first evaluated independently. Afterwards, the interaction of these two sub-structures was investigated by performing structural analysis on the model of the Cathedral. The obtained results pointed out the significant influence of the connections between the sub-structures on the global structural behaviour of the Cathedral. According to the different pushover analyses performed, the lower bound lateral load-carrying capacity of the entire structure was found in the transversal direction with a value of only 0.28g. This value is much lower than the PGA recommended by the Peruvian Code for this region.

Therefore, global strengthening is required for reducing the out-of-plane mechanisms identified by the pushover analyses, in particular that of the north-western corner of the Cathedral. Tying, ring beams, adequate connections can represent efficient strengthening techniques to improve the structural performance of Ica Cathedral.

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МЕТОДИЧЕСКИ ПРИНЦИПИ ЗА ВЪЗСТАНОВЯВАНЕ НА ИСТОРИЧЕСКИ ГРАДИНИ И ПАРКОВЕ

проф.д-р л.арх. Пенчо Добрев, e-mail : pentso_dobrev@abv.bg

METHODOLOGICAL PRINCIPLES FOR RESTORATION OF HISTORIC GARDENS AND PARKS

Prof., Landscape Arch. Pencho Dobrev, PhD e-mail: pentso_dobrev@abv.bg

Abstract: Based on Bulgarian and foreign expertise, the report draws up and systematizes some methodological principles that should be followed to restore historic gardens and parks.
The documenting of the existing information that can be collected for a historical garden (park) should focus on historical analysis, study of the historical development of the garden (park) in respect of elements, facilities and flora, and on analysis of the current state of the garden (park) as a landscape design site.
The research then serves for the drawing up of a Historic Garden (Park) Development Plan as a monument of culture and a Management Plan (involving administrative management and recovery). It also underlies the development of criteria for restoration work and a concept for functioning of the historic garden (park) in the future.

Key words: *Historic Garden (Park), Development Plan, Management Plan (involving administrative management and recovery)*

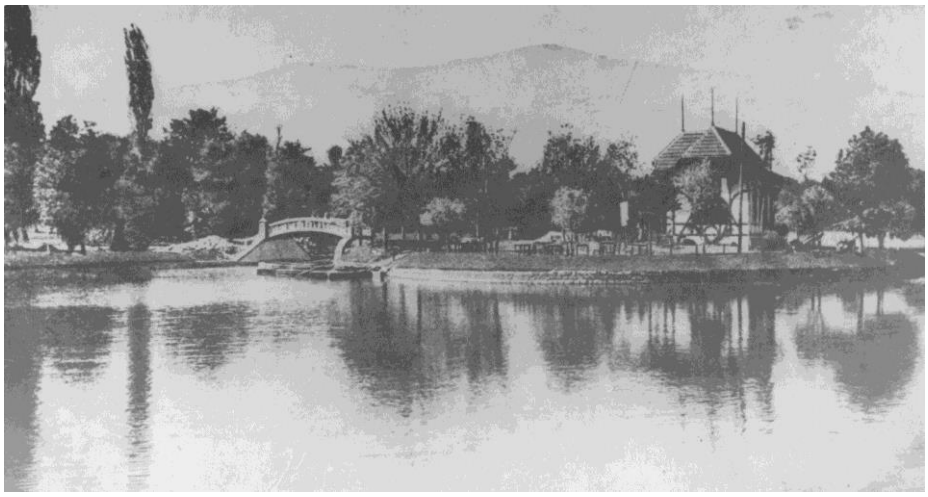
1. Въведение

Широко разпространено всред професионалните среди е становището, че не е възможно да се разработи универсална методика за възстановяване на историческите градини и паркове.
В настоящия доклад, въз основа на натрупаният опит в тази област у нас и в чужбина, е направен опит да се систематизират и изведат някои методически принципи, които могат да послужат като основа за възстановителни работи по всеки конкретен исторически парков обект, обявен за културен паметник.. Както при всеки един проект, в основата на успешното разработване на Програма за възстановяване на една историческа градина/парк, стоят задълбочените предварителни проучвания.

2. Предварителни проучвания

Предварителните проучвания, когато целта е възстановяване на един парков обект обявен за исторически и културен паметник имат обхват, много по-широк от този, който е проето да се извършва за другите видове нови или съществуващи озеленени пространства.

От първостепенно значение е събирането на цялата достъпна възможна информация за даденият парков културно-исторически паметник и нейното документиране, което ще даде възможност да се извърши един подробен исторически анализ. Той трябва да се основава на пространствено проучване на градината в исторически контекст – какъв е бил нейният първоначален замисъл, предназначение и облик, и какви промени са настъпвали в нейната композиция през годините, в резултат на различни социално-икономически, градоустройствени и естетически фактори.
В това отношение, на първо място от значение е събирането на максимално подробен исторически текстови и графичен материал - проучване и събиране на текстове, описващи състоянието на градината през различни исторически периоди и събиране на графични материали (снимки и проекти за градината/парка), представящи планиране или извършване на опити за промени или реставрации през различни епохи от нейното съществуване.
Задача на етапа на предварителните проучвания е попълване на информацията за съществуващите в момента растителност, архитектурни съоръжения и обекти, с обхождане на историческата градина. Предвид на най- силно променящият се със времето основен парков елемент – растителността, от значение е извършването на компетентно от съответните специалисти ботанико- историческо проучване. В неговия обхват трябва да бъдат включени информация за първоначалния видовия състав и неговите промени през годините, държавите и местата, от които е бил доставен посадъчния материал, извършване на фитопатологични проучвания, проучвания на едафичните (почвени) условия и на фауната.



Фиг.1. Езерото „Ариана в Княз Борисова градина (архивна снимка)

Съществуването, ползването и опазването на историческите градини и паркове е неразривно свързано с проучване на връзките и задълженията на различните институции към историческата градина/парк. Важен фактор е и съвременното разбиране за обвързването на историческите градини с опазването на околната среда и извършването на социологически проучвания за отношението на обществото към тях. Предварителните проучвания включват и извършване на аналитични изследвания за историческото развитие на критериите за естетичност и художествено оформяне, които са повлияли върху визията на една градина/парк през периодите на нейното съществуване, проучване на планирани, но неизпълнени паркови перспективи и техните изгледни пунктове, изучаване и анализиране на досегашните функции на градината за бъдещото й функциониране и др.. Анализирането на физическите и духовни реалности на градината като културен

паметник, трябва да доведе до постигне при възстановяването й, на възможно най-автентичния й образ, формирал се по време на историческото й съществуване и развитие, който да има своето присъствие и значение за съвременното й състояние и облик.

3. Програма за развитие на историческата градина/парк като паметник на културата

Вторият основен етап в проектантския процес за възстановяване и развитие на една историческа градина/парк, е съставянето на целева Програма. Нейни съставни елементи са Паркоустройственият план за възстановяване и Планът за управление след възстановяването. Програмата трябва да се основава на исторически анализ на събраната информация при предварителните проучвания.

Тя трябва да включва обща информация, свързана с градината/парка по отношение на нейното описание, местоположение, общите проблеми, причините за възстановяване и първите идеи за възстановяване и ползване при условията на съвременността.

Направената основна историческа справка, трябва да бъде отправна точка за сериозно аналитично изследване на градината не само като парков обект, но и като исторически културен паметник. То може да бъде извършено и от компетентен историк, запознат с историческата епоха на нейното създаване.

Не трябва да се забравя, че често историческите градини през последните десетилетия са функционирали и като околна среда на исторически музеи, в каквото са били превърнати сградите, ситуирани в тях. Инвестирането в предварителни исторически проучвания от една страна ще даде основание за обосноваване на проекта за реставрация (възстановяване) чрез съставянето на каталог, подреждането и класифицирането на събраните документи и от друга, ще послужи като основание за създаването на информационен център към историческата градина, разполагащ със собствен документален фонд за публикуване на рекламни и информационни материали.

Основно място в Програмата трябва да намерят историческите графични материали. Търсенето и намирането на исторически графични материали от епохата на създаването и съществуването на историческата градина , ще помогне за съставяне на визуална представа за нейното развитие и ще представлява интерпретационен документ за постигане на автентичност при реставрацията. Всички гравюри, рисунки, карти, снимки, ескизи и други визуални материали трябва внимателно да бъдат проучени и класифицирани по периоди от съществуването на историческата градина.



Фиг.2.Езеро в парка Врана (архивна снимка)

Програмата представлява и инструмент за архивиране на информацията. Събраната документация по време на предварителните проучвания трябва да се подреди, класифицира и да се оформи в съответните файлове :
- Архив на документацията - хронологично класифициране (подреждане по хронология) и нейното цифровизиране. Архивиране на събраните оригинални ръкописи, чертежи и други исторически материали и т.н., за които файлове да се направят и копия;
- Фотографски архив – Събиране, класификация и подреждане на фотографии, диапозитиви, клишета, филми и други материали както с архивна стойност, така и от съвременността;
- Графичен архив – той се съставя от събраните рисунки, чертежи, скици, щампи, гравюри и други;
- Библиографичен архив- тук има място историческа литература, издания свързани с изкуство, политика и т.н., конкретно отнасящи се за историческата градина, или свързани с творчеството на художници, скулптори, писатели и други дейци на изкуството, работили в съответната епоха;
- Архив на извършените промени в градината. Съставя се от всички събрани статии, информации и материали, за извършени промени в градината през различните периоди на нейното съществуване, включително и за възстановителните работи, които се провеждат в момента на реставрация на градината. Не трябва да се забравя, че тази информация за съвременни промени в градината, ще има за бъдещето същата историческа стойност, каквато има днес за нас всеки материал от различните периоди на съществуване на историческата градина.
- Представяне на промени (реставрация, възстановяване) чрез сравителен анализ на снимков (графичен) материал за облика на отделни градински фрагменти през различните периоди .Това е един интересен метод, да се работи върху снимки, чрез които се сравнява и проследява нагледно последователността на естествени или изкуствено предизвикани еволюционни промяни, които са се случили във времето.
В Програмата трябва да се опише и актуалното за момента състояние на историческата градина/парк. Успоредно с проучвателните работи и събиране на информация от исторически източници, трябва да се събере и оформи информация и за текущото състояние на историческата градина. И двата вида проучвания изискват допълнителни изследвания. Често е много трудно да се намери оригинален дизайн на първоначалният облик на градината и проектантският колектив ще бъде щастлив, ако намери някакви първи скици. Най- често за условията на България това е почти изключено да се случи, което значително затруднява задачата да се оформи представа, как е изглеждала градината след нейното създаване.

4.Изготвяне на Паркоустройствен план за възстановяване на историческите градини и паркове

Реализирането на основната цел на Програмата – разработване на необходимите марки за възстановяване на историческата градина/парк, се осъществява с изготвяне на Паркоустройствен план, който е неин съставен елемент. Той цели да се зонира градината (освен при градините, които имат много малки размери) на зони, които се отличават по своите географски особености, ландшафт, ботанически различия, естетическа визия и др. Въз основа на това зониране, по късно ще могат да се детайлизират всички дейности по възстановяването.
Под внимание трябва да се вземат релефните (топографски) особености на терена на градината. Много често тази информация е недостатъчна или непълна, поради липсата на актуална топографска карта. Проучването на релефа трябва да бъде

извършено по същата методика както историческото проучване, но въпреки важността на тези проучвания, за съжаление те зависят от наличния бюджет.
Извършеното ботаническо проучване осигурява информация за основните насоки в паркоустройствения план, по които трябва да протече възстановяването на растителността.
За бъдещите устройствени мерки, които трябва да се вземат по отношение на растителността, важно място заемат извършените фитопатологични обследвания. Като елемент на Програмата е необходимо да присъства и доклад за фитосанитарното състояние на всички растителни екземпляри. Тази информация е необходима за последващото поддържане на растителността, както и за търсене помощта на компетентни специалисти.



Фиг.3.Опит да се възстанови кипарисовата алея в Морската градина- Бургас(снимка автора)

В Паркоустройствения план се набелязват и всички мерки по отношение подобряване състоянието на почвите, опазване на биоразнообразието от гръбначни животни, птици, риби и херпетофауна, развитие или запазване на алейната мрежа, ситуиране на периферни паркинги и т.н.. Важно място в Паркоустройствения план трябва да се отдели на осигуряване на необходимата техническа инфраструктура – възможности за напояване, изграждане на канализационна мрежа, дрениране, осветление, ситуиране според конкретните условия на стопанска база и др.
Извършените в подготвителния етап на проектирането екологични и социологични проучвания трябва да се използват максимално в Паркоустройствения план във връзка с бъдещото ползване на историческата градина/парк като място за отдих и туризъм. Устройствените мерки трябва да бъдат насочени към опазване на исторически формиралите се паркови перспективи и пейзажи, както и на изгледните точки към тях. Решаващо значение при това трябва да имат естетическите качества и характеристики на декоративните елементи с участието на растителността.
В Паркоустройствения план всички нови намеси, които се предвиждат в историческата градина, трябва да се базират на аналитично историческо проучване на стила, в който композиционно е оформена градината(парка). Необходимо е детайлно проучване на историческите свидетелства за стиловете, използвани в градинско- парковото изкуство въз основа на информацията за годините, когато е създадена градината. Обратно, ако се разполага с първоначалния план, може да се определи преобладаващия стил, в който е оформена градината . Ако такава

информация липсва, за определяне на стила може да се направи аналогия с други творби на автора от този период, ако за тях е известен стилът в който те са оформени.
Ако се предвижда внасяне на нова растителност, важна информация ще даде историческото проучване за декоративната растителност, използвана в периода на създаване на градината. Такава ботаническа информация може да се получи от архивите на декоративни разсадници и оранжерии от това време(ако има останали такива). За използваните първоначално видове, информация може да се получи и от финансови документи за тяхното закупуване.
Паркоустройственият план трябва да се съобрази и с досегашните функции и използване на историческата градина/парк.. Преди в окончателния проект да се определи ползването на обекта като паметник на културата за широк обществен достъп, за неговата експлоатация проектно трябва да се решат въпросите за достъп с обществен транспорт, паркинги за колите на посетителите, битова сграда за персонала, който ще се занимава с поддържането, наличието на обекти за обслужване на посетителите и т.н.

5. Изготвяне на план за административно ръководство на обекта по време на неговата експлоатация (План за управление).

Този план трябва да послужи на ръководството на обекта в работата му да поддържа историческата градина, да се посочи видът на данните, които трябва да се събират за нея, изискванията към реда, който трябва да се поддържа при стопанисването й , нивото на детайлност на грижите за отделните фрагменти, системата за функциониране на историческата експозиция , необходимото оборудване и видове работи през различните сезони и т.н.
Функционирането на историческата градина(парк) като паметник на културата след възстановяване, най-често е целесъобразно да се използва от обществото като място за отдих и запознаване с културните достижения през различните исторически епохи. С оглед на собствеността й (държавна, общинска, частна) и възможностите за поддържане, за посещението й могат да бъдат въведени различни режими на достъп.

Заключение

След като до тук бяха разгледани накратко някои методически принципи за изготвянето на проекти за възстановяване на една историческа градина (парк) , за да може тя да се развива и да изглежда като едно "цяло" в следващия период от историческото й съществуване, нейното възстановяване трябва да се съобрази и с определени критерии.
На първо място това са общите критерии. Те се изразяват в спазването на международните критерии и съображения върху възстановяването на историческите градини и паркове, както и на законовите и подзаконовите разпоредби в тази област на държавите-членки на ИКОМОС, които са в сила за всяка отделна страна.
Други критерии това са специфичните критерии за възстановяване. Такива критерии ще се появят във всеки конкретен случай, при тълкуването на общите методически правила и тяхната приложимост за отделните условия. Тези специфични критериите могат да бъдат и в основата при определянето на конкретните насоки за реставрация на една историческа градина (парк) и на нейни отделни елементи. Тяхното прилагане е ефективно в случаите на възстановяване на загинала растителност, деградация на парковата територия, разруха на сградния фонд и др.
В процеса на възстановяване на една историческа градина, в резултат на многостранните проучвания се оценяват и изучават различни проблеми. Често и нормално в тези случаи могат да възникнат непредвидени събития, нови открития и

т.н., които да наложат промяна в първоначалните идеи за реставрационни работи, или извършването на определени по-нататъшни действия. Ето защо, винаги е препоръчително, Паркоустройственият план да съдържа различни етапи на проучване и изготвяне.

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RESTORING THE LOAD-CARRYING CAPACITY OF A HERITAGE CONCRETE TIED ARCH BRIDGE

Ph. Van Bogaert[1]

Ghent University, Civil Engineering Department

***Abstract**: In the past, concrete arch bridges were built to cross moderate spans, whereas today the alternative of beam bridges is preferred. In view of their aging, it has become necessary to assess carefully the load-carrying capacity of these historic bridges. In the case of the seriously damaged Pontweg bridge, both numerical simulation and dynamic testing have demonstrated the necessity to reinforce substantially the lower chord and floorbeams. The initial refurbishment program including the use of CFRP-laminate, was modified due to the necessity of rebar splices and an additional reinforcing beam was connected to the lower chord. The sealing of the arches and hangers was successful, due to the use of micromortar, whereas an unfortunate polymer-containing repair product of the deck, has modified the texture and appearance of these parts. A load test is being prepared. This showcase demonstrates that an adequate type of repair product is important to preserve the characteristic aspect and texture of historic arch structures. Replacing the movable bearings required temporary lifting of one side of the bridge.*

***Key words**: Historic concrete arch, load-carrying capacity, colour and texture of concrete repair, strengthening, roller bearings*

1. Introduction – Concrete arch bridges from the past

During the first decades of the past century, concrete tied arch bridges have been built regularly to cross small rivers or roads. This type of structure was used for crossing spans, varying from 30 to 50 m. The examples being presented, demonstrate that these structures can no longer be built in an economical manner. Today, most designers would suggest simple beam structures for crossing this type of span. However, the examples also demonstrate the heritage value of these bridges, since the aesthetical value of arches has made them appreciated by the public. The natural elegance of the parabolic arch shape highly contributes to this.

Some of these arch bridges completely consist of reinforced concrete, while others have steel or iron hangers connecting the arches to the lower chord. In the former case, the hangers may become rather stiff and a framework effect may be introduced. However, various verifications have shown that the framework effect was of minor importance. An important characteristic of most showcases is the absence of upper bracing, connecting both lateral arches. The upper bracing is not so much needed to resist wind actions, and

[1] Philippe Van Bogaert, sr full Prof, PhD, Technologiepark 904 B 9052 Gent, Belgium, philippe.vanbogaert@ugent.be

merely avoids lateral arch buckling. Due to the rather solid character of arch cross-sections, structural second-order effects are expected to be low. However, the use of bracings, connecting two parallel arches, apparently was found necessary for various bridges, although it influences aesthetics badly.

With ageing of these concrete structures, and because traffic loads have increased considerably, the primary question about the load carrying capacity arises. Many bridge owners have doubts about the functionality of these valuable bridges, even if no major damage has been detected so far. Obviously, the main concern is about the effect of higher loads and not about material characteristics. Within the framework of this question, our department is conducting a more systematic research, aiming mainly at determining realistic limiting slenderness values of unbraced arches [1]. The nominal stiffness theory of EC 2 [2] proves to be an effective method in finding accurate results.

Apart from the Pontweg-bridge, which is presented more in detail hereafter, a fine example is the Albert bridge near Brussels, also called Rampe du Lion, built in 1923, consisting of 2 series of 3 continuous RC tied arch bridges. A picture is shown in Fig. 1. From this angle, the repetition of arches becomes quite clear. The span length equals 34.42 m, the arch rise being limited to 5.5 m. The Rampe du Lion bridge has been refurbished recently. The octagonal cross-section of the arch members are a particular characteristic of this bridge.



Fig. 1. Rampe du Lion Bridge



Fig. 2. Dendermonde Bridge

Another example is a particular structure, located in the town of Dendermonde (B) and crossing a railway station. The single span equals 60 m, the rise being 10.75 m. The Dendermonde bridge was built in 1932 and, as shown in Fig. 2, given its age, it is in a perfect condition. It may be seen from Fig. 2 that the arches have a particular arrangement, since they consist of two separate members, connected at the hanger nodes. Hence, the cross-section of the individual arch members is relatively low, compared to the size of this bridge and the concrete compression is high. In addition, the arch springs are considerably large, since they are more than 5 m long.

Other bridges, involved in this survey, are the 27 m span bridge across river Emu in Australia (Tasmania), and the 34.1 m span bridge at Katelijne-Waver (near Mechelen) across the Brussels to Antwerp railway lines.

2. Pontweg bridge across river Lys

The Pontweg bridge (Fig. 3) is located near Ghent and is the sole connection, crossing the river Lys between the city suburbs to a residential area. However, lorries are using this road as well and the bridge is considered to carry a consistent amount of heavy traffic. The Pontweg bridge was built in 1926.

The bridge is shown from various views in Fig. 3 and has a typical form. The nodes are heavily reinforced and evidently they match the flow of bending moments. The opening in the nodes is a specific characteristic. In addition, the arch springs show a change of curvature, evidently outside the intersection of the arch and lower chord centerlines.

Because of its relatively rare concept, the specific details and the historic value, this bridge is now listed as a monument [2], meaning that no alterations can be done, which can change the aspect, colour, texture and function of the structure. Late 2010, inspection of the bridge showed serious deterioration of some concrete parts. This has distressed the owner and inspired him to consult our Institute. The inspections detected rather serious deterioration of the concrete and corrosion of rebars. However, the deterioration is concentrated at various locations. Both arches show no defects and some hangers have superficial concrete cracks and cracking. These are of no particular consequence and can be easily repaired.



Fig. 3. Views of Pontweg Bridge before refurbishment

The main defects are found on 2 particular locations of the bridge deck lower side. The lower chord North edge girder shows a single section in between two consecutive crossbeams with serious cracking. These cracks have opening width of several mm and have mostly horizontal orientation. The initial situation is shown in Fig. 4.

After hammering the loose concrete, the heavy corrosion of the rebars became visible. This is seen in the lower part of fig. 3.



Fig. 4. Condition of Pontweg Bridge before refurbishment

In addition, the central longitudinal stiffening beam in the bridge deck shows an identical damage pattern. However, the location of this deterioration does not coincide with the section of the former defect.

Due to corrosion, the steel roller bearings are in poor condition and both longitudinal displacements and end rotations may be blocked. However, free angular rotation is low, since only the part due to live loads and temperature change are concerned. Fig. 4 clearly shows that the damaged areas have a different colour, compared to current concrete members. This may suggest that these locations are repaired sections, and poor materials have been used during these repairs. However, this is not the main concern.

The damage might be due to one of the various concrete deterioration mechanisms, such as alkali-aggregate reaction, chloride- or carbonation attack, or various shrinkage effects. According to chemical analysis, the damages are mainly due to carbonation attack. This damage mechanism is rarely found on local areas, thus confirming the cause of poor local refurbishment with wrong materials.

3. Load-carrying capacity

Various methods for determining the remaining load-carrying capacity of the Pontweg bridge have been reported in [3]. Non-destructive dynamic tests are also reported, showing that the damaged lower chord member does not show a fundamentally lower natural frequencies than the opposite, unharmed chord. In view of the consistent concrete and steel damage, this was a surprising conclusion, which was solved after creating an elaborate numerical model, including the damage found during inspection. As shown in Fig. 4, the central stiffening beam plays an important role in redistributing stress resultants. Because of this member, loads can be redirected from lower chord members to the central beam. The bridge deck slab also contributes to this process. A fortunate condition for this redistribution is the fact that both heavily damaged areas of the lower chord and central beam appear at unequal cross-sections of the bridge.

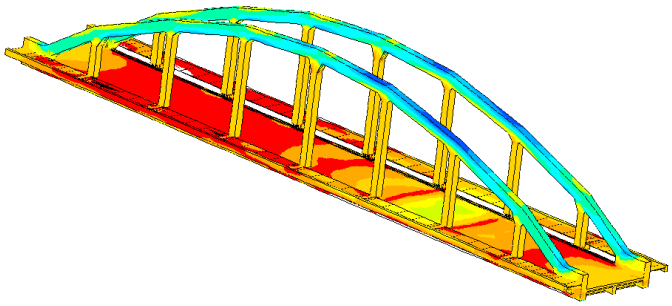


Fig. 5. Volume model nonlinear simulation

Two numerical models have been used, the first consisting of beam elements and plates, the second one consisting of bars for the reinforcement and volume elements for concrete, which served only to confirm the results from the first model. The former is shown in Fig. 5, at a load equal to 1.5-times the characteristic value. The numerical models included nonlinear material characteristics as well as large displacements and imperfections. Thus, the failure load of the bridge, both in the unharmed as in the damaged conditions has been found. There are various ways for assessing the load-carrying capacity of older bridges and structures. The evident way is to apply the existing codes as EC 1 and 2 to the bridge and verify the ultimate limit state of resistance, by using LM 1 as the characteristic design load. Obviously, this bridge was built at a time when design loads were considerably lower and calculations were based on the 'allowable stress' method. A fair chance existed that even the unharmed structure does not satisfy the criterion of ULS by partial factors. A second alternative is to determine the SLS conditions for various loading conditions and compare the level of steel stresses to historic data, since concrete stresses are always very low in this structure and concrete strength is no issue at all.

The Belgian National Annex [4] to EN 1991-2 is a very useful document for load-carrying capacity assessment. The latter allows verification of existing infrastructure through the use of a realistic LM 5. This LM 5 may replace LM 1 for existing structures, provided the bridge carries local traffic only, which may apply to the Pontweg bridge. LM 5 corresponds to one of the frequent lorries of FLM 2. It requires the use of adapted factors such as a combination and an impact factor.

Due to the redistribution effect and the mainly tensile nature of the load effects both in the lower chord and the central beam, the latter becomes the most critical member. Failure is due to excessive steel stress and for LM 1 the load-carrying capacity is limited to 0.28-times the total load. For the LM 5 condition, the capacity is less than 80% of the total loading. Hence, the owner decided that the condition of the bridge did not allow normal road traffic anymore and ordered to install a temporary Bailey bridge (see below). Thus, the damaged bridge was decommissioned till after refurbishment and our Institute was asked to propose reinforcement alternatives.

4. Initial refurbishment programme

Clearly, the damaged concrete parts had to be repaired. Apparently the cause of the carbonation attack is not generally present and there is little chance for this type of attack to start again. Further carbonation can be prevented by decreasing capillary porosity and refining the pore structure of the concrete. Sealing with fine granular mortar is expected to efficiently improve the concrete condition. However, the sealing should render acceptable colour and texture of the concrete surface, since the bridge is listed as a monument and changes in the aspect of the concrete surface will have to be minimal. Hence, the refurbishment process was to be preceded by various trials of the sealing product, to establish whether it complies with the existing concrete surface aspect.

The refurbishment also includes mechanical cleaning of the remaining rebars and passivity by cold galvanizing. However, on the basis of stress analysis many members would require additional reinforcement. The evident conclusion has been to reinforce the central beam and the damaged edge beam. For this purpose CFRP-laminate has been proposed, which can be glued to the repaired concrete surface. For the edge beam 4 laminate strips of 1.2 mm thickness are sufficient, whereas the central beam can be reinforced by 2 such strips.



Fig. 6. Views of Pontweg Bridge before refurbishment

The bridge bearings, in particular the movable roller bearings, are equally in bad shape. One bearing can be seen in Fig. 6. The roller bearing suffers from serious corrosion, and its function seems to be compromised. After closer examination, repair of these

bearings is possible, as well as the removal and replacement, although this type of bearing is typical for the historic bridges.

The picture shows that the rulers, which should be fitting in the upper grooves and block lateral movements of the bearing, are missing or lay loose on the lower plate. In addition, there is no hope to loosen the bolt nuts. Consequently, our various alternatives for refurbishment were not adapted and the owner decided in favour of replacement of movable bearings.

5. Refurbishment work

In view of the reduced capacity, and to guarantee the access to the the neighbouring residential area, the owner decided to establish a temporary Bailey bridge, as can be seen in Fig. 7. Traffic was thus maintained on a single lane. Unfortunately the temporary bridge was not equipped with footpaths, which presented a rather critical situation for pedestrians.



Fig. 7. Temporary Bailey bridge

Works have started immediately by removing the cobblestone pavement and inspecting all concrete parts, thus reducing the structure's dead weight. After removing the deteriorated concrete of the lower chord, the overlap areas of the rebars have appeared. Many of these connections were located in the damaged area (Fig. 8). In order to guarantee successful overlapping, sufficient concrete quality is necessary. The removal of concrete was thus to be expanded beyond the area required for protecting the rebars.



Fig. 8. Extension of concrete removal due to overlapping rebars

While removing a larger amount of concrete, the contractor came to the conclusion that the lower chord would be weakened too much, to resist the remaining dead weight and proposed to build a reinforcing edge beam, shown in Fig. 9. This beam contains 70% of the original longitudinal reinforcement and is connected to the original parts by dowels,

anchored chemically to the original structure. Obviously, since the lower chord is mainly a tensile member, the additional longitudinal reinforcement continues through the crossbeam webs, the number of dowels being doubled in the first and last sections between crossbeams. This reinforcing beam was added across the entire length of the bridge and replaces the CFRP reinforcement. The use of short dowels does not correspond to theoretical arrangements, since the functioning purely depends on shear of rebars. However, the arrangement proved to be effective.

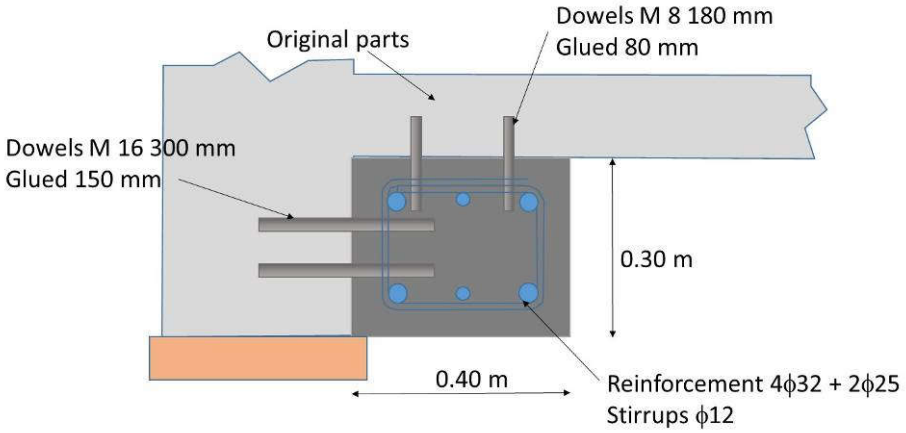


Fig. 9. Principle of reinforcing parallel beam



Fig. 10. Reinforcement put in place



Fig. 11. Walkway slab after removal concrete

Fig. 10 shows the additional reinforcement put in place. It may be noticed that the original lower chord member was already repaired before building the additional beam. Since pouring of the concrete was difficult and for improving the adhesive connection of concrete phases, the beam was built with sprayed concrete.

Apart from the lower chord, the corbelling slabs from the walkways were degraded more severely than expected. This is due to de-icing salt and chloride attack. The concrete walkway slab initially had a thickness of 40 mm only. Hence, the deterioration can be easily understood. Mechanical removal of damaged concrete showed that at various location concrete thickness was reduced to 10 mm, while at some locations, the slab no longer existed. This can be seen in Fig. 11. Rebuilding this slab did was rather easy, since the reinforcement bars were generally in satisfactory condition.

As mentioned before, the owner decided that the movable bearings were to be replaced, the bridge was lifted on one side, thus allowing to remove the roller bearings and replacing them by identical devices. The lifting required connecting the abutments by prestressing bars to temporary supports as seen in Fig. 12. These supports allowed to free the corroded bearings and replace them, as seen in Fig. 13.

The sealing of exposed concrete first required soft cleaning of unharmed surfaces. For this, and to prevent any environmental issue, a protective wrapping (Fig. 14) of

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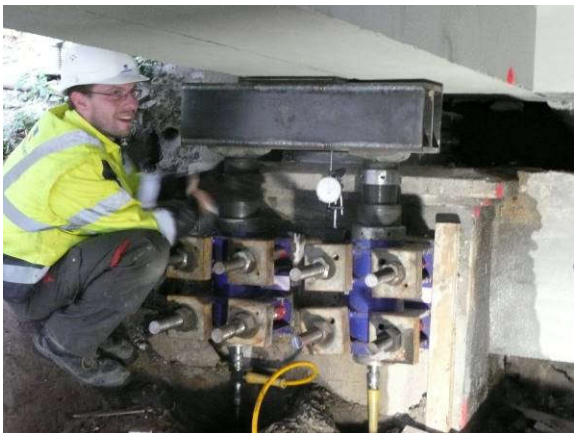


Fig. 12. Jacking of superstructure



Fig. 13. New roller bearings

the bridge was installed. Since less consequent deterioration was found on the arches and hangers than on the lower chord and deck, a different type of sealing was adopted for both. The lower chords and deck were repaired with a general protection of polymer cementitious mortar. As can be seen in Fig. 15 this results in a new, rather unnatural aspect of the concrete, thus losing the initial texture and original characteristics.



Fig. 14. Protective wrapping of bridge



Fig. 15. Sealing of lower side bridge



Fig. 16. Sealing of arches and hangers



Fig. 17. Concrete texture

Fortunately, this was not allowed for the arches and hangers. In these most visible parts, superficial concrete degradations were repaired locally, using micro cement mortar. While trying to obtain a texture and colour corresponding closely to the original ones, 20 types of products have been tested. Fig. 16 shows the result during a rainy period, with lighter colour of the new parts and the contrast with the unnatural lower chord. Once dried, the colours become identical. In addition, effort was made to obtain identical texture of the concrete surface, by using light surface indents as from the original formwork from wooden planks. The latter can be clearly seen in Fig. 17.

6. Load test

At the time of writing, a load test of the refurbished structure is being considered. Experience has shown that load tests of concrete structures are generally less successful than for steel structures. The owner refers to national technical specifications for testing, which are limited to survey of deflections. Strain measurements of various types are more successful [5], but may be too costly for a small structure like the Pontweg Bridge. However, deflections should be sufficiently large and at least exceed the measurement precision. To allow the owner deciding on the type of test, first the influence of replacing the cobblestone pavement was examined. This is a distributed load, which is not critical for arch bridges. The beam element model showed a deflection of 0.218 mm and concrete tensile stress of 0.66 MPa. This means that the concrete repairs are loaded below the cracking condition. However, this loading condition is unpractical to assess the effects of repairing.

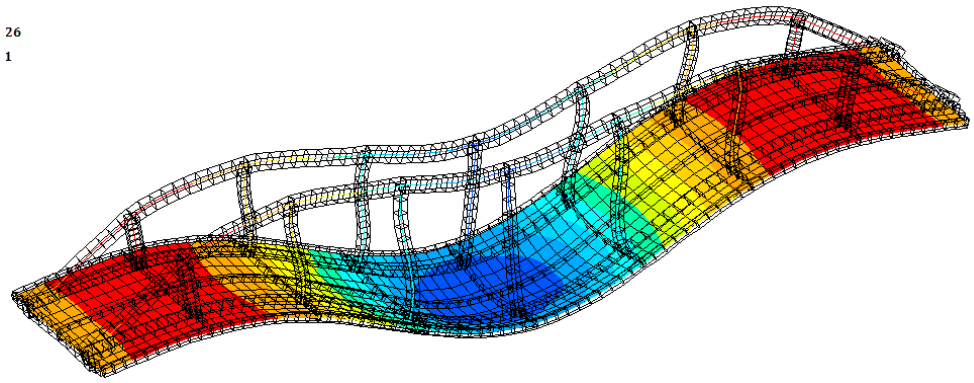


Fig. 18. Deflections caused by 44 Tons truck

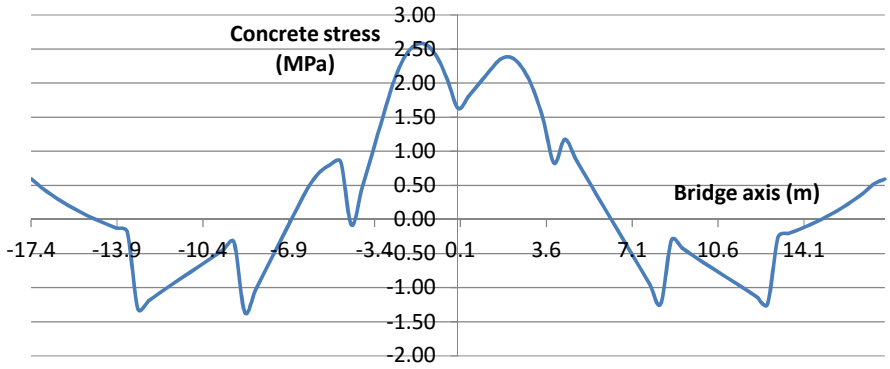


Fig. 19. Concrete stress caused by 44 Tons truck

A 44 tons truck was considered to serve as test load. This type of truck causes maximum deflection of 5.23 mm (Fig. 18), a magnitude that can be measured successfully

by total measuring stations. In addition, the lower chord stresses have been derived and are shown in Fig. 19.

Adding the stress to the part caused by the pavement, a maximum value of 3.21 MPa is found. Hence, the concrete remains uncracked and the use of longer strain gauges can accurately serve to assess the effectiveness of the refurbishment. Both these alternatives have been suggested to the owners, who are in the process of deciding. However, in view of the care that was taken in the refurbishment, surely the load-carrying capacity of this bridge has been restored effectively.

7. Conclusion

Right after inspecting the Pontweg bridge in 2012, the general opinion concluded that the bridge should be demolished and replaced. The arch shape, the characteristic nodes and RC-hangers make this bridge a rare heritage structure. Careful analysis and testing allowed to convince parties involved that restoring the load-carrying capacity and refurbishment was possible. The use of polymer-containing repair products has deprived the structure of its original appearance. Fortunately, the arches and hangers have kept most of the concrete colour and texture and show the effort made to preserve the bridge.

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DIAGNOSTICS OF WOODEN POLES LOCATED IN THE OPEN-AIR MUSEUM USING SONIC TOMOGRAPHY

Oto Makýš[1], Renáta korenková[2], Peter Krušinský[3], Dominika Šrobárová[4]

Faculty of Civil Engineering, Slovak university of Technology in Bratislava.
Faculty of Civil Engineering, University of Žilina .

***Abstract**: The paper deals with the lifetime of wooden poles, located in the archaeological open-air museum of Liptovská Mara - Havránok, which were erected outdoors about 12 years ago. It introduces the diagnosing of their condition using sonic tomography. The poles differ from each other by the location, positioning and anchorage considering the terrain slope. Investigation was focused on the free-standing poles (quasi sacrifice poles) and the poles that are part of the fortification (gates, walls). Diagnostics was made using the device Fakkop ArborSonic 3D Sonic Tomograph which has 18 sensors. It measures the sonic response (sound velocity) in a tree stem. Sound wave velocity within sound wood depends on its species, moisture content, and the direction of measurement. The measurements brought remarkable results.*

***Key words**: sonic tomograph, timber element, wood damage*

1. Introduction

The archaeological site on Mount Havránok, situated in the region of Liptovská Mara, is one of the most important Celtic culture sites of the late Iron Age/early Roman period (2nd century BC - 1st century AD) [1] not only in Slovakia but also in Central Europe. Research has been running here since 1965; conducted by Mgr. Karol Pieta, PhD from the Archaeological Institute of Slovak Academy of Sciences (SAV). In 1986-1992 the first phase of project was finished - a gradual model and experimental reconstruction of selected parts in the area in order to bring visitors a three-dimensional view of the mentioned age directly in its original location. Fortification of the sacrifice area on the eastern terrace was reconstructed using various methods. All reconstructed structures came under the Liptov Museum, which has set up here the first archaeological open-air museum in Slovakia.

2. Archaeological open-air museum of Havránok

In 2002-2007, the team from the Archaeological Institute SAV, Liptov Museum, Faculty of Civil Engineering of Slovak Technical University (STU) in Bratislava, and the civic association Tree of Life managed to organize maintenance and renovation works to

[1] Oto Makýš, Doc. Ing., PhD., Radlinského 11, Bratislava, oto.makys@stuba.sk
[2] Renáta Korenková, Doc. Ing., PhD., Univerzitná 8215/1,Žilina, renata.korenkova@fstav.uniza.sk.
[3] Peter Krušinský, Ing. arch., PhD., Univerzitná 8215/1, Žilina, krusop@fstav.uniza.sk.
[4] Dominika Šrobárová, Radlinského 11, Bratislava, dominika.srobarova@stuba.sk

make good certain damages - especially in the sacrifice area. After finishing these works (partly supported by some grants), however, the problem of adequate maintenance reappeared, thus now the area is damaged again. To be objective it should be added that the material and design solution used (for the open-air museum of this type essentially irreplaceable by other ones) will require fundamental structural repairs, reconstructions, or interventions some time later. The question is to what extent the degradation of wooden structures have moved after about 12 years since their renovation.

3. Sacrifice area

The sacrifice area of Celtic culture in Havránok is among the most important archaeological sites of its kind in Central Europe. Due to its authenticity and use, only a few fragments survived, which provided space for artistic interpretation. The area is unique because it was originally fortified and entered through the curved space in front of the gate protected by a tower, which is the oldest evidence of such an entrance into a protected place in our country. Further similar entrances occurred thousand years later.

Extensive damage to its structures came after about 12-15 years. It was caused by building material (a significant portion of poorly treated wood) and construction details (wooden poles fixed into the ground). The situation was worsened by unstable waterlogged mount slope which is located in the landslide area. A considerable part of problems (but not all) was managed to solve in 2002-2007 and so the major part of the museum area could be reopened - see Fig. 1,2.



Fig. 1. View of the sacrifice area

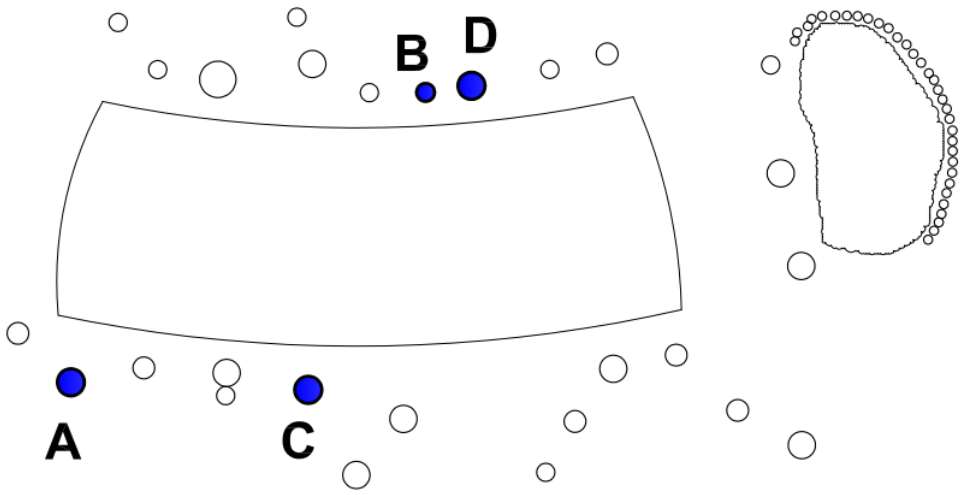


Fig. 2. Arrangement of wooden poles investigated in the sacrifice area

When the open-air museum was created, there were placed wooden poles and modified trees (totems) into the original pole pits. The author of totem decorations was the academic sculptor Ľudmila Cvengrošová, Unfortunately, almost none of the original totems survived, since they rot away in the contact ground-air zone or in their upper parts. Few original pieces of the artwork were managed to save and now they are exhibited in the open-air museum building. They were replaced by good copies in the open-air sacrifice area.

4. Design solution

In 2003-2007 totems in the sacrifice area were reconstructed using green larch wood. Bark was immediately removed and 3 weeks later the stems were decorated with carvings inspired by original motifs. The poles were then fixed into pits considering diameters of original Celtic poles. They were experimentally fixed into different foundations. Some poles were fixed directly into the ground - i.e. into the soil, others were fixed into the lime-mortar, cement-mortar, or concrete bed. Beds were made relatively massive - each had a 5-7 cm thick mortar layer in the bottom. Then mortar was poured around the poles to create a layer 10 cm thick and wrap the pole as far as the ground level. Mortar was covered by turf to camouflage it.

Such complicated works were chosen due to research purposes. Different fixations were supposed to be evaluated many years later, what have just happened. It was also supposed that concrete fixation will prolong the lifetime of the poles, which has been proved. It should also be added that the terrain in the sacrifice area is well wetted by rainwater running down the slope.

5. Experimental measurements

The Fakopp 3D Sonic Tomograph is used in practice to diagnose latent, i.e. internal, damage to living trees. We used this device for decay detection within wooden elements in the archaeological open-air museum of Havránok. The method is semi-invasive; there are minimal interventions in wood. In fact it is the measuring of time taken for sound stress waves to pass through the wood of a tree or a wooden element. Longer time indicates internal biotic damage, possibly a cavity in a tree stem or wooden element.

In general, the denser wood, the higher speed of sound. When the wood moisture content is higher, sound waves will pass through it more slowly because capillaries contain water instead of air [5]. It results in higher sound-wave resistance. The velocity of sound waves in sound wood depends on its species, moisture content, and the direction of measurement [6]. Average sound wave velocities for different tree species are given in Tab. 1, made according to [7]. The paper brings in-situ measurements of wooden elements using Fakopp 3D Sonic Tomograph.

Tab. 1 Average sound wave velocities according to tree species

Average sound wave velocity measured across the grain (m/s)			
Degree of damage	Tree species		
	Spruce, Fir	Pine	Oak
1	1260 - 1800	1160 – 1750	1640 – 2100
2	920 - 1260	840 – 1160	1180 – 1640
3	750 - 920	680 – 840	850 – 1180
4	500 - 750	500 - 680	600 - 850



Fig. 3. Color range in the sonic scan of a wooden element - approximate evaluation.

Sonic scans of measured elements record sound wave velocity among the individual sensors. In fact, sensors are steel nails hammered into a wooden element around its perimeter at regular distances. Hammering on a sensor create sound waves whose velocity is recorded in other sensors. Sensors/nails are hammered about 15 mm deeply, i.e. the sonic scan of particular section of measured element is reduced compared with its actual dimension - see Fig. 3.

5.1 Wooden pole fixed in plain concrete (Fig.2 – A)

The measurements were taken on May 5, 2016 at 14:46 hour in a round barked larch pole. The pole is fixed 80 cm deep; the pit is filled up with plain concrete. The first measurement was taken at ground level, i.e. 0 cm above ground level - see Fig. 4. Second measurement was taken 30 cm above ground level - see Fig. 5.

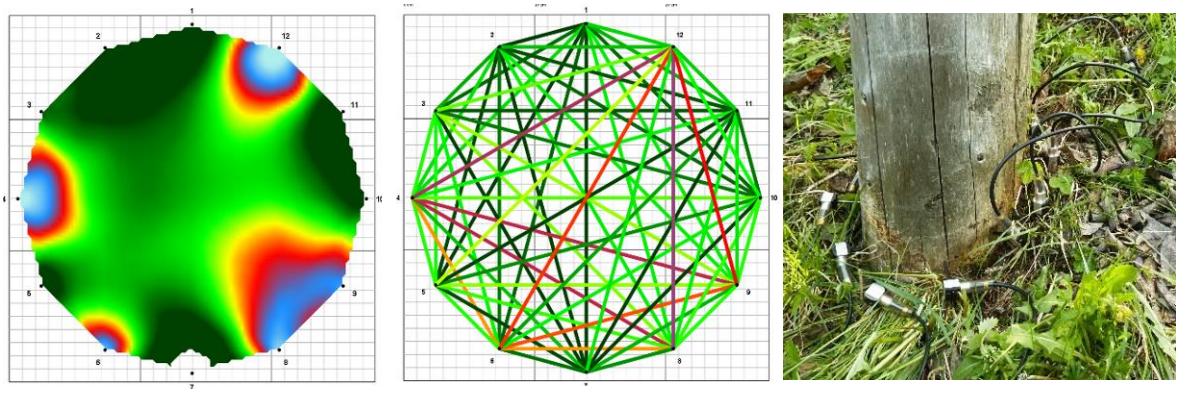


Fig. 4. Sonic scan at ground level

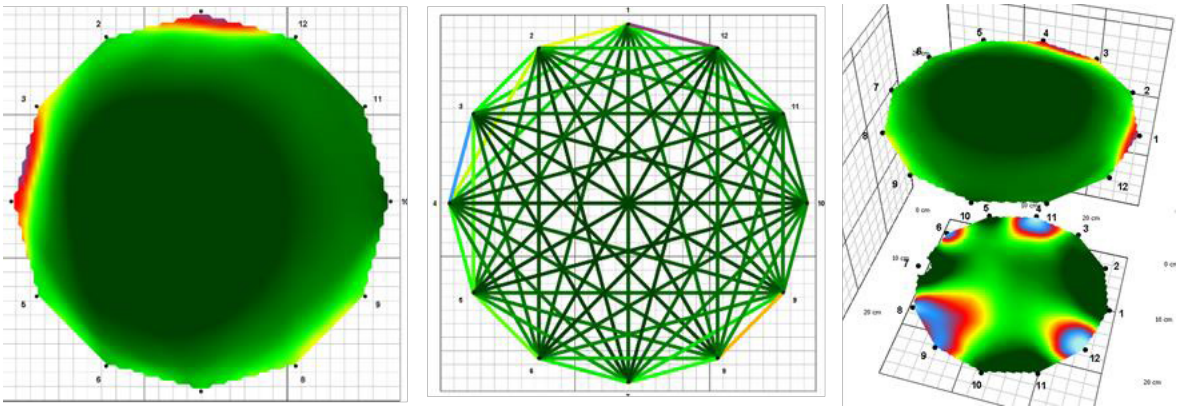


Fig. 5. Sonic scan 30 cm above ground level

The absolute moisture content of the wooden element, temperature and relative humidity was measured at the same time with measuring the sound wave velocity. The sonic scan evaluation shows the pole bottom is more damaged compared to second measurements. Inside the wooden element there is not a hollow or damaged wood. There is a surface damage, occurring in the contact zone near the ground. Decayed parts reach inside the diameter. The degree of damage in the first layer is 23 % and in the second layer it is 3 % of a section.

5.2 Wooden pole fixed in lime mortar in the sacrifice area (Fig.2 – B)

Measurements were taken on May 5, 2016 at 15:32 hours in a round barked larch pole. The pole is fixed 80 cm deep; the pit is filled up with plain concrete. The first measurement was taken at ground level, i.e. 0 cm above ground level - see Fig. 6. Second measurement was taken 50 cm above ground level - see Fig. 7.

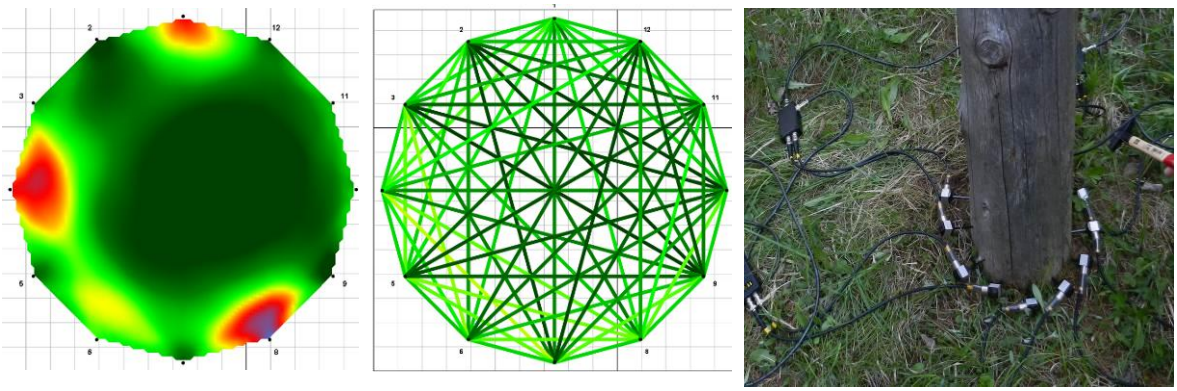


Fig. 6. Sonic scan at ground level



Fig. 7. Sonic scan 50 cm above ground level

The sonic scan evaluation shows the pole bottom is more damaged at the contact zone near the ground. Inside the wooden element there is not a hollow or damaged wood. Second level measurement shows no surface damage, but the investigated section contains internal damage; the pole probably contains damaged wood in the middle. The degree of damage in the first layer is 9 % and in the second layer it is 31 % of a section.

5.3 Wooden poles fixed in soil without treatment in the sacrifice area (Fig.2 – C)

Measurements were taken on May 5, 2016 at 15:32 hours in a round barked larch pole. The pole is fixed 80 cm deep; the pit is filled up with plain concrete. The first measurement was taken at ground level, i.e. 0 cm above ground level - see Fig. 8. Second measurement was taken 30 cm above ground level - see Fig. 9.

The sonic scan evaluation shows the pole bottom is more damaged at the contact zone near the ground. Inside the wooden element there is not a hollow or damaged wood. Second level measurement shows no surface damage, but the investigated section contains internal damage; the pole probably contains damaged wood in the middle. The degree of damage in the first layer is 9 % and in the second layer it is 31 % of a section.

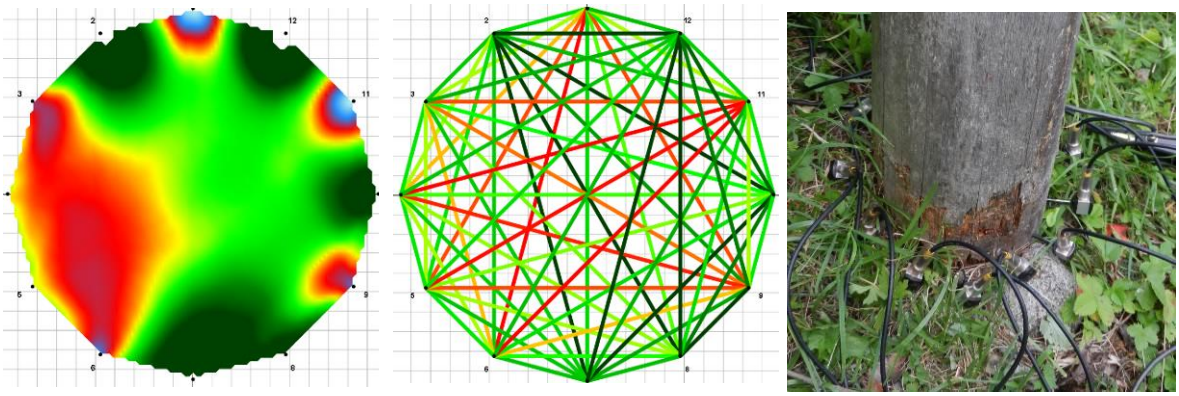


Fig. 8. Sonic scan at ground level

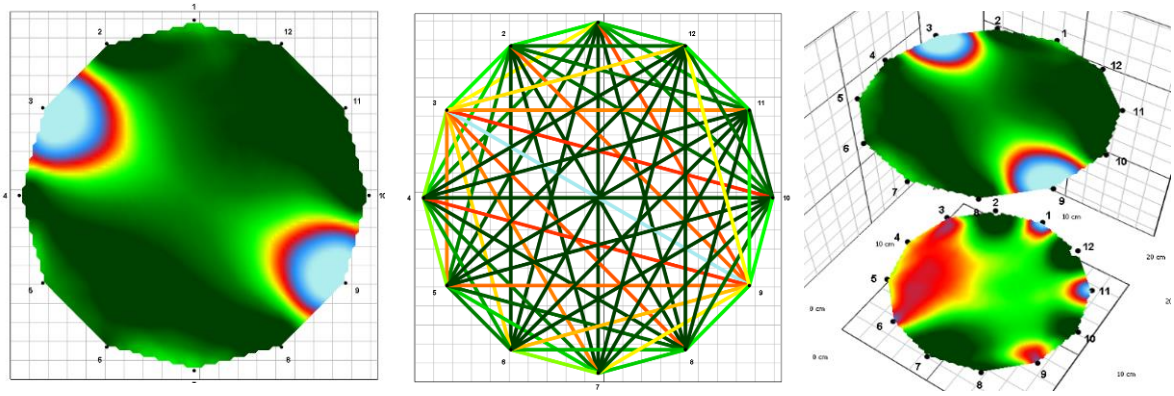


Fig. 9. Sonic scan 30 cm above ground level

Further measurements were taken on May 30, 2016 at 15:34 hours in a round barked larch pole. The pole is fixed 80 cm deep; the pit is filled up with soil. Measurement was taken at ground level after removing grass. The pole is fixed in a slope. Visual inspection shows evident damage on the side facing the slope - see Fig. 10. The degree of damage is 39 % of a section. The wooden pole is significantly attacked by rainwater running down the slope.



Fig. 10. Measuring of the pole covered up with soil: left to right - sonic scan, bottom view of measurement, view of the damaged side - the hollow.

6. Wooden pole fixed in soil using birch bark (Fig.2 – D)

Measurements were taken on May 30, 2016 at 16:40 hours in a round barked larch pole. The pole is fixed 80 cm deep, it is wrapped into birch bark under the ground; the pit is filled up with soil. The first measurement was taken at ground level, i.e. 0 cm above ground level after removing bark and grass - see Fig. 11. Second measurement was taken 20 cm above ground level - see Fig. 12.

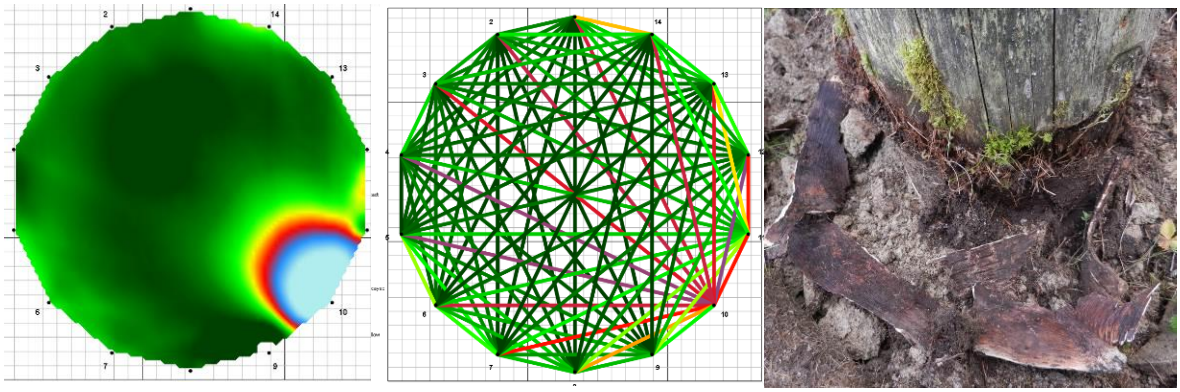


Fig. 11. Sonic scan at ground level

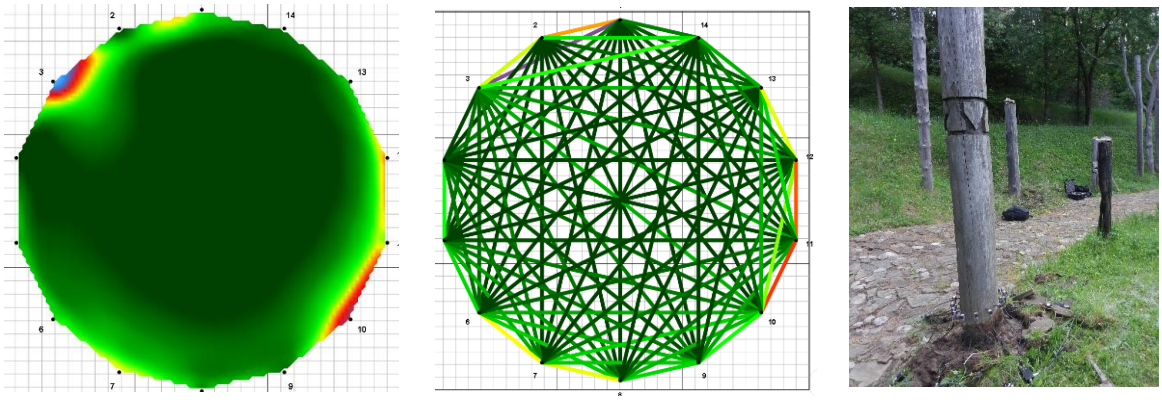


Fig. 12 Sonic scan 20 cm above ground level

Visual inspection shows damage in the contact zone with the ground. Wood degradation is 1 cm deep. The sonic scan shows the pole bottom is more damaged in the contact zone with the terrain. Inside the wooden element there is not a hollow or damaged wood. Second level measurement shows no surface damage. The degree of damage in the first layer is 9 % and in the second layer it is 3 % of a section.

7. Discussion

Gathered data indicated that wooden poles fixed in and covered up with soil contain the heaviest damage. An important factor in this case is the shape of the terrain. In the case of sloping terrain, the wooden elements are much more attacked by rainwater running down the slope. All visually inspected poles showed significant damage on the side facing the slope. Wooden elements were gradually degraded in the contact zone with the terrain.

In poles fixed in added material such as lime mortar and plain concrete it can be stated that the wood damage in the contact zone with the terrain was more heavier when fixed in plain concrete. Poles fixed in lime mortar showed less damage in the contact zone, but above ground level they contain more internal damage.

8. Conclusion

The paper introduces the inspection of wooden poles located in the sacrifice area in the archaeological open-air museum of Havránok. To know technical condition of wooden elements is of utmost importance, especially due to the safety of wooden structure located in the area with people´s movement. The inspection was focused on the wooden poles fixed in the ground in 2003. We assessed technical condition of wooden poles experimentally fixed using different methods. Poles were fixed 80 cm deep in plain concrete, lime mortar, and soil, as well as using the wrapping with birch bark. Technical condition of poles was first assessed visually and tactually, then using the sonic tomograph (measurement of sound wave velocity in wood). The above mentioned device may be used to detect internal - hidden damage to wooden elements.

The paper was aimed at highlighting and evaluating of measurements related to the internal damage to wooden poles. We looked for the appropriate solution and method to fix wooden poles in the sacrifice area. Technical condition of poles was experimentally verified 13 years after their fixation. The diagnosing of their technical condition revealed the least damage to the poles wrapped into birch bark. All poles showed significant damage in the contact zone with the terrain. It can be claimed that poles shows weak damage after 13 years, which is not great risk in terms of the wooden structure safety.

Acknowledgement

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INTERPRETATION OF CONSTRUCTION DETAILS IN DIAGNOSING THE FAILURES

Görün Arun

Hasan Kalyoncu University, Faculty of Fine Arts and Architecture, Gaziantep, Turkey

***Abstract**: The study of historical constructions oriented to their preservation requires multidisciplinary teams of specialists formed in relation to the type and the scale of the problem [4]. To achieve preservation in a building's historical and cultural context, diagnostic studies for understanding the causes and mechanism of decay based on historical information, environmental monitoring, evaluation of the present level of safety and selection of appropriate preservation methods and materials are indispensable scientific and technical basis for correct interventions. The study of building construction method and structural details has a great importance in the mechanical and dynamic behavior of a building. The main objective of this paper is to point out the importance of acknowledging the design skills of master builders during diagnosis of the failures in historic buildings. This study is made through reviewing archaeological and history of architecture publications, discussions with archaeologists and experiences met during diagnosis phase of restoration works.*

***Key words**: Template, formats, instructions, length, Times New Roman, 12 pt, Italic, Justified*

1. Introduction

The conservation and enhancement of the architectural heritage is a vital part of the future sustainability, and to the maintenance of social, economic and technical traditions. Nevertheless due to aging, to the aggressive environmental effects as earthquakes, soil settlements, increased loading as traffic vibrations, air pollution and to the fact that many old buildings and historic centers were not maintained properly, a large part of this heritage suffers structural problems that menace the safety of buildings and people.

The decision making process of the preservation problem of these culturally valuable and potentially functional architectural structures should keep the structure's original and authentic architectural message. It requires accurate evaluation procedures, efficient repair methods and rational design criteria. To achieve preservation in a building's historical and cultural context, diagnostic studies for understanding the causes and mechanism of decay based on historical information, environmental monitoring, evaluation of the present level of safety and selection of appropriate preservation methods and materials are indispensable scientific and technical basis for correct interventions.

The study of historical constructions oriented to their preservation requires multidisciplinary teams of specialists formed in relation to the type and the scale of the problem [4]. And requires special technical and analysis tools adapted to the structure's geometry, building materials and changes it had passed all throughout its lifetime [4]. Today, significant knowledge is available in modern testing and advanced analysis of heritage structures for the assessment of the failures. Constraints to be considered in the preservation of the architectural heritage are working together with a multidisciplinary team, the need of experienced professionals who can collaborate with different disciplines and lack of knowledge in the interpretation of the building construction methods and structural details in the evaluation of structural problems for intervention decisions. In investigating heritage buildings mostly constructed with the leading technology of its time and to understand their mechanical and dynamic behavior, it is important to take into account the engineering knowledge and practice of their construction time for proper interpretation of the causes of the failures and for decisions on proper intervention.

Earthquake was always one of the most threatening actions to buildings in Anatolia. In order to make buildings safe, there exist several ancient construction codes partly parallel to portions of the Hammurabi code, a well-preserved Babylonian law code, dating back to about 1772 BC. This Code of Hammurabi consists of 282 laws, with scaled punishments, adjusting "an eye for an eye, a tooth for a tooth". So, ancient building masters designed their buildings taking proper account of environmental conditions.

Today, the seismic zone map of Turkey in 2007 Specification for Structures to be built in Disaster Areas, classifies the country into five seismic zones- in which Zone 1 is most severe. During the investigation, it has been noticed that in seismic areas, the master builders introduced special techniques to make the structure withstand the lateral forces in substructure and superstructure.

The main objective of this paper is to point out the construction method and structural design of master builders from various civilizations lived in Anatolia that was in the heart of cultural and trade routes of the Europe, Asia and Africa. Ancient building masters, using techniques developed by previous cultures, their own trial and error, and techniques transferred from one generation to another, were able to empirically size and design the structural elements. The ignorance of the accumulation of master builder's knowledge and construction technique of their time may lead to incorrect intervention and long-term harmful effects on the structure.

2. Organization of Masonry Structural Elements

Masonry structural elements are composed of stone, brick or adobe units that are laid dry, joined to each other with metal clamps or laid in mortar. Resistance of a masonry building to exposed loads depends on the geometry of the structure, the strength and stiffness of the materials used, geometrical configuration of the units and the way the units are connected to each other. The masonry material's high compressive strength and the friction resistance generated by the compressive action, helps masonry elements to withstand tensile stresses exerted by earthquake forces.

Masonry building dissipates energy with the movement of their units. If the connection of the stone units is made with iron clamps, these clamps were laid in lead. Lead covered the iron, avoided corrosion of the iron and let the blocks move. If the stone and clay brick blocks are laid in mortar, using weak, rather than strong mortar, this let sliding along the bed joints dissipating energy so that the masonry unit will be safe. The ignorance of this knowledge and construction technique may lead to incorrect interventions.

Thick masonry wall with two outer faces where the space in between is left empty or filled with rubble and mortar, the outer leaves are connected with suitable lacing at certain intervals to limit the support movements, to prevent wall bulging under gravity loads, to reduce the slenderness ratio of the wall and to prevent crack initiation at another location. As lacing, timber, stone in brick walls, brick in stone walls was used. Iron or copper ties were used after 1840. These ties were joined to each other either with metal agrafe, seen out of the wall or inserted in lead in a round clevis, not apparent from outside (Fig. 1). It is important to identify their place in order to assess the slenderness ratio of the wall. Slenderness ratio of a wall is very important in resisting earthquake forces.

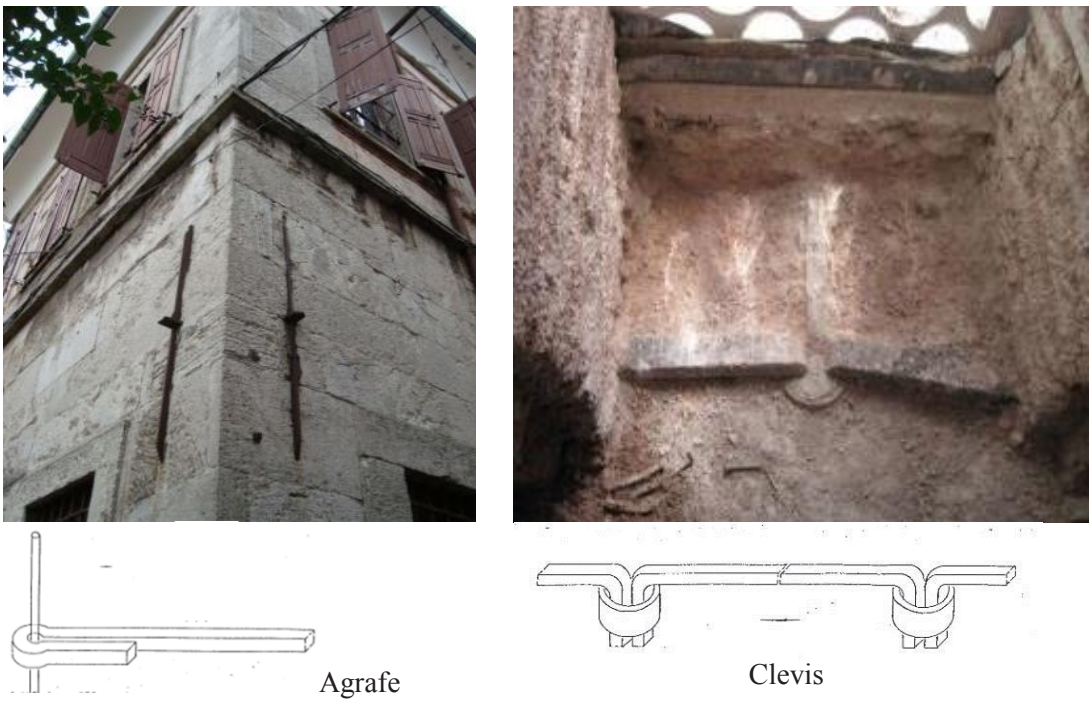


Fig. 1. Metal Lacing

In the building geometry, long projecting and different weighing components of a building were separated as expansion or seismic joints. Here, the building parts staying side by side were separated by not joining the masonry units to each other. Such construction features may be incorrectly interpreted as damage. As in Süleymaniye mosque in Istanbul, different weighing parts has two arches side by side belonging to different parts of the building (Fig. 2).



Fig. 2. Seismic joints between the two arches

In many cases of archaeological excavations, it is seen that new structures have been built upon old foundations. Just as bricks and columns could be reused, so could foundation systems. In this case, the inner grillage foundation walls were not completely bounded to the perimeter wall foundation. When different components of a building were not of the same weight and would have settled differently, the intersecting lines of the foundations were not bounded.

Ancient building masters knew the geometry and behavior of the structural elements they constructed and provided proper measures to exterminate the weaknesses. Some geometry of vaults as cylindrical and torus vaults and spherical domes inherently has tension at the base along one of their principal curves. To encounter the tensile stresses; building masters provided continuous boundaries as walls thickening or closely spaced arched columns or piers at the base. And to reduce the weight of the structure, they used clay pipes in the construction of the compressive part of the vault or dome (Fig. 3a). The vault with an elliptical parabolic surface has compression on both of its principal curves. To make a roof or floor over such vault, amphora was used to fill in the space not to give extra weight to the vault surface [11] (Fig.3b). This vault looks very similar to a pendantive dome that contains tension stresses at the base.

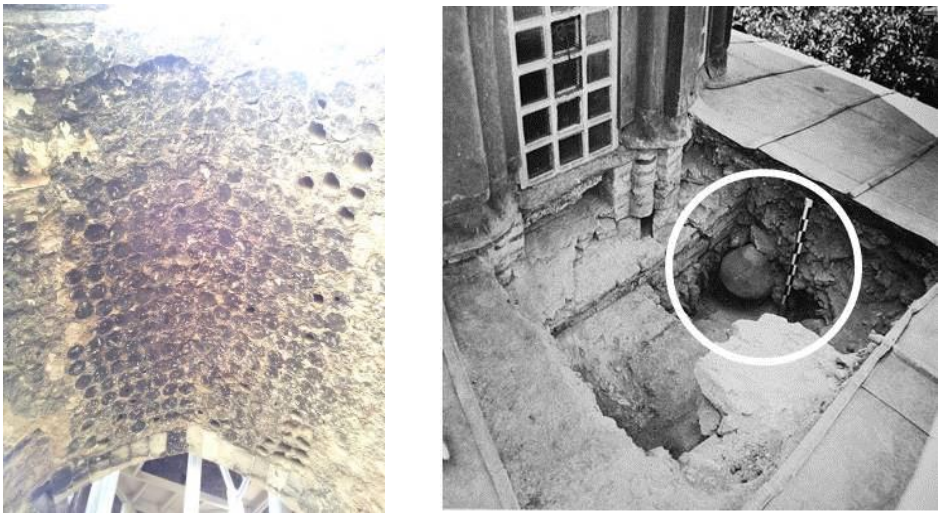


Fig. 3. Reducing the weight of the vault or dome

3. Underground Water Drainage

Ancient building masters were aware that the water was the most serious non-seismic threat to masonry buildings in areas of both high and low seismicity. Depending on the porosity of foundation construction material and soil characteristics, it can damage the wall and soil by eroding away portions and by reducing the strength. To prevent weakening instability of the building through humidity resulted from underground water movement the surface water of rainfall; they designed an effective drainage system.

In archaeological excavations, it is seen that surface and subsurface drainage was given high priority during its design and construction. The foundation rituals in Sumerian, Akkadian [6] and Egyptian texts [7] for temples, palaces, tombs, and forts show that before starting the construction of the foundation, master builders constructed a well with galleries or channels that discharge the water out of the building, and gates out of the building for ventilation. This construction system, constructing a well in the building, was practiced till late 19th century especially in high seismic zones in Anatolia.

The major components of the drainage system to drain interior ground surfaces of a building included wells or cisterns in the basement, galleries or channels that discharge the water out of the building, and gates for ventilation out of the building (Fig. 4). The size of the galleries or channels connecting wells to each other or discharging water away from the

building varies from 30-40cm to 1.0-2.5m depending on the size of the building. These are generally constructed of stones or bricks with mortar binding [8]. These channels removed the moisture from surface and underground water, served to keep the structure warm in the winter and cold in the summer. And during earthquake, they discharged the raising underground water avoiding soil liquefaction.



Fig. 4. Wells, gates, channels in the building

In settlements, the channels, penetrating the walls, generally continued to the other building's drainage system then was discharged to a channel along a main road or to a cistern or to a fountain tank. In most of the Byzantium buildings in and around Istanbul, the underground water was discharged to a cistern or the foundation of the buildings included cistern. In the area of Topkapı Palace, more than forty cisterns were found within the substructures of buildings [3]. The twelfth-century the church of Pammakaristos includes a large colonnaded and vaulted cistern that extends under the naos and parts of the ambulatory, now filled with soil. Yavuz Selim Mosque in Fatih district includes a large gallery heading toward a cistern that is blocked by the foundation of the mosque. There is also a cistern near the Fatih Mosque. In Ottoman settlements, the channels, penetrating the walls, generally continued to a nearby fountain tank.

Because this practice is completely forgotten demolished drainage system due to new constructions around the heritage structure is a frequently met phenomenon. Such blocking of the subsurface water control system causes water to rise to the building and soften the soil which leads to the building settlement. During diagnosis of the failures of the building, if this knowledge is ignored consolidation of the soil will not solve the problem.

4. Foundation Organization

Foundations, as distributing the loads from superstructure to the earth below, have to resist compression, tension and shear stresses imposed by the soil pressure and earthquake forces. The thick ancient building foundations of stone or brick masonry generally were a vertical wall down to the hard soil. The construction of foundation wall was either solid or cavity wall constructed of two rows of stones, where the space between the rows is filled with the rubble and earth. During the process of time as the wall thicknesses became thinner consequently the smaller sizes of foundation walls widening at the foot were practiced. If the wall was composed of closely spaced piers and there was not sufficient depth to step the foundations, sometimes inverted arches or vaults were made (Fig. 5). Soft soil was consolidated by timber piles. The foundation walls rested on timber mesh embedded in a khorasan mortar over these timber piles.

The foundation construction of the walls depends on the type of soil. Acceleration, generated by ground displacements, is amplified or attenuated by the soil structure. To

minimize amplification of acceleration input and prevent resonance, adequate construction would be stiff structure on soft soils, flexible structure on hard soils and rock.



Fig. 5. Inverted vault foundation of Edirnekapı Cistern [5]

At high seismic zones, to provide the lateral stability of structures, building masters had introduced special techniques to change the natural frequency of soil.

If the rock bed or hard soil was not so deep, the foundation walls rested on a pillow layer of sand, gravel or small stones as in Phaselis, Antalya (Fig. 6), or rested on three layers of brick or stone blocks as in Alaca Höyük from Chalcolithic era (Nauman 1991), in Urartian buildings at east and Greek temples at the southwest of Turkey. The foundations of masonry village houses at east Anatolia were constructed on a layer of ~40cm sand till 1960s. The thick layer of sand, gravel or stone pieces provided a change in the natural frequency of soil as well as adequate subsurface permeability to avoid a high water table condition [1].

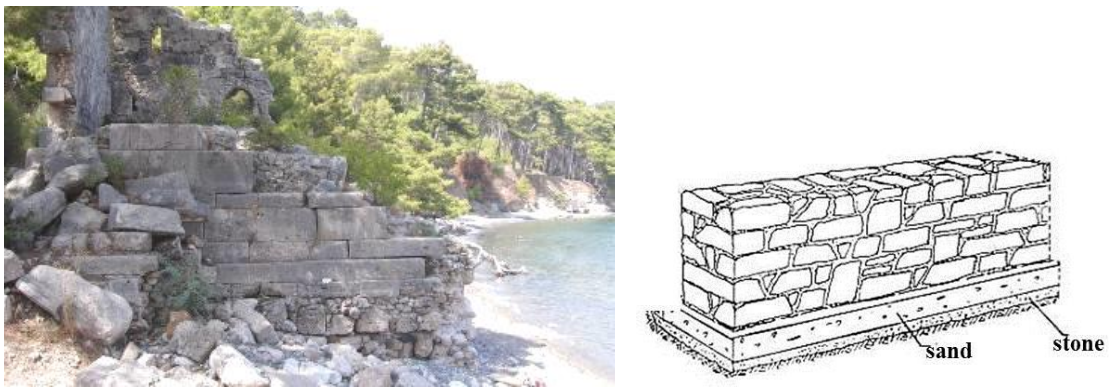


Fig. 6. Pillow layer of gravel and sand

If the rock bed was close to the surface, a flexible base was provided by placing single or more layers of wooden grillage at the foundation base (Fig. 7). At the bottom of the foundation wall in Beycesultan, single layer of round wood grate projecting out 1.0-1.5m out from the foundation wall was laid side by side with small stones in between them (Nauman 1991) and in Acemhöyük, layer of wood poles under the foundation is placed over cut stones (Fig. 7b). Foundation walls of a Byzantine chapel in Üsküdar (Fig. 7a), Süleymaniye Mosque from 16th C. and the inverted vault foundation of Edirnekapi Cistern (Fig. 5) from late 19th C. in Istanbul are constructed over 2 layers of wooden grillage laid perpendicular to each other. The foundation of Konjic Bridge, an Ottoman bridge in Bosnia & Herzegovina also contained two layers of wooden grillage laid in between two dolomite layers forming a platform for foundation footing [10].

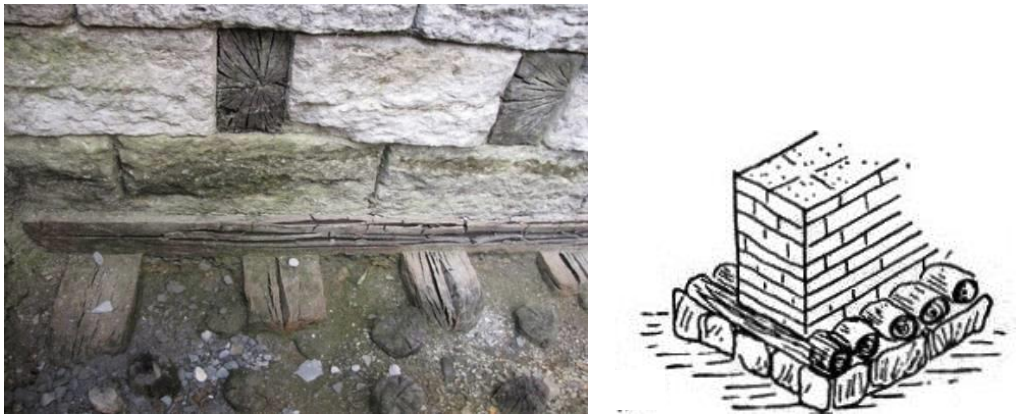


Fig. 7. Flexible footing of Byzantine chapel and Acemhöyük foundation walls

If the rock bed was on the surface, the rock was carved in the form of trough so that each stone of the foundation wall could be placed in the rock as if resting in a cradle (Nauman 1991) (Fig. 8). In between the rock and the foundation stone; briar, pieces of coal or animal skin was placed [9]. Such rock foundations in the form of trough were often met in tells at southeast Turkey, in Boğazköy, a Hitite settlement at Middle Anatolia (Nauman 1991) and Temple of Diana at Ephesus [8].

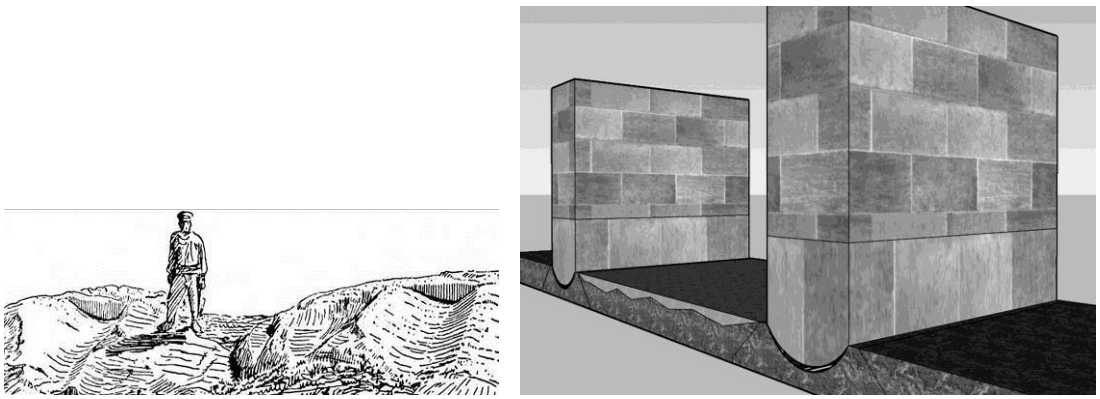


Fig. 8. Foundation wall on rock [2]

5. Conclusion

Ancient building masters, with accumulation of knowledge from previous cultures were able to size and design structural system through;

- Connecting the masonry units properly so that they disperse energy
- Providing seismic joints by not connecting the different weighing components of a building.
- To construct a building over an old foundation, not connecting the new foundation walls to the old foundations
- Constructing vaults and domes taking into account of the stresses required by their geometry.
- Designing an effective underground drainage system
- In EQ areas; changing the natural frequency of soil providing flexible base by placing a pillow layer of sand or gravel under the foundations, placing round wood layer at the foundation base; carving the rock in the form of a trough

Before making a decision on structural intervention it is indispensable to determine first the causes of damage and decay, and then to evaluate the safety level of the structure with experts of multi-disciplinary team [4]. In diagnosing the failures investigation of the historical records is important. Historical documentations records should be investigated by experts and historians who are able to adequately interpret the ancient texts, in cooperation with the structural engineers, assisting the historian in the identification of structurally meaningful records.

Ancient engineering systems are different than current practice ones. The knowledge of the old construction technique was lost during the last century. In investigating heritage buildings, it is important to take into account the engineering knowledge of their construction time. Ancient building masters had introduced special techniques to make the structure withstand the lateral forces and to control the underground water movement. Ignorance of the master builder's knowledge and construction technique may lead to incorrect intervention and long-term harmful effects on the structure.

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CONSTRUCTION HISTORY- A NEW LOOK TO THE HISTORICAL HERITAGE

Marina Traykova[1]

University of Architecture, Civil Engineering and Geodesy

***Abstract**: The concept of Construction History relates to the safeguard, recognition and continuation of cultural and historic traditions in national construction practices for the public interest of the society. All these construction practices represent the culture and the techniques of time along with sentiment, intent and conscience of its designer, artist or craftsman. The outlines of Construction History consist of increasing the awareness for historical and cultural aspects of structures and structural engineering and improving methods and practice in structural engineering by showing ways for integration of historical and cultural aspects in intervention projects to adapt or modify structures of high cultural value for future demands. The recognition and the comprehension of the Construction History influence the selection of the method, policy and degree of intervention, preservation methodology and techniques. Construction History is an inspiration for the new design solutions and creates the possibility to exchange good construction practices.*

***Key words**: Construction History, Historical Heritage, Preservation*

1. Introduction

The historical buildings and facilities represent one of the most important part of the Historical Heritage. They can be viewed as a work of art representing its own time. Preservation of these buildings and facilities for the future generation is a way of sustainable development and also an act of culture.

The concept of Construction History relates to the safeguard, recognition and continuation of cultural and historic traditions in national construction practices for the public interest of the society. All these construction practices represent the culture and the techniques of time along with sentiment, intent and conscience of its designer, artist or craftsman.

The outlines of Construction History consist of increasing the awareness for historical and cultural aspects of structures and structural engineering and improving methods and practice in structural engineering by showing ways for integration of historical and cultural aspects in intervention projects to adapt or modify structures of high cultural value for future demands.

The recognition and the comprehension of the Construction History influence the selection of the method, policy and degree of intervention, preservation methodology and techniques.

The most sensitive aspect of Construction History is the structural preservation because of the decisive role of the structure in the global behaviour of the buildings and facilities. Usually the structural preservation is related to the solution of the problem

[1] Marina Traykova, PhD, Professor, marina5261@abv.bg

"safety versus authentic structure". There is no generally applicable answer and the solution should be based on the specific conditions. Finally, the most important is to make a decision which will permit to preserve, to rehabilitate or to reconstruct the original structure. This decision will enable to prolong the life of the buildings and the facilities and will give the possibility to the future generation to learn the history and should be considered as a continuity of history.

Construction History is important because of the possibility to: 1) increase the professional knowledge and experience, 2) make the connection with the history and the national traditions of the place, 3) learn about the old structures, construction materials and techniques and their application in actual situations.

2. General aspects of Construction History

Stefano Musso presents a very elegant definition of Construction History [3]: "A construction represents and occupies a sort of boundary between the world of nature and the artificial world of culture". The definition of Werner Lorenz is very precise [3]: "If we accept that construction is a specific link between nature and culture, the role of Construction History then is no more or less than to provide an explanation of the action of producing this hinge, in fact construction in all its facets thinking/planning, designing, abstracting, modelling, calculating and measuring, specifying, financing, manufacturing, building, maintaining, reinforcing, destroying, disposing - in all its cross-linkages, interdependencies, and processes of interchange, right up to the use of practical applications and technology. It is the process of construction in its entirety that constitutes Construction History."

The importance given to construction is since the Antiquity. The study of the construction practices and construction technologies is essential for all contemporary solutions. The nineteenth century is marked by the publication of major contributions to the history of construction like those of Gottfried Semper, Eugene- Emmanuel Viollet-le-Duc (Fig.1) or Auguste Choisy. Very often these authors are architects, engineers or historians and for them the analysis of the different construction techniques of the past is inseparable from the theoretical and practical development of the construction process. Significant step is the study of new materials and innovations in building industry. Today, we are probably returning to a conception closer to the pre-industrial one with all researches on composite and smart materials and the tendency to answer more and more questions at the level of material design rather than structural design. An important part of Construction History is the study of the technological details. It is often difficult to get an exact idea of the machines or the processes evoked in many historical studies of industrial innovation, numerous construction history studies are based on precise and often minute descriptions. In [5] Picon asks: "Can one understand a project like Eiffel's Nice Observatory without entering into the detail of its hydraulic mechanism?" (Fig.2).

Specific interest in Construction History is dedicated to one of the most common construction material: Reinforced Concrete. The application of this material and all the techniques related to him represents a revolution in the construction practice with a very big social effect. Here is the place to mention the names of Hennebique, Freyssinet, Torroja (Fig. 3), Le Corbusier.

Authors like Antoine Picon [5], are analyzing the Construction History as boundary between the Technological and Cultural History: "Usually, when one tries to relate modem and contemporary construction developments to cultural issues, one has to consider their impact on architecture and engineering".

In his 1957 book, "The Reason of Structural Types", Torroja writes that [5] "Vain would be the enterprise of somebody who would propose himself to design a structure

without having understood to the backbone the mechanical principles of inner equilibrium."

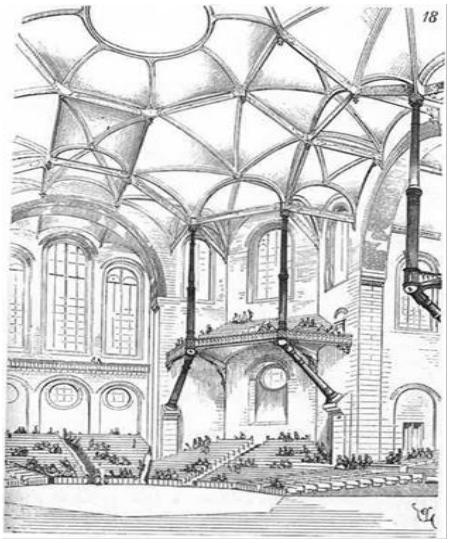


Fig. 1. E. E. Viollet le-Duc, vaulted room inspired by gothic principles, Entretiens sur l'architecture, Paris, 1863-1872 [5]

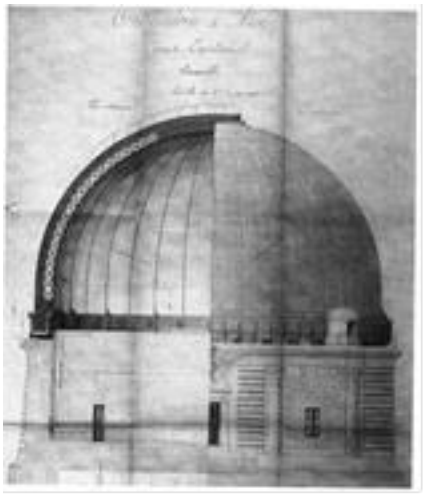


Fig. 2. G. Eiffel, Nice Observatory, (Archives Nationales, Paris) [5]



Fig. 3. E. Torroja, Zarzuela racetrack stands [1]

The challenge in Construction History is to go beyond the standard concepts for preservation, conservation and rehabilitation. The challenge is to show the potential of the structure (Fig.4) and the possibilities for sustainable development, economic growth and improvement of the quality of life of people.



Fig. 4. Bessieres Bridge in Lausanne, canton of Vaud (2 bridges from different periods: 1909 and 2007), Switzerland [2]

The future of Construction History is related to the participation and the cooperation with disciplines such as architecture, archeological sciences, cultural anthropology, social sciences, economics, law, etc.

The main task in Construction History could be summarized in the following: inspection and monitoring of Historical Heritage; development of specific methodologies for Historical Heritage; spreading, exchange of practices and sharing the knowledge for historical buildings and facilities; investigations for identification of the potential of these structures. All these activities will provide the new innovative reuse of the Historical Heritage and in the same time will provide its preservation and safety. These activities are related to the development of new cultural products, construction industry, tourism etc.

2. Specific problems in preservation of Historical Heritage in Bulgaria

The protection of the Historical Heritage is related to many structural problems in general. The biggest part of the historical buildings and facilities was built essentially following empirical rules and usually has not specially designed structure for seismic action. In the same time the authenticity is necessary to be preserved for the future generations. Very often the best techniques for the mitigation of the seismic risk are in conflict with the preservation of the cultural value of the building or the bridge. The Heritage Buildings and facilities are an important link between the present time and history. They reflect the social, cultural and economic experiences of the past. They are damaged or have collapsed because of the interior factors such as their ground features and location, and the exterior factors such as earthquakes, other natural disasters and accidents. For this reason, it is very important to protect them by taking measures from structural aspect to ensure their sustainable durability and development. Regarding to this, first of all, the determining the reasons for the damages and analysing the structure of the Historical Heritage have to be done. The applied Rehabilitation and Strengthening should be determined respecting the results to the integrity and authenticity of the cultural and historic heritage buildings and facilities.

Rehabilitation and Strengthening of cultural and historic heritage buildings and facilities plays an important role in sustainability policies, mainly due to its role in: the documentation of ancient knowledge, practice and culture, among others, which could be used on actual source of improvement; the reuse of existing structures, frequently made of sustainable building materials like masonry and wood; the promotion of cultural and historic values and valorisation, which produce positive impacts both in economy and

society; promotion of job creation, due to the very specific and labour-intensive techniques required.

As well known, several countries and many cities in the southern part of Europe, namely the Mediterranean and Balkan area, are greatly exposed to seismic hazard, which causes its large and valuable building heritage to be strongly at risk of severe damage or even destruction due to earthquake occurrences. This problem mostly stands for historical and monumental constructions, due to the fact that most of them frequently lack basic anti-seismic features and / or were never fitted with adequate provisions against earthquake actions. Earthquakes are one of the most serious causes of degradation and destruction of historical buildings and facilities. An earthquake protection of Historical Heritage is needed in all countries with seismic activity on their territory. These problems are decisive in the design of the Bulgarian Historical Heritage.



Fig. 5. Bulgarian Historical Heritage

Within the technical field of seismic rehabilitation, two aspects are receiving an increasing attention by engineers and researchers, namely [4]:

- preservation of 'structural integrity' of existing historical buildings and facilities under severe or exceptional seismic actions;
- improvement of seismic performance by means of 'reversible mixed technologies'.

Cultural value is preserved when sustainable development principles are followed. This implies preservation of building's and bridge's features, substance and appearance as well as its relation to the overall appearance of the location and surrounding landscape. As a consequence, any intervention on a building or bridge needs to be economical, must respect the environment and resources and be socially and culturally compatible when considering current needs and requirements. The challenge for a structural engineer is to demonstrate that the real load-carrying capacity of the structure is sufficient for

contemporary needs and that only minor interventions are necessary to re-establish and/or improve durability. In [2] two problems related to bridges with cultural value are presented for discussion, but we can apply them for Historical Heritage in general:

1) Does the original character – the structural form, structural details and surface colour and texture – need to be preserved?

2) Shall the bridge's (building's) appearance be intentionally modified by the intervention? In other words, will the intervention be visible?

Three important preservation principles should be kept in mind when undertaking seismic retrofit projects:

• Historic materials should be preserved and retained to the greatest extent possible and not replaced wholesale in the process of seismic strengthening;

• New seismic retrofit systems, whether hidden or exposed, should respect the character and integrity of the historic building and be visually compatible with it in design;

• Seismic work should be "reversible" to the greatest extent possible to allow removal for future use of improved systems and traditional repair of remaining historic materials.

It takes a multi-disciplined team to plan and to execute the project for Historical Heritage (Fig.6).

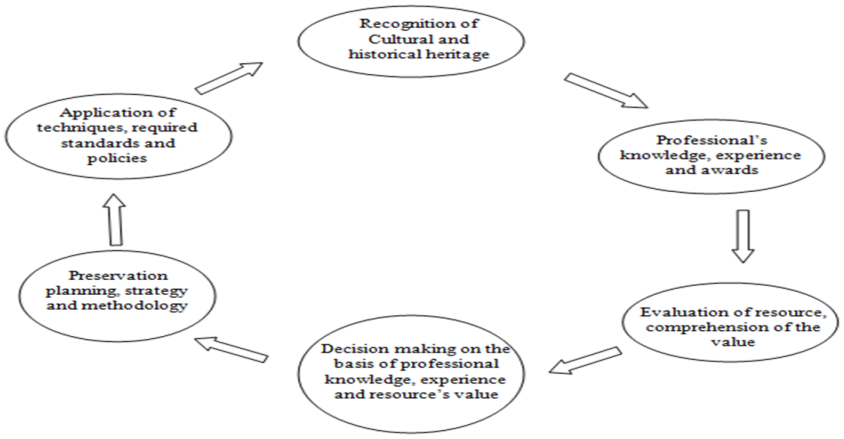


Fig. 6. Stages in planning of project for Historical Heritage [6]

The Bulgarian Historical Heritage (Fig.5) needs special care and new approach in the process of adaptation and preservation. Bulgaria has a very big diversity of Historical Buildings and bridges, mainly timber structures, stone, adobe and brick masonry structures. The existing regulations do not take specific care for this group of buildings and facilities. New contemporary standards are necessary to be provided. To prevent further loss of cultural value, structural engineers, owners, preservation authorities and the public need to be encouraged and empowered to give adequate esteem and importance to Historical buildings and facilities. Special studies and investigations on old construction materials and technologies are required for the good understanding of the behaviour of the existing structures. Of course, the application of innovative materials and techniques should be encouraged.

The Bulgarian Historical Heritage is the core of the national identity. The preservation and the adaptation of these buildings and facilities is one way for revitalization and future development of many regions in our country and one excellent possibility to stop the depopulation and the loss of the cultural diversity.

3. Conclusions

1) Construction History is an inspiration for the new design solutions and creates the possibility to exchange good construction practices: learn from the past, think for the future.

2) While during traditional Rehabilitation and Strengthening various approaches could be used, the limitation of the high statute of the considered type of buildings and facilities is decisive for the overall approach.

2) Extending service life means not only giving value to the building and bridges themselves, but also appreciating the identity of the engineers and the art of structural engineering.

3) In principle, the basic concept of an intervention should be evident and understandable. The original character should be preserved in rehabilitation interventions. In modification interventions, however, the appearance of the structure may change according to the needs.

4) Historical Heritage with high cultural value and aesthetic quality deserve respectful treatment and construction interventions must balance these assets with the severe requirements of utilisation.

5) A change of paradigm is needed in the structural engineering community to clearly distinguish between codes for new and existing and historical structures.

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LATEROMAN STONE BRIDGES WITH NEEDLEPOINT VAULTS– ORIGIN AND AREA OF SPREADIND THE CONSTRUCTIVE TYPOLOGY

Nikolay Tuleshkov[1]

Scientific Center for Architecture, Construction, Urbanization and Design
Scientific Institute of Architecture, Construction and Urbanization

Abstract: *In the article for the first time, from the known in the scientific literature information, is considered a complex issue for the emergence and spread of the peaked vault in the architectural practice of the Roman Empire. It is proved that in the base stand megalithic and later stone-square false peaked arches from Mesopotamia, developed by Assyria and subsequently implemented by the Syrian craftsmen in the construction practice of the Roman Empire. This is done in Anatolia territories during III-VI century, but then appear and some realizations in Southeastern Europe, i.e. Balkans. The study is based on analysis of established by author 15 bridges, 6 Aqueduct and several other late ancient buildings with peaked vault, all with varying degrees of preservation of the original structures.*

Key words: *peaked arches, bridges, ancient architecture, Assyrian, Roman Empire, Anatolia*

One of the questions in the area of architectural history, that has still evoked not less different opinions and even sometimes accompanied with a lot of unjustified suggestions, is according establishment on the ways of appearing the needlepoint vault constructions in the architecture of the ancient world.

But in contrary researches dealing more detailed are not too many and may be this is the reason to be used a few cliches, the most used claims, that it is Islamic import in Eropian architecture. There is no lack of more specific suggestions talking about Roman origin, but in most of the cases with additional opinion for Iranian, or not localized Mesopotamian influence on it. The early historians of architecture like Havel [2] and Rivera [3], in the beginning of the last century even suggest like a territory of its appearance Buddhist temples from VII century in India. But the ideas with this have not finished. Almost in the same time Skot vitally would think for inventing the needlepoint arch, like a lyric invention from the palm leaves. [4] Fletcher, a little bit earlier (somehow corectly) will show,that in Islamic architecture needlepoint vaults and arches would invade Europe through Iran, where are accepted after joining Syria [5], but without giving a real image of reality, that it would be a bit of later secondary movement to ideas. More categorical nowadays is John Warren, who claims that its appearance in Persia is long ago the existence of Assyrian. [6] Even though this phenomenon temporary dating from centuries later, the direction of his thought is somehow correct, especially according to the historical fact, that the territory of Iran have been for a long time part of Assyria and there for the first time penetrate leading constructional ideas of Assyrians, undoubtedly together

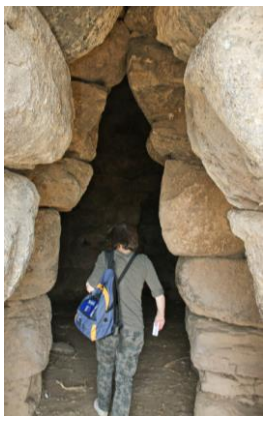
[1] Arch. Nikolay Tuleshkov, Academik, PhD/Proff. The Bulgarian Academy of Sciences and Arts (BASA)

with them, coming builders. And after that, if we could pay attention on the famous sign for construction of Darius palace in Suza (after 492 AD), according which the builders are Syrians, Ionians, Midians, Egiptians and Sardinians (Greeks Minor Asians from Sardo-Sardinia), as well as recognized like skillful masters in treatment and construction with stone, would be seen, that this movement of masters towards Iran is traditional during the whole I millennium BC. From various sources, as well as from the style features of construction and building and mosaic decorations, is known participation of Syrians in building another Ahamenidians, and later Iranians palaces, temples and other structures. Definitely Syrians together with Middleasians and Persian masters, stand in the base of creating of Islamic architecture in the time of early Arabian caliphate. According the style features they are those, that rise up The Big Mosque (705–715) in Damascus and the palace Amra (Quasayr Amra, 712–715), where we can find the earliest Islamic needlepoint arches.

Due to present research, I am trying to clear, or to fullfill those ideas from accumulated mistakes during the last century, using comparative analysis, historical documents and results from archeological researches in the area of spreading needlepoint arch from II millennium BC, till VI century AD.

Actually appearance of needlepoint vault constructions is based in megalith building from II millennium BC, and it is possible, this to be happened, earlier. We discover it for the first time in few preserved primitive Mycenae bridges from Peloponnese, dating at the moment XII – XI century BC. This type megalith constructions are carried due to Phoenician - Greek colonies in Sardinia, in the same period of time, but in XI – X century BC they are already built with partly stone adjusting. Obviously due to constructions of megalith Nuraghes, here is upgraded bricklaying skills, till level, that would allow centuries later to export masters back to Minor Asia.





Mycenaean Petrogefiri (XIII – XII BC), near the village Arkadiko Argolos, Peloponnese, Greece

The entrance of Tholos nurages „Santa Sabina" (XII – X BC), Sardinia, Italy

Availability of modern and even more architecturally bricked gates from Hittite kingdom and Assyria, has no doubt, that if there is no logical constructive coincidence by chance, so that this typology has its own beginning, rather in Northern part of Minor Asia. Unfortunately that types of bridges in these lands were not survived, with the exception of one from Hittite capital Hattusha, so that it must be shown, that the construction is not that clear, because we know it only by its remains of the bases. At the expense of that from images on stone Assyrian reliefs and archeological discovered fortress gates from Assyria and Hittite kingdom, is getting clear that needlepoint arch is known to early Northern – Mesopotamian cultures at least during II century AD. Namely here, appearance of needlepoint faulse vault constructions in this point and bridges, is established in early brick

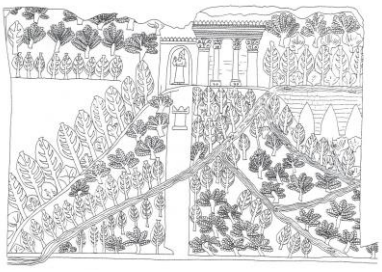
and megalith stone, dating from II century BC, and after that completely stone full fill realizations during IX – VII century BC.

Undoubtedly these new, already non megalith needlepoint constructions are appeared like architecturally worth image, based on the logic of primitive cyclopean constructions from large river stones, accumulated in bidder rows from the loop of elongated in the vertical because of static resistance, false vaults. So that the new stone realizations are made up with similar in configurations elongated loops to same needlepoint false arches, but already due to modelling of their adjacent sheets from used for the building rectangular stone blocks, through cutting along the curve of the holes.

The earliest of these false vault constructions for now are established in the ruins of Nippur, Ur, Tello, Nineveh, Nimrud and other ancient Mesopotamian cities, in the brick temple and castle constructions from the period 2100 – 1200 BC, but mostly from the second half of II century BC.

More later stone – kvadra false vault constructions continue to develop from assyrians even in early centuries from I millennium BC. This the time of huge bridge building among the territories of Assyrian empire, accompanying building the developed road structure and huge water supply systems.

In Assyrian relief shown in the literature for originating of Dur – Sharrukin (today Khorsabad, next to Mosul, Iraq), but registered in British Museum, where is preserved, as delivered from Northern Palace in Nineveh (today Koyundzhuk, Turkey), are featured constructions of king Sargon II (Assyrian Sarru - ukin, around 721 – 705 BC), from the period after 721 BC, when the Assyrian ruler has created the new capital Dur – Sharrukin, his palace composition. On the image is seen and stone – kvadra aqueduct with false needlepoint arches stepped on rather slender pillars. And really next to the city itself are digged archeological parts from the mighty bridge construction from huge tooled kvadras, with row of false needlepoint arches, that undoubtedly are ruins from the same one aqueduct. Partly in the literature about this topic are described as remains of bridge, dating from 717 – 705 BC, connecting the palace of the ruler with the temple of Naboo. But this temple exists featured in the relief, too like neighbor of the aqueduct, that is shown definitely as watering the garden infront of it, so that the thesis remains contentios. But wheather it is an aqueduct or a bridge, in the case, where is researched architectonics of arches prebridge constructions from the age, it is without any matter.

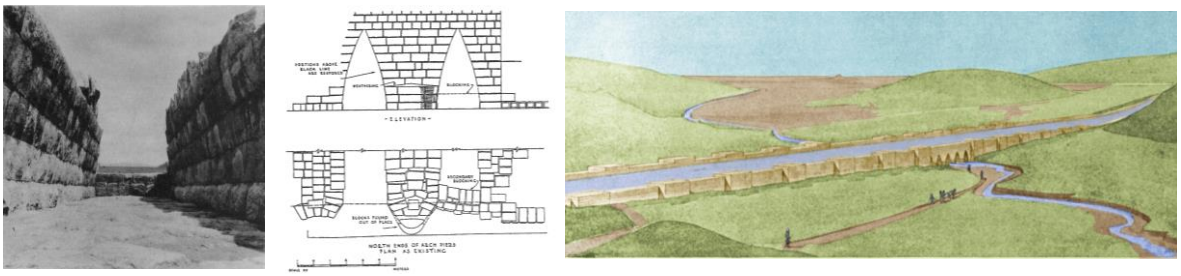

False vault from Ziggurat of Ur (around 2000 BC), Minor Asia, Iraq
Aqueduct on Dur-Sharukin (around 717 – 705 BC) in stone Assyrian relief from the palace of Sargon II. Khorsabad near Mosul, Iraq
Ruins of false vault from the aqueduct on Dur-Sharukin

Remains of another discovered in archeological manner, construction with false needlepoint arches, issued to overcome the bank of the river Khsor infront of „Park gate" of Nineveh, obviously is undoubtedly bridge, because it lies on the trace of the king military road of Saneharib, dating around 690 BC.

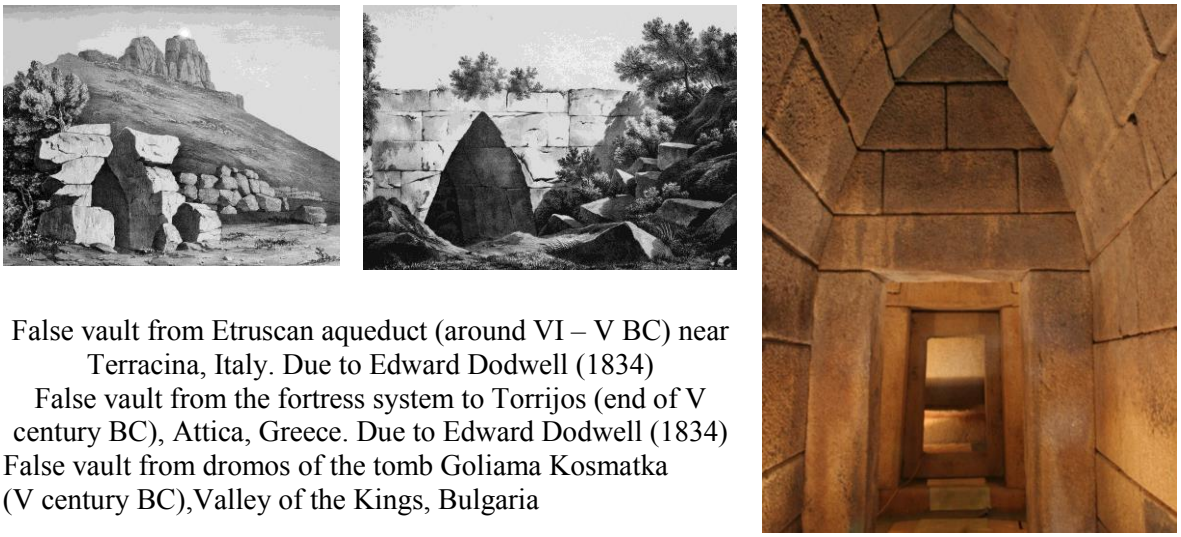
In the ruins is discovered the biggest preantique aqueduct next to today Jerwan (Iraq), supplying water for distant around 40 км from here Nineveh, akad. Ninwe (today

Koyundzhuk). It is built by king Sennachirim I (704 – 681), together with the palace, city walls with 15 big gates, infront of the main gate through the created systems of ditches, were laid short bridge crossings. The installation of aqueduct itself, has length of around 300 м, but asa well as Dur – Sharrukin, with five false Mycenae arches is built up only prebridged above mainstream of the river, that overcomes. Preserved free bridge resists, as well as the whole corpus of the construction are raised up with huge precision tooled kvadras, as well as tilts on configuration of the false arches, are received due to logged curves on the frontal sides to mainly horizontally mounted blocks. Width of the construction is (around 24 м) is significant, that means, this aqueduct has transported huge quantity of water.

On one sign, discovered in Bavian, is told wordy for this construction: „... At this time I have significantly increased Nineveh. Its walls and the outer wall around them, that has existed earlier times, I have built up again as high as mountains. Its area, because of lack of water is completely neglected and ... while his people, ignorant in artificial watering, turned eyes up to the sky for rain for watering; from the villages Massiti, Banbarina, Shapsharishu, Kar-Shamash-Nasir, Kar-Nuri, Rimussa-Hamma, Dhalain, Resch, Eni, Sulu, Dur, Shibaniba, Isparrira, Gingilinish, Nampa-Porta, Tilli, Ahumsusi; and the water you have got is above the town of Hadabiti (axcept) with eighteen canals, that I have digged; and pointed on their apron river Khosser. From the border of town Kissiri up to the center of Nineveh I have digged a canal and these waters I have obeyed to flow in it. And I have named the canal Senahirim after my name." [7]



Ruins from aqueduct in Nineveh (around 704 – 681 BC) near Jerwan, Iraq (photo 1935)
Recoveries of aqueduct near Jerwan and on a fragment from the arcade with bulbous in Jacobsen and Lloyd (1935)



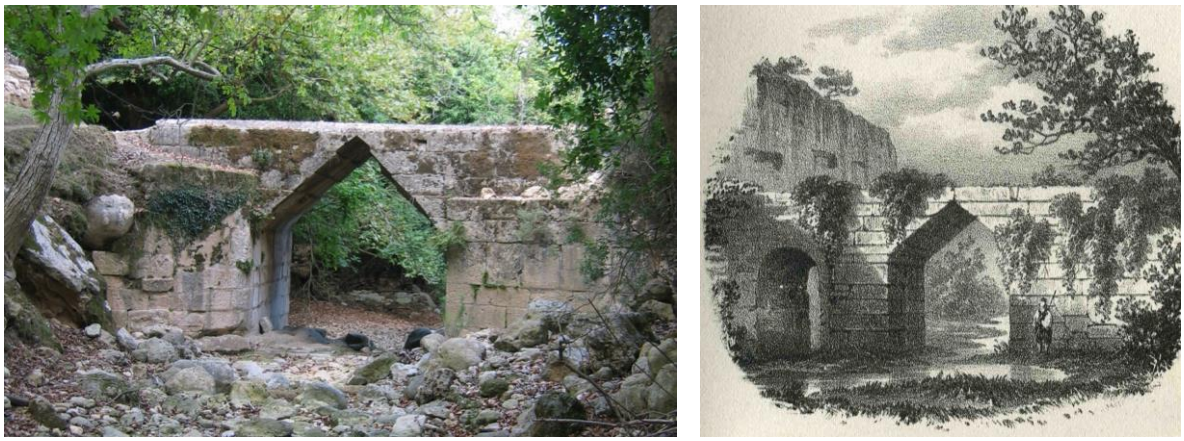
False vault from Etruscan aqueduct (around VI – V BC) near Terracina, Italy. Due to Edward Dodwell (1834)
False vault from the fortress system to Torrijos (end of V century BC), Attica, Greece. Due to Edward Dodwell (1834)
False vault from dromos of the tomb Goliama Kosmatka (V century BC),Valley of the Kings, Bulgaria

All Assyrian bridge constructions built up after X – IX AD are built only by accurate tooled large-format stone. According Shuazi this new stone tooled technique has its beginning in Mesopotamia during the Iron Age, when, he thinks are appeared strong tools

affording realization of this production. [8] Due to his opinion again, sample for transition up to new technique represents a kind of cyclopean masonry with horizontal leveling adjusting of stonesthrough every two rows, that, as it is shown, is appearing in Sardis tombs in Lydia and Lycia. [9]

With bricklaying processed, but still variousformat huge stones are constructed and few are preserved or are known from old engravings needlepoint false vault constructions from VI – Vcentury BC in ancient Etruria.

False needlepoint vault constructions made by stone kvadras countinue to be used in Minor Asia and during Hellenistic period, where they have gone to the Balkan Peninsula in ancient Tracia and Peloponnese (VI – IVcentury BC), and a little bit earlier on Crete. Namely from here are known two bridges with needelepoint vaults dating to IV – III century BC, one of them is destroyed at the end of XIX century, but it is known precision engraving from Thomas Abel Brimage Spratt (1851-1853).



Bridges near Euterna, Crete (IV–III century BC). Views from exsisting and from ruined in engraving of Thomas Spratt (1851 – 1853)

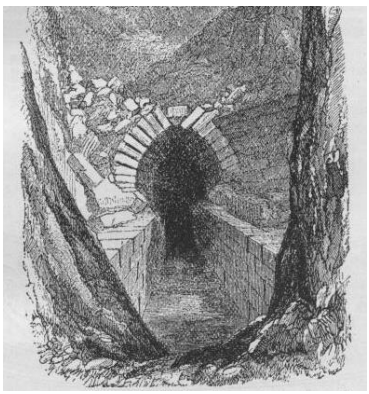
One early realization of false needlepoint we discover in one brick reconstruction of roman bath from vault II – III century in antique Phaselis, near the sea resort Kemer, province Antalya- Tekirova in minorasia Turkey. The most interesting is that it is written in higher, again needlepoint, but already false arch, that is earlier. Both are dating probably from IV – VI century.

It is necessary to be underlined, that in parallel with the false vaults in Mesopotamia and mostly among the territories of Assyrian empire, X century BC are built and buildings with real vault constructions, as well as needlepoint, and semi-cylindrical. Built up in the beginning with bricks in II century BC, lately, already during the next millennium for this purpose will be used stone elements, including and with trapeze facades. There are known such realizations from Nippur, Tello, Nineveh, the oldest of them usually are dating to 2100 – 2000 year BC, but archeological stratigraphy, clears that actually they are from newer upgradings mainly from XIII – XII, or even VIII – VII century BC. Such is the case with temple complex of Enlil (Bell) in Nipur, where are found 7 following upgradings, one on the another. Sir Austen Henry Layard, fo example, has digged up rather well preserved needlepoint vault from the northern palace (IX century BC) of Nimrud (near Mosul, Iraq) in northeren Mesopotamia. During the next centuries this type vault would continue to be used alongside with semi-cylindrical one, that in contrary, would start replacing it, changing thatway into main, so that during Hellenistic and followed it Roman period, would prove as the most mass construction.

In order to outline the whole picture of spreading of needlepoint vaults, that in many ways seems to be advocated mainly during late roman antiquity early Byzantium, in the







False arch inscribed in older needlepointed Arch (III – VI century), from Roman bath of Phaselis (II – III century) up to Kemer, Minor Asia, Turkey
Needlepointed arch from the complex in the temple of Bell (II – I millennium BC) in Nipur, Mesopotamia. Photo John Hainess (1892 – 1893)
Needlepointed arch from the north-east palace of Nimrud (IX century BC). Visual drawings from Austin Layard (1849)

author's work are discussed by me 15 bridges, 6 aqueducts and few more adjacent constructions from Minor Asia (Turkey, Syria, Israel, Palestina), as well as at one bridge installation from Crete and Eastern Europe (Constantinople and Bosnia). And due to their datings very clear is outlined period of application in the frames of IV – VI century. Meaning, the time of the emperor Constantine I the Great, till emperor Justinian I the Great.

According the availability of needlepoint vaults in bridge building during the Roman period of Eastern Roman territories, it seems till nowadays, mass in the literature, is shown only Karamagara Kyopryusu (Karamağara Köprüsü) above the flow of Euphrates river Arapdzhir, near Elazig in Cappadocia, minorasian Turkey, dating towards V – VI century. Its dating is well-founded still from Cyril Mango in 1976 year, through palaeographical analysis on preserved greek sign on the vault, using a quote from the Bible: „ Lord God preserves your going in and out nine and prisno, ever and forever, amin,amin,amin" („Κύριος ὁ Θεὸς φυλ(ά) ξει τὴν εἰσοδ(όν) σου κε τὴν ἐ(ξ) οδόν σου ἀπὸ τοῦ νῦν καὶ ἕως τοῦ αἰῶνος, ἀμὴ(ν), ἀμ(ὴν), a(μὴν)"). [10]

It was built on the trace of Roman road towards Malatia (latin Melitene, ancient greek Μελιτηνή), in order to be protected from collaps from hanging over it black cliff swath, the last one is cutted appropriately in hight of 75 м. That gives its name Karamagara, meaning Black cave. It is one-arch, with the length of 29,95м, as its vault is wide around 17 м and approhimately same is the common hight from the highest point of the road lane till the level of the water. Needlepointing up on the top of the vault is killed by slight curving, something wellknown to us from the false arch on the Lion Gate (XII century BC) from Hattusha and a few Assyriano. As well as for the vault of the bridge, and for facade surfaces are used huge face kvadras connected between with iron gaps flooded with lead and forming the sheets of a corpus filled with Roman concrete.

Unfortunately in 1975 year this bridge is submerged in the cup of dam Keban, [11] something that would have happened a few dacades later with the other from these unique minorasian bridges – Akkyopryu, above the river Dalaman in Koichegiz.

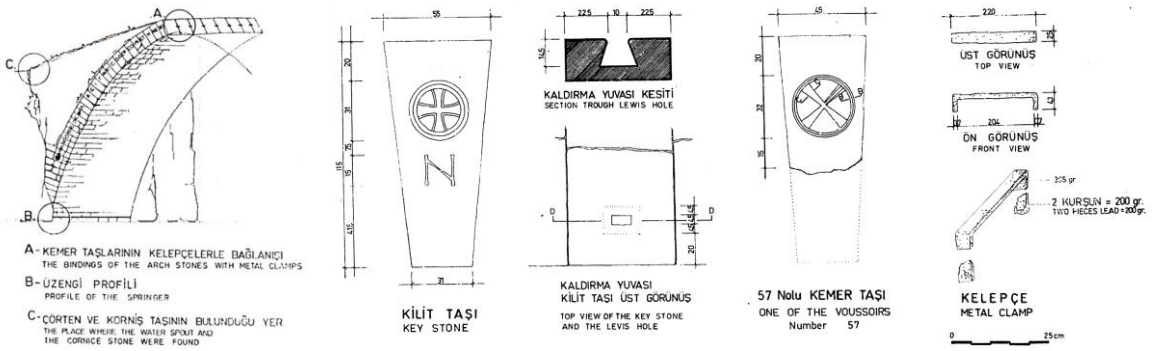
Near Akkyopryu the most interesting is that the main vault construction, dating to V – VI century and again with needlepoint up to the top form, is built with bricks. Actually in this case as the big main arch, as the secondary lie on older bases, probabaly from a bridge dating not lately than I – II century. This primary construction owe two rows of impost, on that during the building stepped shuttering forms – lower from gigantic kvadras and upper

slimmer. There are remains from recuperative the banks, supportive walls with the same structure.





Bridge Karamagara (V – VI century) above the river Arapgir, Cappadocia, Minor Asia, Turkey
Details from the bridge Karamagara in Ahmed Chulpan (1975)



The main brick arch is built up with the help of scaffolding connected with its two sheets already in holes, that is another from the main bridgebuilt systems in antique Roma, for installation of scaffolding carrying vault shutterings. Vaulting is realized in the typical Assyrian double row method, for constructive insurance against fission of the zenith. The system that is revealing and from European territories of the empire, like brought from working there minorasians.







Akkyopryu (VI century on bases from I – II century) above river Dalman, in Koichegiz, Minor Asia, Turkey
Bridge Geshar Naharaiim (Jasr el-Madgami, VI century), above river Jordan. Golan Heights, Izrael
Bridge Zakho (also Delal, or Al-Abbasi, IV – VI century) above the river Little Khabur, Kurdistan, Iraq

Interesting in its architectonics bridge is with needlepoint central arch is survived above river Jordan, on the road from Damascus towards the ancient city of Beit-Shean (ancient greek Σκυθόπολις, latin Scythopolis) during Goland Heights of today Izrael. Actually the biggest bloom, this city has had during Emperor period, as well as the first huge constructions are realized during the time of Pax Romana (27 years BC – 180 year), but mostly in I and II century. The bridge known as its Juwish and Arabian name Gesher Naharayim and Jisr el-Majami', is situated in the valley of Skitopolis, around the middle of the road to Dekopolis (Decapolis), next to today kibbutz Gesher (Kibbutz Gesher), name,that in Hebrew means Bridge. Kibbutz is created near middleage mamelyuk roadside inn, known today like Old Gesher, or in Arabian Al-Majami (Al-Majami), that means „Bridge of meeting". It is completely possible this inn to inherited a Roman mansio, destroyed not earlier than devastating earthquake in Golan, where is destroyed and the bridge near. But from the whole Middle age are suggested repairs only from the time of crusaders (XI – XII century) and Mamelyuks (XIV century). In 1837 year during strong earthquake the bridge has had another demages, that later are removed, while its neigbour inn is semi destroyd and abandoned. Even though it is with very well lined features. It owes typical broken in plan configaration, with icreased resistance on natural cataclysms, shuttering compost fortified beneath with consoles, tipical Syrian differentformat kvadras of vault, some of them are formed like triangular teeth, allowing better cohesion with horizontal rows of face kvadras and from the facades in the common bridge corpus. From all early stone bridges with needlepoint vaults, only in it the face arch is solved like two step feature, but not in the spirit of later typology with shallow two step feature, received with bidding of the face lining from corpus in front of frontal surface in the arch shuttering, and by using of double vault where the second, upper kvadra layer from the vault is bidding considerably above lower inner. Here like stepping of shutterings is applied the Roman manner for combination of impost with its edditional jackig beneath and with console.

Another way for installation of shutterings carrying kvadras in the vaults is applied in Roman bridge Al-Abassi (yet in Kurdish Pira Delal) in Zakho, meanwhile in most of the simplified Syrian vault constructions. Not coincidentally the bridge Gesher Naharaym is called and Syrian bridge. Typical for it, is archaic vault of the top of the arch, even though, a little bit more from this side of the bridge Karamagara, and so that we suppose to pay attention, that this could be due to a later repair, where the hight of the bridge, in this highest point, is a little bit diminished.





Bridge Erimedon above river Aspendos (IV century, rebuilt V – VII century and XIII century), near Kyopryupazar, Minor Asia, Turkey
Bridge Hovi Kamuriia (Turkish Chobandere, kurd. Parsiniie, VI–VII century), near Kyopryukyoi (arm.Daroink), Minor Asia, Turkey

Bridge with interesting history is preserved in Kyopryupazar on the road to antique town Aspendos, Minorasia Turkey. It is known as Eyrimedon kyopryusyu, meaning the bridge above Eyrimedon. It is accepted that, in its today image is seldzhuk from the time of sultan Aladin Keykubat I (1219 – 1237) [12], but built up on the bases of Roman from IV century, demolished in big earthquake in this region in 363 year. This is justified with

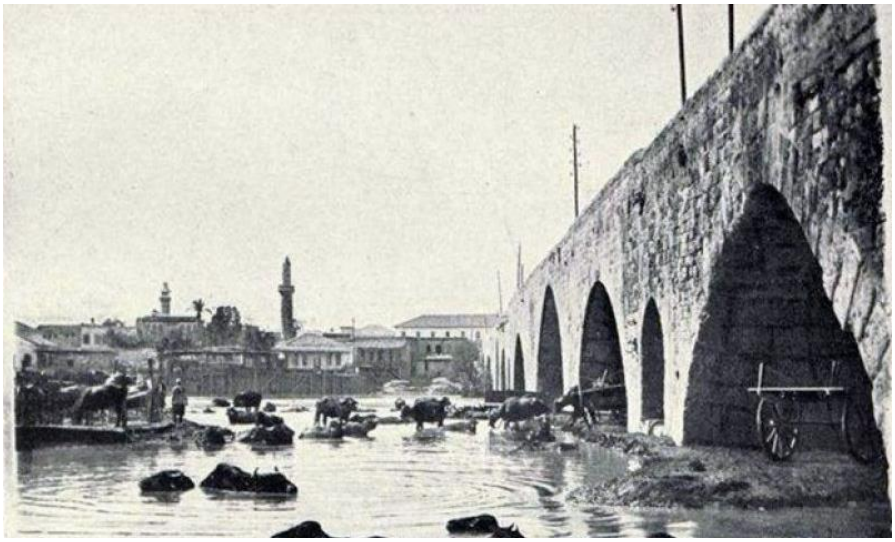
established presence of reused material, from the near aqueduct in the antique town, demolished during the same earthquake. [13] Klaus Greve with his team has created serious computer reconstructive research, according which they have reached the conclusion, that in this reconstruction the bridge has become narrower and lower, so that except the bases and part from antique concrete from the roman period, nothing else has left. At the end is shown, that except Arabian sign from seldzhuk construction, there was and greek on „few stones" used as spoletos. [14] But if we could analyze the exsisting architectonics of the construction,we could see rather clear differences between formorganising and technology of construction in vaults, that all are needlepointed,but with different configurations – from rather closer to semicylindrical in both banks, to obviously needlepointed in the midstream of the river. All of them have in their heels symmetric positioned roman shuttering holes, which unambiguously pointed us towards the thought, that narrowing and accompanied lowing the bridge has happened after the reconstruction of the last earthquake, but not in that, during the time of seldzhuks, when such holes have not been done. Interesting for our research is the second in the order vault hole from the left bank, where there is one more higher positioned row of shuterring holes, and its vaulting is two rowed, meaning typical minorasia-roman elements. So that it undoubtedly must be accepted like the only according to whole preserving remain, from reconstructed as narrower and lower bridge, probably from the period V – VII century, and with needlepointed vault holes, while the left of its parts are dated from later repairs, in this point and from seldzhuk century.

Similar is the fate of another big multivault bridge from the region of same Minorasia Turkish town Kyopryukyoi, Erzurums. Buit up the river Aras, it is known to onetime local Armenian population with the name Hovvi kamuriia, as well as with later Turkish Chobandede kyopryusyu and Kurdish pira Parsiniie. It is shown to built up in 1297/8 year, meaning during the third rulling of Seldzhuk sultan Gyuaseddin Masud II (1294–1301). In armenian historiography its general appearance is searched to VII – VII century, and one, already destroyed sign, read in 1865 year from the Armenian priest Timeteos, announced that „..this bridge built up from Armenian princes, I the master (abbot) of the monastery „St,Mary" of the city of Daroink (today Kyopryukyoi) has repaired in в 1160 year". [15] So and here, obviously, there is late antique, or early-middleage bridge, but in this case it has been had more serious reconstruction at the end of XIII century. Probably from that time is dated and processing of undoubtedly ruined bulbouses, with stonetooled decoration in Byzantium tracery in its Armenian stonetooled perusal. It is possible, even if earlier,it seems in already existing shuterring holes, are laid profiled consoles. It is visible, that the new layings of bulbouses are touched on fugue to the bridge corpus. And architectonics of the needlepointed vault construction guesses, that it is work, undoubtedly of Armenian masters.

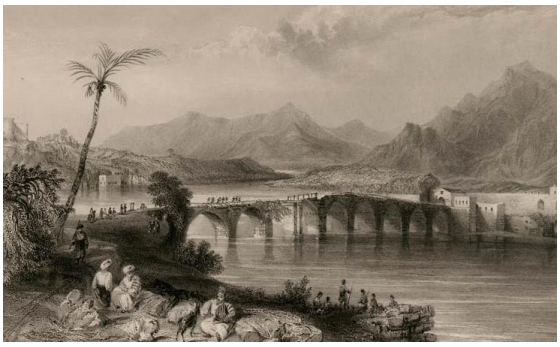


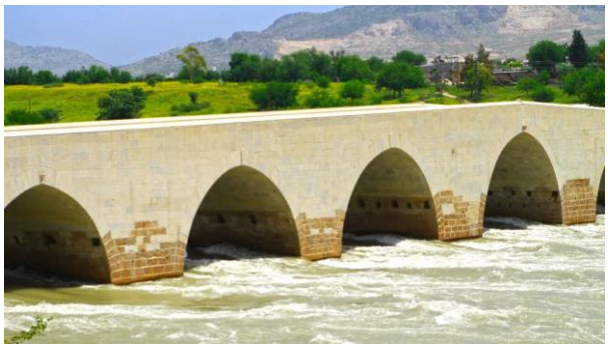


Mill bridge (III – V century) above river Ceyhan (antique Pyramus) near village Kazultahta, Adana, Minor Asia, Turkey



Tashkyopryu (384 year, rebuilt VI century, 742 year, 840 year) above river Ceyhan (antique Pyramus) in Adana. Photo 1911 year.





Bridge above river Djeihan in Misis (350 – 361 year and VI century), near Adana, Kilikia, Minor Asia, Turkey. Views in engraving of Henry Bartlet (1836 – 1838) and today after restauration

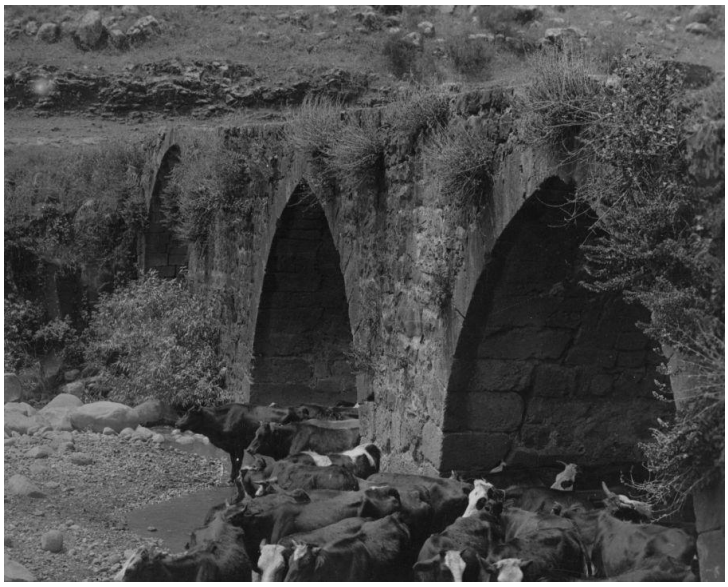
During VI – VII century on older bases, probably from III – IV century, is rebuilt Kurt kyopryusyu (also Mihrapli, or Vizier kyopryusyu), near the village Kajabash in the area of Samsung. Preserved in different hight stone lower parts from the original arches, as well as places with remains of face kvadras, match with configuration of new vaults, that are needlepointed. This means, that the baseones were the same. Dating of the second bridge till this moment, is in XIII – XIV century, as well as, are made efforts to be claimed for seldzhuk,even a bit evasively, to be suggested „Byzantium builders". [16] Motivation is connected, mostly, with the existance of three row bridge girdles from its building system, which in this case is Opus mixtum, so it is claimed that, they are typical for this period.

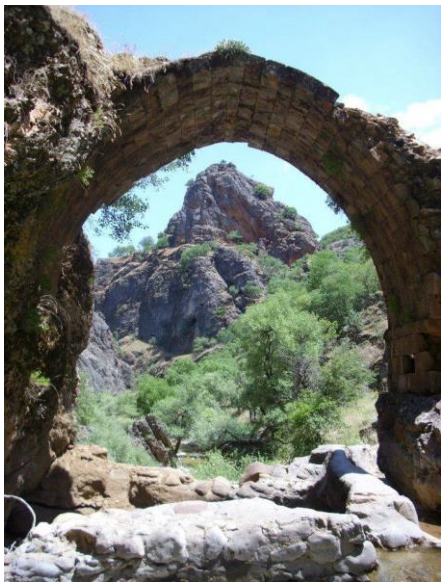




Late antique mills (IV – VI century) from Misis and from Caesareia Martima, Palestina, Izrael

Which is not true, because we know similar realisations from IV – VI century, for example quadriburgius Kastra Martis (today Kula, Bulgaria) built up completely with three row brick girdles,or the fortress wall of Mesambria (today Nesebar, Bulgaria), where the same way like in Kurt Kyopryusu, are fact three or four rows in Opus lateritium. So that, it is absolutely possible and the dating up to time of big restorative constructions on Justinian I Great (527 – 565). Even more, in new middleaged constructions in late Byzantium, Seldzhuk sultanate and Karaman, mitigation holes are disappearing, replaced by high strong short horns and small arches in the periphery. As indeed, that times were not practiced and shuterring holes and consoles, and only in few cases like unbearing decorated element are performed slim profiled impost.





Bridge above Al-Hasbany (IV–V century) on the road Palestina-Damascus, Lybia. Photo 1912 year
Kemer kyopryusu (IV – VI century), above river Pyulyumyur, near village Rabat Koyunyun, Minor Asia, Turkey

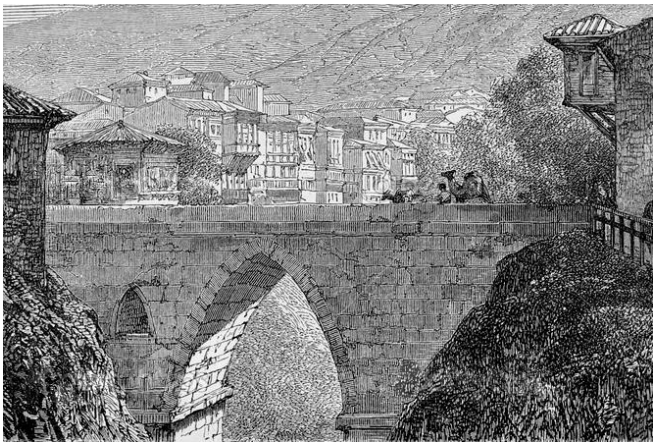
Interesting late-roman utilitarian building is preserved in the high ruins near Kuzhultahta in Adana (Kilicia Antioch, Ἀντιόχεια τῆς Κιλικίας). This is a massive mill above river Ceihan (ancient Piramus), connected due to a bridge and thatswhy is known like Mill bridge (Akdeğirmen köprüsü). The construction of the face surfaces is stone-kvadra, as well as, not only the bridge has needlepointed arches and a part of vault breakthroughs under the mill corpus itself. Dating up to III century, but I have the feeling, that is later.

In the region of Adana there are and another roman needlepointed vault constructions , and seems,that some of needlepointed arches on the big bridge in the city (Taşköprü), positioned near a few survival mitigation holes, dating from late antique, probably from the repairs in the time of Justinian I Great.

With needlepointed vaults is nine-arched bridge, built up also, above river Ceihan in the near city Missis (ancient Mopsuestia). It is created in the time of emperor Konstancii II (350 – 361), but according to Prokopii opinion is rebuild in the time of Justinian I Great. In the beginning of XIX century are survived five from original needlepointed arches. According engraving of William Bartlett, published in 1836 year as an illustration in work of William Henry, they are rather tall and in the heels of arches, are seen a rows of shuterring holes. Today in the process of rebuilding the bridge on the preserved bases, together with lower parts from the vaults, these holes are still there. This bridge has no mitigation holes, that probably means, during its rebuilding in VI century, are used survival

bases of the primary one in the middle of IV century, when in Minor Asia very often were built without such breakthroughs.

In the region, in high ruins are preserved and other late antique vaults. That type are for example, water mills in Misis near the bridge, on the bank of antique city. There are remains of the them, some of fencing walls and undervault bracing arches with needelepoint form. Dating up to II – III century, but more possible is, to be from the time of building the bridge during the second half of IV век, or a little later. Completely similar in structure roman ruins with needlepoint arches, are preserved and from the big antique seaside town Caesarea Maritima, Izrael.





Bridge Setbashi (V–VI century) in Bursa. Engraving of W. Crames (1860)
Aqueduct above river Ibrachim (antique Adonis, III – Vcentury) on the road Beirut – Tripoli

Few bridges on the trace of the road from Palestina towards Damascus, trom the territory of ancient Syria, or today Lebanon, that are with needlepoint vaults, have got their origin in the period IV – VI century. Unfortunately, the most significant of them Abu Wadee, built up above the river Al-Hasbani near Hosbaiyya, wasdestroyed during military actions in 2006 year. On its earliest photos dating from the beginning of XX century, is seen three arch structure, but the third, the biggest one, unlike other two, that are needlepointed, is semicylindrical and is shorter supplement for the antique tworowed corpus, probably dating from IV – VI century. It is built with large-sized kvadras, like the ones dismounted from the walls in the corpus in the zone of supplemental breakthrough, are reused in its vault.

There are preserved and few small onearch bridges with needlepointed vaults. That type, for example is still preserved, even in semi ruined form Kemer kyopryusu near village Rabat Kyonun, county of Tunceli in area Erzurum, Minor Asia, Turkey. It is built up in the trace of ancient caravan road, near the antique castle, known as Rabat kalesi, that is definied it and as long survived road station. It is built with asymmetric stepping, so that the one puncheon beds on lower bank and so that, there is shuttering impost and a hole beneath it, while from the other side, it has relied on bleed cliffs under kvadra base.

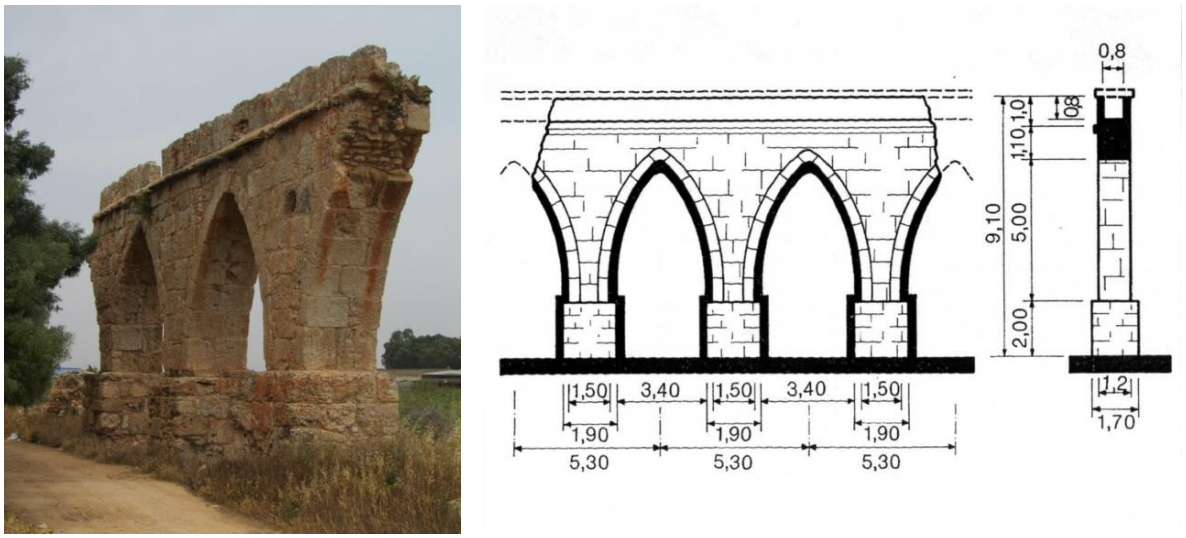
One engraving, published in 1860 year that depicts a part of Bursa (ancient Prusa, Προύσσα), includes, to the fore, high bridge, from that you can see one vault and mitigation hole for each. It was built up above Gyokdere with one – sized kvadras, like in the heels of vault, which is needlepoit, there are roman shuttering impost. Here and the mitigation hole is needlepoint. This antique bridge is known as Setbashi and only for it, there is no information for the time of its building (fact, that means, especially, for Ottoman empire, and in this case for Bursa, that it is older than XIVcentury), and only for repairs, the earliest of which is held in 1565 year. Attached bridge building technics, definitely is late roman.



Aqueducts near Kaizeri (IV–VI century) in today condition and near Izmir (V–VI century) in a record photo from the beginning of XX century

Mainly among the same northern territories of minor Asia are built and aqueducts with needlepoint arching. One of the arches is preserved of two belt aqueduct near Maronite village Nahr Ibrahim (antique Adonis) with precisely tooled face kvadras and filling from roman concrete. The arch, that is from the lower row, is with elegant form and steps on profiled shuttering impost. The breakthrough is sized due to the principles of „Golden ratio".

In more simplified built multiarch constructions, is noticed that the needlepointed, usually are built, only bigger prebridges from areas above rivers and deep gullies, probably because of the bigger constructive resistance of the form. Such are, for example, Korukyopru kemeri near Kaizeri and Pinarbashi above Tabakhane deresi near Aiden (antique Trales, Τραλλεῖς), area Aegean, and the both in Minorasia Turkey. Completely with needlepointed arches in two rows, one above the other, are built the both aqueducts in Mediterranean seaside town Izmir (antique Smyrna, Σμύρνη), so that a few were rebuilt up after destructions during Middle Ages, as well as semi cylindrical. They have passed above the river Yeşildere and are known as Kuzulchuru and Vezirkyopryu. The second of them, partly, is rebuilt during repairs in XVII century.



Aqueduct of Salamin (VI century, rebuilt in VII century), Crete. Views today and in architectural shooting of fragment in it.

The arches are built up with brick that in this case, is dating up to V – VI century.

Fine needlepoint arches has the aqueduct of the antique city Salamin on the island of Cyprus, built up during the time of emperor Neron (54 – 68) and basicly repaired in VI century and according the sign from stone plate from VII century. [17] The difference in

carved stone treatment of kvadras, from sockets in bases, in the left face construction, probably means, that the construction from VI – VII century steps on fundamentals of Neron aqueduct.

The most interesting fact is that, exept in Minor Asia, roman bridges and aqueducts with needlepointed vaults are built on Balkan Peninsula. It seems to happened firstly in Istanbul in IV – VI century. This is the time of significant social and religious constructions in the city, where still, from the time of Constantine I Great after 324 year, participated variety of masters from all over empire, but mostly from minor Asia. During this period are built and more of the aqueducts in city water supplied system, few of that are preserved in ruined, or rebuilt condition. And like in Minor Asia, and here, there are in parallel with cylindric vaults are fact and needlepointed. For example, such type is Aivat Kemeri near the neighborhood Gyotkyurk Merkez, built up with needlepointed vaults, for which building are used roman shuttering consoles released out in the heels of arches. Due to Minor Asia manner of building, accepted from Roma, the bases are fortified with pilasters, in this case sloping towards the main corpus, outside surfaces, the same way as the aqueduct of Valens.





Aqueduct Aivaz Kemeri (V – VI century) I neighbourhood Gyoktyurk, Istanbul
Aqueduct Kodja Kyopryu (VI century, rebuilt around 1152 year) above river Samia near Ferre, Aegean Thrace, Greece

The big needlepoint arch, like a part of aqueduct, prebridges river Samia near the greek city of Ferre, in Aegean Thrace. It is accepted, that the aqueduct is built up during the second half of XII century, for the needs of ,here built up, in 1152 year from emperor Isaac II Komnin (1057 – 1059), monastery. But the late antique type of forming, the arch and mostly presence, in the bases of roman shuttering holes, shows, that may be in XII century only was renovated. On the question where it has carried waters, the answer could be hidden in mentioned in monastery typikon created by Isaac Komnin, neighbor fortress that was built in order to protect the monastery.

It is interesting to mention, another image on the coin curved in the time of emperor Arkadius I between 383 and 388 year that is main city gate of Thessaloniki (Bulgarian Solun), in the shape of needlepointed arch, with the same minor Asia architectonics.

Obviously the spreading of needlepointed vault constructions on the Balkan Peninsula is continued on the west from the emperor capital. Example for this spreading is a bridge from the territory of today Bosnja and Hercegovina. It is one arch, not that big in sizes, preserved till today even in very bad condition, near village Klinchici, county Olovo, north-east from Saraevo. Built up above the small Orlia, it has shy river 8,50 м length, to 2,20 м width. Its vault construction is constructed from trapezoidal large kvadras with rather big size in the zone of fundaments and bases above them, as well as up to the needlepointed top, the arch gradually is getting thinerato. The interesting part is that, key stones and from the both facades are curved with wedge forming below, so that in it are

lined the tops of vault needlepointing. In the same time, the left Minor Asia bridges with needlepointed vaults in most of the case, have not key stones, and in its top is lined a vertical fugue between two finishing the each of side curve stones, or brick rows, as well as, it is in Akkyopryu. The corpus holding the vault of the bridge from village Klinchici has lost almost the whole face surface, but from one-two survived pieces, is still seen, that it was built like kvadra. On its place in later are made a few repairs with large and small river stones, that are used and for the filling of the original roman bridge. It is dating from II – III century, but I think, it could be and later.





Main gate of Thessaloniki, on the coin from the time of emperor Flavius Arcadius I
(between 383 and 388 year)
Bridge above the river Orlia (III – IV century)
near village Klinchici, Bosnia

The exsistance of transfer on this Minor Asia in origin, form of bridge vault construction in east Europe, has its historical explanation in known, from the historical sources information, not only for migrations of minor groups, but and more compact masses Syrians and Armenians V and especially VIII century, when Arabian invasion towards these territories from Byzantium are forced. The most massive from the migrations is realized in 789 year emperor Leo IV Hazarski, when he has transferred in Thrace 150 000 Syrians and Armenians. Archeologically, constantly is establishing that, not a minor part in church building on the Balkans is dated from IV – VI century, owes all features of Syrian early Christian architecture, stone plastic and mosaic. Some of the survived, or known as more older engravings and photos building constructions, also carry the features of Minor Asia building practices, for example two- and three rowed vaults and on the needlepoint constructions.

From the made review is clearly defined the areal of spreading up to VI century of needlepointed vault construction, prevailing on the northwest territory of Minor Asia from late – antique Armenian lands up to northern Palestina. It is an issue for mainly Syrian lands from this age, or for Syrian architectural features, when the buildings are out of them. It should not be forgotten, that this is the time, when Armenians and Georgians are trained in the stone construction technics, exactly by Syrians. And that's why later, they will be the main builders of Seldhzuk sultanate, using massively needlepointed vaults. And long before Assyrians, Armenians and Georgians will implement this type of vault constructive system in Iranian lands, and later among the territories of early Arabian caliphate, in order to convert into a main element, from the Islamic architectonics.

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[13] Same place.
[14] Same place, c. 1e
[15] Wikimapia.org/17854749/Hovvi-kamurj-Shepherd-s-bridge. This is an evident, shown in 1872 year from archbishop Tevkanz. There are shown repairs of the bridge and in 1612-1640, 1727, 1872, 1946-1948 and the last from 2011 year.
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НАПРАВЛЕНИЕ 3

Исторически строителни материали и тяхното диагностициране; Нови материали за опазване на културно-историческото наследство; Исторически структури и техния мониторинг; Нови технологии за опазване на културно-историческото наследство.

TOPIC 3

Historic materials and their diagnostics; New materials for safeguarding culture heritage; Historic structures and their monitoring; New technologies for safeguarding culture heritage.

THERMAL INSULATION AND AUTHENTICITY OF ARCHITECTURE

Miomir Vasov[1], Nikola Cekić[2]

University of Nis; Faculty of Civil Engineering and Architecture
Serbia - 18000 Nis, Aleksandra Medvedeva st. 14

***Abstract**: The most common basic structure of facade walls of buildings belonging to the cultural heritage, consist of two typological groups, or two types of walls structure. The first group belongs to single homogeneous walls without thermal insulation, the second constituted a double-layer walls, three-layer and multi-layer walls with a adequate thermal insulation designed and dimensioned according to the then applicable regulations and standards. So generally speaking, there are at least two reasons for the structural transformation of façade envelope, which can be defined as a works on cultural heritage and energy-efficient revitalization. Recent trends of conversion in architecture, whether it is a whole or only some part of the building, also generate adequate implementation with regard to energy efficiency. Aware of the fact that it is pointless to resist the application of new technologies, an attempt to bar the initiation of discourse analysis on the topic of achieving adequate authenticity for the purpose of sustainability of construction and architectural value of the buildings, would be more than enough reason.*

***Key words**: cultural heritage preservation, architectural authenticity, energy efficiency, thermal envelope*

1. Introduction

A large number of buildings, in statistical terms, was built in the times when there were no adequate standards and regulation, concerning thermal protection of buildings. Many of these buildings belong to the category of cultural heritage and buildings under protection. The result of such condition of all buildings from this period, is their design without any thermal insulation. The external walls, which have the most important role in the thermal balance of the building, were most frequently constructed of traditional materials having high density, such as bricks, stone and concrete combined with those two previous materials. In terms of position and function, the external walls are exposed to various external (and internal) impacts. Due to their action, there variety of negative consequences may occur, causing various forms of structural damage. The most frequent effect is the impermissible condensation of water vapor inside the building and on the wall surfaces. This physical phenomenon results in the reduction of thermal-insulation capacity of material and deterioration and decay of material and its destruction.

It is not difficult to assume that such walls do not meet the prescribed requirements of energy efficiency. The importance of this view, from the aspect of energy saving, is emphasized by the fact that 25%-30% contemporary buildings is constructed as energy

[1] Assoc. Prof. Miomir Vasov, PhD, architect; GAF, University of Nis, Serbia; e-mail: vasov@medianis.net
[2] Academic Prof. Nikola Cekić, PhD, architect; University of Nis, Serbia; e-mail: ncekic@yahoo.com

inefficient, and without sufficient thermal-insulation properties. Regarding the previous facts, it is a logical conclusion that it is necessary to restore and revitalize such buildings in terms of energy. One of the most implemented principles is designing and construction of thermal insulation systems for external walls (WDVS; ETICS). There is a limitation, in terms of implementation of these thermal insulation systems on the structures that have the status of cultural monuments, since the facades and their architectonic and formal characteristics must not be amended authenticity. Apart from this primary limitation, there is a certain number of cases when the external insulation is not practicable for technical or regulation reasons.



Fig. 1. Remodeled architectural authenticity with ETICS
"A historic brick building in Germany covered with EIFS (ETICS) on the right side"

Therefore, if we want to keep the authenticity of the heritage architecture, the only possible method of application of thermal-insulation layer of the façade (external walls), is to place it on the interior, "warm" side of the wall. Proper design of this layer ought to primarily prevent the harmful effects of impermissible condensation of water vapor. The proper design and construction of appropriate of structures of walls with internal insulation also brings about rapid heating of interior space (schools, churches, office blocks, etc.) A special problem (and an unsolvable one too, according to data available to the author) pose the buildings whose interior is protected along with the exterior. [2]

2. About thermal rehabilitation of the cultural heritage

In the article published in the *Federal Office for the Protection of Monuments, Austria,* on the topic: Historical building between thermic renovation and conservation, Johannes Sima head of Department for Architecture and Building Technology Vienna, presents the "Guidelines" and basic principles for the optimization of energy efficiency in historic buildings, through the following observations:

In the field of monument preservation we are faced with two major but apparently irreconcilable problems – the legal requirement to preserve monuments in an authentic manner on the one hand and the high targets of reducing energy consumption on the other. In the preservation of monuments measures have to be taken, with regard to energy efficiency, which use the existing fabric, such as drying, optimised interior insulation or heating of building components be used. The restoration methods which are used, have to be evaluated and, if necessary, adapted. Only in this way can the level of knowledge and wealth of experience grow continually and preserve our monumental heritage from irreversible damage.

"Energy-saving" is an urgent challenge for Europe's future and one that calls upon each one of us to make our own contribution to dealing with it. Large numbers of individuals from a broad section of the population have now committed themselves to taking responsibility. It is a challenge that can only be met with appropriate measures and with activities that in part have to be radical in character.

Those involved in the conservation of historical monuments and the protection of the environment are bound to share the common goal of long-term, sustainable progress. This means that we have to be extremely careful in the way we handle not only the resources available to us but also our historical monuments, which are by their very nature "non-renewable"; and ideally we also have to take measures that promote both the best possible energy-related technology and also the goal of authentic conservation (Fig. 2a. [1]



a) b)

Fig. 2. An example of: a) Conflict between thermal revitalisation and architectural authenticity; b) Stone walls with substantial mass have high thermal inertia

3. Characteristics of the cultural heritage external walls

The most frequently implemented traditional building materials for external walls of the buildings belonging to the cultural heritage category have been constructed as a masonry building of the following basic materials:

-Stone (stone wall),
-Brick (brick wall),
-Brick and stone (mixed wall of stone and brick)

In the Table 1 are given thermal protection characteristics of the materials of the system of analyzed external walls in: density ρ, specific heat c, thermal conductivity coefficient λ and relative water vapor diffusion resistance μ.

Table 1. Thermal protection characteristics of materials of masonry walls layers

Material	ρ (kg/m3)	c (J/kgK)	λ (W/mK)	μ (-)
Stone / S /	2700	920	2,33	65
Brick / B /	1800	920	0,76	12
Lime mortar	1600	1050	0,81	10

The presented calculation and analysis includes masonry walls made of brick and stone, that is, constructed and mixed type masonry walls formed by combining these materials. Densities ρ (kg/m^3) used in calculation and analysis of basic building materials were selected according to the case study principle for the certain type of external wall (**EW**). Accordingly, the appropriate coefficients of heat conductivity λ and the relative

resistance to water vapor diffusion **μ** were chosen. Standardization of the analyzed walls, according to the assumed characteristics of the basic material, brick, stone and concrete is also provided in a table (Table 2).

The table of external wall which are made of bricks with the density ρ=1400kg/m^3, which is in the analysis reflect in the coefficient of heat conductivity and relative resistance to water vapor diffusion which used in the calculation, is provided in the table 2.

The standardized walls included in the calculation are:

-Type (EW-S) external wall of stone,

-Type (EW-B) external wall brick,

-Type (EW-SB) external wall of brick and stone

Table 2. Standardized analyzed external masonry walls

Wall type label	Wall material	D_w (cm)	d_l (m)	λ (W/mK)	μ (-)
EW-S	stone	40	0,40	1,16	22
EW-B	brick	38	0,38	0,76	12
EW-SB	stone	52	0,40	1,16	22
	brick		0,12	0,76	12

One of the most important parameters for the quality of walls, from the aspect of thermal protection is heat passage coefficient **U** (W/m^{2}K). The valued of heat passage coefficient $\mathbf{U_{stv}}$ (W/m^{2}K) for certain structural elements of the building, according to the code of energy efficiency building must be lower or equal to the maximum permissible value $\mathbf{U_{max}}$ (W/m^{2}K). The values of heat passage coefficient $\mathbf{U_{stv}}$ were calculated for the analyzed standardized walls, which are recognized as the walls most often occurring as a type of external walls of the cultural monuments buildings. The results were provided in a table, along with the maximum values of heat passage coefficient $\mathbf{U}_{max}$, depending on the building category (existing or new building).

Table 3. Heat passage coefficient $\mathbf{U}_{stv}$ of the typified external walls of masonry buildings, belonging to the cultural monuments category

Wall type label	U_{stv} (W/m^{2}K)	New building	Existing building
		U_{max}=0.3 (W/m^{2}K)	U_{max}=0.4 (W/m^{2}K)
EW-S	1,942	no	no
EW-B	1,493	no	no
EW-SB	1,486	no	no

On the basis of the values of calculated heat passage coefficients, presented by the previous table (Table 3), it can be concluded that none of the assumed examples of the existing walls does not meet the maximum permissible values according the *Code on energy efficiency of buildings („Official Gazette of the R Serbia" No. 61/2011).* [3]

4. General characteristics of internal thermal insulation covering systems

Structure, characteristics, materialization and the form of the façade envelope of the building, including thermal properties, are exposed to constant transformation due to the accelerated technological development. As a consequence, there has been a development of thermal insulation systems which can be easily and rapidly applied to the façade walls on the outer side and their increasing application in contemporary engineering practice.

The most frequent methods of application are by adhesion, by adhesion and plug anchoring or by fixation by rails and anchors to the wall. However, in case of the buildings belonging to the cultural monuments category as mentioned and elaborated in the

introductory section, application of these systems is very limited, and in a large number o cases almost impossible. Therefore, conventionally proper location of thermal insulation material (as close to the external "cold" side) within the cross-section of the façade wall is in case of these buildings unfeasible. The reason for such designing-architectonic approach of installation of thermal insulation on the interior side of the façade wall which was almost axiomatic in case when the building was under protection ("protected façade") is very clear and more than obvious. From the aspect of theory of heat technology and thermo-dynamics it is, to say the list – disputable, but not impossible.

The paper will include the design of the internal insulation system for three different thermal insulation materials, two of them being very often used in construction. In the first variant mineral rock wool was used as thermal insulation material, in the second variant, it was the extruded polystyrene, and in the third variant it was the glass foam thermal insulation, which, unfortunately is barely present in our building practice (according to the facts available to the authors).

The analysis will include the design parameters which are, in methodological terms, based on the current regulations in the area of building thermal protection. Thermal stability criterion of the walls will not be analyzed because the walls have a large surface mass (Figure 2b). Therefore, evaluation of each of the analyzed variants of internal thermal insulation will be performed according to two criteria:

a) Permissible heat passage coefficient criterion,

b) Permissible condensation damp criterion.

Internal thermal insulation covering system is placed on the interior side of façade walls, and except the thermal insulation layer, it comprise the mechanically protective layer of materials of appropriate characteristics. The most frequently applied finishing-protective layer is the gypsum-cardboard panels. Apart from GC panels, the internal layers can consist of mortars base on artificial or silica resins, mineral mortars with reinforcement meshes, wooden panels, PVC material but also the brick-ceramic elements and similar. The data used in the calculation, were defined by the code on EE of buildings, standards, building purpose, i.e. by the functional use of a room in the building. The adopted values of input data for temperatures and relative humidity are presented in the table 4. [3]

Table 4. Data values for the calculation

ZONE (acording [6])	Temperature		Humidity	
	θi (°C)	θe (°C)	φi (%)	φe (%)
A	20	-5	55	90
B	20	-10	55	90

4.1. Variant A – Internal Thermal Insulation Covering System with MW

In the first variant of **ITICS.MW** the thermal insulation layer was the **mineral rock wool** d=10cm thick, and as a finishing-protective layer **GC panels** d=12.5mm thick. The heat protection characteristics of used materials are provided in table 5.

Table 5. Heat protective characteristics of finishing-protective layers of IT ICS-MW

Variant A	Material	ρ (kg/m3)	λ (W/mK)	μ (-)
ITICS.MW	MW – mineral rock wool	85	0.035	1,1
	GK - gypsum wallboards	900	0,21	12

a) ITICS.MW - Criterion of the permissible heat passage coefficient

Based on the results presented in Table 6 it can be concluded that all the analyzed standardized walls, with the added internal thermal insulation of MW-mineral rock wool,

meet the requirements of thermal protection based on the maximum prescribed heat passage coefficient $\mathbf{U}_{max}$, both for new and for the existing buildings.

Table 6. Heat passage coefficient $\mathbf{U}_{stv}$ of the standardized external masonry walls

Wall type	U_{stv} (W/m^{2}K)	New building	Existing building
		U_{max}=0.3 (W/m^{2}K)	U_{max}=0.4 (W/m^{2}K)
EW-S + ITICS.MW	0,291	**yes**	**yes**
EW-B + ITICS.MW	0,279	**yes**	**yes**
EW-SB + ITICS.MW	0,279	**yes**	**yes**

b) ITICS.MW - Criterion of the permissible condensation damp

In all the analyzed examples of walls in the first variant the total condensed damp ($\mathbf{x_{uk}}$) is higher than the maximum permissible value ($\mathbf{x_{max}}$). However, according to the calculation for the required number of days for drying ($\mathbf{z}$) in case of **zone B** the number of days is higher than the maximum number of days ($\mathbf{z_{max}}$). The results according to the criteria of permissible condensation damp are provided in table 7.

Table 7. Values of total and permissible material humidity and number of drying days

Wall type	Zone	Humidity (%)		Draying (days)	
		$\mathbf{x}_{uk'}$	$\mathbf{x}_{max}$	$\mathbf{z}$	$\mathbf{z}_{max}$
EW-S + ITICS.MW	A	**182,822**	72,024	80,978	90
	B	**218,427**	72,024	**97,905**	60
EW-B + ITICS.MW	A	**172,014**	72,024	73,868	90
	B	**209,222**	72,024	**91,098**	60
EW-SB + ITICS.MW	A	**2,832**	2,625	65,574	90
	B	**2,91**	2,625	**81,194**	60

4.2. Variant B – Internal Thermal Insulation Covering System with XPS

In the second variant of **ITICS.XPS** the thermal insulation layer was the **extruded polystyrene XPS** d=10cm thick, and as a finishing-protective layer **GC panels** d=12.5mm thick. The heat protection characteristics of used materials are provided in table 8.

Table 8. Heat protective characteristics of finishing-protective layers of ITICS.XPS

Variant B	Material	ρ (kg/m3)	λ (W/mK)	μ (-)
ITICS.XPS	XPS - extruded polystyrene	40	0.034	200
	GK - gypsum wallboards	900	0,21	12

ITICS.XPS - Criterion of the permissible heat passage coefficient

Based on the results presented in Table 9 it can be concluded that all the analyzed standardized walls, with the added internal thermal insulation of the XPS-extruded polystyrene, meet the requirements of thermal protection based on the maximum prescribed heat passage coefficient $\mathbf{U}_{max}$, both for new and for the existing buildings.

Table 9. Heat passage coefficient $\mathbf{U}_{stv}$ of the standardized external masonry walls

Wall type	U_{stv} (W/m^{2}K)	New building	Existing building
		U_{max}=0.3 (W/m^{2}K)	U_{max}=0.4 (W/m^{2}K)
EW-S + ITICS.XPS	0,284	**yes**	**yes**
EW-B + ITICS.XPS	0,272	**yes**	**yes**
EW-SB + ITICS.XPS	0,272	**yes**	**yes**

ITICS.XPS - Criterion of the permissible condensation damp

In all the analyzed examples of walls in the second variant (Var.B) the total condensed amount of damp ($\mathbf{x_{uk}}$) is lower than the maximum permissible value ($\mathbf{x_{max}}$), that is, the number of draying days (**z**) is consequently lower than the maximum number of drying days prescribed by the standard ($\mathbf{z_{max}}$). In one case for zone B (EW-B+ITICS.XPS) there is no condensation. The analysis results are provided in table 10.

Table 10. Values of total and permissible material humidity and number of drying days

Wall type	Zone	Humidity (%)		Draying (days)	
		$\mathbf{x}_{uk'}$	$\mathbf{x}_{max}$	**z**	$\mathbf{z}_{max}$
EW-S + ITICS.XPS	A	13,264	30,357	14,684	90
	B	13,663	30,357	22,353	60
EW-B + ITICS.XPS	A	there is no condensation			90
	B	12,924	30,357	4,925	60
EW-SB + ITICS.XPS	A	13,130	30,357	13,425	90
	B	13,524	30,357	22,200	60

4.3. VARIJANT C – Internal Thermal Insulation Covering System with GF

In the third variant of **ITICS** the thermal insulation layer was the **glass foam GF** d=10cm thick, and as a finishing-protective layer **GC panels** d=12.5mm thick. The heat protection characteristics of used materials are provided in table 8.

Table 11. Heat protective characteristics of finishing-protective layers of ITICS.GF

VARIANT C		MATERIAL	ρ (kg/m3)	λ (W/mK)	μ (-)
ITICS.GF	1	GF – glass foam	145	0.056	10.000
	2	GK - gypsum wallboards	900	0,21	12

ITICS.GF - Criterion of the permissible heat passage coefficient

Based on the results presented in Table 12 it can be concluded that all the analyzed standardized walls, with the added interior thermal insulation of GF-glass foam, **do not meet** the requirements of thermal protection based on the maximum prescribed heat passage coefficient $\mathbf{U}_{max}$, both for now and for the existing buildings, except in the case of the wall EW-B and EW-SB for existing buildings. In order to meeting the requirements $\mathbf{U}_{stv}>\mathbf{U}_{max}$ the thicknes of glass foam in thermal system ITICS.GF must be increased by a certain value. This increased must be about 60%. Therefore if you increase the thickness of the thermal insulation layer on d=16cm conditions according to the criterion of the permissible heat passage coefficient will be met in all cases.

Table 12. Heat passage coefficient $\mathbf{U}_{stv}$ of the standardized external masonry walls

Wall type	U_{stv} (W/m^{2}K)	New building	Existing building
		U_{max}=0.3 (W/m^{2}K)	U_{max}=0.4 (W/m^{2}K)
EW-S + ITICS.GF	0,424	no	no
EW-B + ITICS.GF	0,398	no	**yes**
EW-SB + ITICS.GF	0,397	no	**yes**

ITICS.GF - Criterion of the permissible condensation damp

In all the analyzed examples of walls in the variant (Var.C) there is no condensation meaning that the equilibrium state is achieved. The analysis results according to the criteria of permissible condensation damp are provided in table13.

Table 13. Values of total and permissible material humidity and number of drying days

Wall type	Zone	Humidity (%)		Draying (days)	
		$\mathbf{x}_{uk'}$	$\mathbf{x}_{max}$	**z**	$\mathbf{z}_{max}$
EW-S + ITICS.GF	A	there is no condensation			
	B	there is no condensation			
EW-B+ ITICS.GF	A	there is no condensation			
	B	there is no condensation			
EW-SB+ ITICS.GF	A	there is no condensation			
	B	there is no condensation			

5. Conclusion

The presented analysis of the walls in the internal thermal insulation system, in certain conditions, occurrence of water vapor condensation is most frequently the consequence of impact of the characteristics of water vapor diffusion of thermal insulation material and of the interior finishing (protection) layer.

Considering their, from the aspect of thermal protection, specific position, it is necessary that thermal insulation is designed as sufficiently water vapor impermeable. In a general case, in theoretical terms, whether and in what form there will be condensation of water vapor inside the partition, depends on temperatures and humidity of interior and exterior air and structure of the partition.

Based on the analyzed variants of exterior masonry walls (standardization given in table 2) of the structures belonging to the cultural monuments, which have three thermal insulation materials applied from the inside, and which are different in terms of characteristics of heat conductivity λ and relative resistance to water vapor diffusion μ, it can be considered that:

- application of thermal protection (VARIANT A) on the interior side of façade walls, using thermal insulation of mineral wool **is not possible** unless special layers are added to compensate for the emergence of impermissible damp condensation inside the partition, in any of the prescribed building climate zones.
- application of thermal protection (VARIANT B) on the interior side of façade walls, using thermal insulation of extruded polystyrene XPS **is possible** without adding special layers for compensation for the emergence of impermissible damp condensation inside the partition, because the total amount of condensed damp $\mathbf{x_{uk}<x_{max}}$ does not exceed the highest permissible value, so the damp material is dryed in the prescribed standard time period $\mathbf{z<z_{max}}$.
- application of thermal protection (VARIANT C) from the interior side of façade walls, using thermal insulation of glass foam **is possible** without adding special layers for compensation for the emergence of impermissible damp condensation inside the partition, because there is no condensation in any of the prescribed building climate zones, and the state of equilibrium is achieved. However, the thickness of TI must be increased to correct the heat conductivity coefficient **U** (W/m^2K) which in analyzed examples is slightly higher than the maximum permissible coefficient $\mathbf{U_{max}}$.

Therefore, it is a general conclusion that thermal insulation on the internal side of the walls, the so called "warm" side, under certain conditions represents the only possible way of application of thermal insulation for buildings belonging to the cultural monuments, of course, considering all the requirements including the appropriate thermal requirements.

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ОСИГУРЯВАНЕ НА БЕЗОПАСНОСТ ПРИ ОПАЗВАНЕ И СЪХРАНЯВАНЕ НА НЕДВИЖИМИ КУЛТУРНИ ЦЕННОСТИ

инж. Ивайло Гаджемов[1]

1. Въведение

Архитектурата, като едно от най-трайните изкуства предава своето историческо послание най-продължително във времето. Всяка сграда е носител на информация за своето историческо време и това я прави е неповторима.

През август 2016 г. горяха 4 склада, част от „тютюневия град" в град Пловдив - много показателен случай за проблематиката на настоящия доклад, илюстриращ действителността на ситуацията по осигуряване на безопасност при опазване и съхранение на недвижимите културни ценности в цялата страна. Когато не се вземат своевременни превантивни мерки, за да се предотврати унищожаването им, те никога не могат да се възстановят в оригинален вид. И най-професионалното изпълнение на негова реплика по информация, която е запазена в документите, не може да замени излъчването на оригинала и неговата историческа стойност. Отделен е въпросът, че инвестицията за съхранение е много по-малка от тази за възстановяване.

Целта на този доклад е да се обърне внимание как такива случаи да бъдат предотвратени в бъдеще, защото състоянието на която и да е сграда е пряко свързано с безопасността на обитателите, посетителите и преминаващите около нея. Като се има предвид конструктивните особености (материали, елементи, връзки, технологии и други) на недвижимите културни ценности и продължителното им излагане на климатичните условия, съвсем естествено е, че те ще са много по-рискови и опасни.

Докладът обхваща само недвижими културни ценности в населените места, поради факта, че са в много по-чест контакт с хора, което завишава степента и вероятността от инциденти. За съжаление много голяма част от недвижимите културни ценности продължават да се рушат, защото са сериозно амортизирани.

Рушащите се недвижими културни ценности създават пасивна и активна опасност. Пасивна опасност има за обитателите, посетителите и преминаващите около нея. Активна опасност се създава за лицата, които участват в гасене на пожари и аварийно-спасителни действия, както и за обитателите на съседни обекти.

Държавата е ръководител и регулатор на процеса по опазване и съхраняване на недвижимите културни ценности, затова има водеща роля и огромна отговорност за вземаните от нея решения, за нейното действие или бездействие.

Що се отнася до случая в град Пловдив и до останките от сградите, в момента най-неотложното и незабавно нещо, което трябва да се направи е тяхното укрепване. Вътрешната конструкция на всяка сграда укрепва фасадите. В момента тази конструкция вече липсва и при един силен порив на вятъра или леко земетресение

[1]инж. Ивайло Гаджемов, специалност „Пожарна безопасност и защита на населението", Експерт по ЗБУТ на TÜVRheinland ® и съдружник в „Център по охрана на труда" ООД, град Варна, ул. „Доспат" № 33, офис 1; e-mail: ohrananatruda@mail.bg

тези фасадни стени могат да се срутят. Това ще бъде още една голяма загуба от културната стойност на този квартал и също така представлява опасност за лицата, които могат да бъдат в близост. Трябва да се направи всичко възможно, за да се предотврати такова развитие на събитията.

2. Причини за създаване на опасност от недвижими културни ценности

Естествено, че основните причини са неподдържането и разрушаването на недвижимите културни ценности.

Преди 10 години, на 19 септември 2006 г. рухва сграда (недвижима културна ценност) в град София, улица "Алабин" № 39, при което загиват две млади жени - Деница Ченишева, на 26 години и Петрина Христова, на 24 години. [1]

Според техническите експертизи по делото срутването е причинено от три фактора - конструктивни недостатъци на сградата, неподдържането на сградата за дълго време, както и допуснати нарушения при извършваните ремонтни работи. [2]



Фиг. 1. Рухналата на 19.09.2006 г. сграда в град София, улица "Алабин" № 39

На 13 април 2016 година, в центъра на град Велико Търново се срива метох на Преображенския манастир - недвижим паметник на културата от 1985 година. Постройката е на повече от век, но от години тъне в разруха. Въпреки че миналата година част от нея се е самосрутила не са взети адекватни мерки за спасяването й.

Мнението на инж. Динко Кочев от община Велико Търново, е че: „С годините не е поддържан и сега последните метеорологични условия, тоя дъжд, който падна и довел да преовлажняване и до срутване на останалата част от къщата. [3]



Фиг. 2. Разчистване на останките от метоха на Преображенския манастир.

За да бъде намален или елиминиран риска, трябва да се определят източниците и причините, довели до опасното състояние на недвижимите културни ценности.

2.1. Правно-нормативни причини

Редно е да се отбележи, че след рухването на сградата на улица "Алабин" 39, в град София, бяха направени законови промени и се даде право на общините да отнемат сгради недвижими културни ценности, които не се стопанисват добре. Доц. д-р арх. Йорданка Кандулкова изразява своето мнение по този въпрос в интервю за www.gradat.bg през декември 2010 година: „В закона за културното наследство има норма, която дава действен механизъм за осъществяване на държавна и общинска грижа за културното наследство. Основните задължения са вменени на собственика, но ако той е безотговорен или не е в състояние да упражни ефективна грижа и паметникът продължи да се руши, има ред, по който държавата или общината

изпълнява необходимите дейности вместо него. Първо се дават предписания за аварийно укрепване. След това се провежда междуведомствена комисия, която дава указания за необходимите мероприятия за заздравяване на обекта. Ако собственикът не изпълни дадените предписания, държавата или съответно общината извършват необходимите спасителни действия, срещу което ипотекират имота в своя полза. Дали има такива случаи трябва да кажат и общините, но според мен тази формула през последните 20 години почти не се е случвала." [4] Доц. д-р арх. Йорданка Кандулкова счита, че: „Законът за културното наследство е твърде рестриктивен. Ако го прегледате и си зададете въпроса какви са задълженията на собственика на недвижима културна ценност ще видите доста текстове. Ако попитате обаче какви са правата му, ще видите, че има право да кандидатстват за подпомагане по програми, финансово осигурени от държавния, общинския бюджет или от други източници и право на консултации. Според мен стимулните механизми в закона са малко, а именно те са тези, които карат хората да влагат парите си за определено нещо." [4]

В ЗКН има императивни постановки, определящи отговорностите: „Държавата осигурява закрилата на културното наследство независимо от местонахождението му" (член 1, алинея 2); Културните ценности са обществено достояние и се ползват със закрила от държавни и общински органи в интерес на гражданите на Р. България. (член 3, алинея 2); Собствениците, концесионерите и ползвателите на недвижими културни ценности са длъжни да: „полагат необходимите грижи за тяхното опазване, съхранение и поддържане в добро състояние при спазване на разпоредбите на този закон и актовете по прилагането му". (член 71, алинея 1, точка 1) [5]

ЗКН дава много интересни решения: „Когато заповедите по чл. 73, ал. 3 и чл. 74 не са изпълнени в определения срок, необходимите проектни укрепителни, консервационно-реставрационни и ремонтни дейности или реконструкция по автентични данни на НКЦ или на част от нея се извършват от държавата, съответно общината" (член 76, алинея 1) и „Въз основа на заповедта по ал. 2 върху имота се вписва законна ипотека в полза на държавата, съответно общината, за обезпечение на вземането им за направените от тях разноски" (член 76, алинея 5). [5]

Но как си кореспондира това с член 17, алинея 3 от Конституцията на Република България: „Частната собственост е неприкосновена". [6]

Още на 06 декември 2010 година, пред репортер на www.gradat.bg, арх. Петър Диков, главен архитект на град София, заявява: „Оказва се обаче, че няма нотариус, който да впише ипотека на чужда собственост в полза на общината без съгласието на собственика. В закона не е ясно уредено дори и да се наложи ипотеката кой и какво ще плаща." [7] Това е една от причините, поради което е съмнително, че този законов механизъм би бил ефективен.

На 26 Август 2016 година, Агенция "Фокус" публикува интервю с арх. Борислав Игнатов, в което той споделя „Това е един много сериозен и строг механизъм, който се прилага по света и особено в Европа. У нас досега нямаме прецедент на прилагане на закона в тази си част. …. Смятам, че с един или два такива прецедента изведнъж коренно ще се промени отношението на всички други собственици към това, което притежават. В момента те са оставени някак встрани от погледа на изпълнителната власт." [8]

2.2. Отсъствие на собствениците от страната

Интересно е оправданието „собствениците живеят извън страната". Означава ли това, че трябва да се оставят много от недвижимите културни ценности да изчезнат. Много показателен пример е проектираната през 1922 година от арх. Дапко Дапков сграда на Софийската банка в град Варна, ул. „Преслав" № 24, чиито скулптури са направени от Кирил Шиваров. През 1998 година е закупена от

„Оувърсийс Девелопмънт" ООД, собственост на Майкъл Бодуроглу и Леонидас Корбетис. Майкъл Бодуроглу е Управляващ директор на Allseas Marine S. A., която притежава 25 кораба, Президент и Изпълнителен директор на Paragon Shipiping и Изпълнителен директор на Box-Ships. Не мога да повярвам, че нямат средства да поддържат сградата, но мога да повярвам, че нямат интерес да го направят.

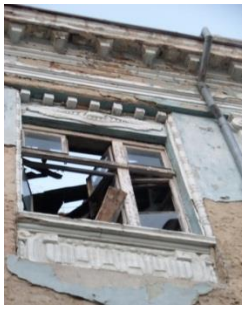


Фиг. 3. Сградата на Софийската банка с поставените от Общ. Варна ограждения



Фиг. 4. Поставената от Община Варна предупредителна табела

Сградата е в пета степен на опасност, при която незабавно трябва да се предприемат мерки, защото освен разрушенията по нея има и наличие на поникнала растителност по конструкцията. [Фиг. 5 и Фиг. 6]



Фиг. 5. Разрушенията на сградата на Софийската банка.



Фиг. 6. Поникнала растителност, по конструкцията на сградата на Софийската банка.

Но какво се прави за разрешаване на проблема? Община Варна постави ограждения и предупредителна табела „ВНИМАНИЕ! ОПАСНОСТ ОТ ПАДАЩИ ПРЕДМЕТИ". [Фиг. 3 и Фиг. 4]

Дали предупредителна табела „ВНИМАНИЕ! ОПАСНОСТ ОТ ПАДАЩИ ПРЕДМЕТИ" [Фиг. 3] ще спре „падащите предмети"? Каква е гаранцията, че ако си на улицата, извън огражденията, няма този „падащ предмет" да попадне върху оградението, да промени траекторията си и да те нарани? Не можеш да затвориш участъка от улицата, намиращ се пред сградата.

А какво ли би се случило, ако падне акцентът на цялата сграда - скулптурата на бог Меркурий, покровителя на банкерите, възседнал орел? [Фиг. 7] Композицията е дело на Кирил Шиваров, автор и на скулптурите на братята Евлоги и Христо Георгиеви пред входа на Софийския държавен университет.



Фиг. 7. Скулптурата на бог Меркурий, покровителя на банкерите, възседнал орел, дело на Кирил Шиваров

Може би някой скептик ще си каже: „Е, чак пък да падне цялата композиция…“. Нека да погледнем фронтона на сградата. Вкореняването на развилата се растителност и наличните вече разрушения са достатъчна предпоставка един ден това да се случи. [Фиг. 8 и Фиг. 9]



Фиг. 8. Вкореняването на развилата се растителност по фронтона на сградата.



Фиг. 9. Наличните вече разрушения по фронтона на сградата.

2.3. Несвоевременни действия от страна н държавата и общините

На 19.01.2016 година се е съборило едно от крилата, рухнал е и половината покрив, а така също са увредени и тайните проходи под една от емблематичните сгради за град Велико Търново на ул. „Пандели Кисимов № 3 [Фиг. 10]; [10] - къщата на Анастасия х. Пенчович, съпруга на русенският нотабил х. Иванчо х. Пенчович, и сестра на известния лекар и книжовник Никола Савов – Пиколо [11]. В сградата е отсядал многократно Васил Левски.

Главният архитект на града Николай Малаков съобщи, че: „Това е огромна загуба за всички. Собствениците преди ден получиха одобрение от Института за недвижима културна собственост за ремонт“.

Г-жа София Белчева, собственик на съседна сграда заявява: „Собственикът на имота Атанас Арнаудов е чакал почти две години да му позволят реконструкция и когато това най-накрая станало, и тромавата държавна машина се задействала, вече било късно. Той планувал да я възстанови и да я отвори за посетители. Преди седмица звънихме на телефон 112 и в общината. Пратиха експерт, който претупа проверката си и ни заяви защо сме ги занимавали. Повикахме ги, защото къщата тръгваше да се срутва и тогава можеше да се направи нещо“ [10].



Фиг. 10. Рухналата част от покрива на сградата в град Велико Търново, ул. „Пандели Кисимов № 3

Независимо дали причините са: недостатъчен брой работещи във ведомствата, лоша организация, липса на интерес в определени служители, процесуални пречки, правно-нормативни пропуски, „чувство за безнаказаност“ и други, важен е крайния резултат – не винаги се реагира достатъчно бързо от страна на държавните и общинските институции.

На 08 април 2016 година, по повод забавянето на разрешението, депутатът Проф. Станислав Станилов се обърна в пленарна зала към Министър Рашидов: „Господин Министър, вашите сътрудници много добре са подредили всички подробности, които казахте, но не разбрах: кой конкретно е отговорен за този голям гаф. Кой трябва да носи отговорност, да бъде наказан”. Въпреки че имаше почти 3

месеца да се запознае с фактите и обстоятелствата около въпросния случай, реакцията на Министър Рашидов беше, че обеща да направи проверка кой е виновен, да го накаже и да уведоми проф. Станилов. [12]. Нещо, което е трябвало да бъде извършено преди Проф. Станилов да повдигне въпроса.

2.4. Финансова невъзможност на собствениците

Ако това са възрастни хора, без подкрепа от близките си, мога да го приема. Но, ако са хора в активна възраст – това е оправдание за мързел или други интереси.

Още на 18.09.2015 година, Министърът на регионалното развитие и благоустройството Лиляна Павлова заяви пред репортер на вестник „24 часа“, че „стари сгради – недвижими културни ценности, ще могат да бъдат реставрирани с пари по Оперативната програма "Региони в растеж". Новото в програмата е, че за европари могат да кандидатстват както сгради общинска и държавна собственост, така и частни.“ [13] Понякога „проектите за реставрация по европейски и други финансиращи фондове създават крайно негативната практика за намеси в културните ценности с цел усвояване на средства за сметка на тяхната автентичност.“ [14] Затова трябва много да се внимава при одобрението им.

2.5. Умишлени действия от страна на собствениците

На 29 юни 2016 г., в град Варна, на бул. „Княз Борис I" 73 се „самосрутила“ фасадата на сграда, която е недвижим паметник на културата. [Фиг. 11, Фиг. 12 и Фиг. 13] По този повод, г-н Георги Недев, кмет на район „Одесос" сподели пред репортер на Moreto.net, че: „Падането на фасадата е по-скоро инцидент, а не търсен ефект, както твърдят живущи и работещи в района“ и че: „са спазени всички условия за укрепване, вдигнато е нужното метално скеле.“ Това поражда въпроса: „След като всичко необходимо е спазено, защо се е срутила фасадата?“.

Според информационната табела на обекта разрешителното за строителни дейности е от юни 2014 година, строителна площадка е разкрита в началото на ноември 2015 година, изпълнител на обекта е „Възраждане 2004" ЕООД, а строителният надзор се осъществява от „Тест билдинг" ООД, сградата е от трета категория, което означава, че за нея е позволено пристрояване и надстрояване чрез запазване на фасадата.

„Това е много грешна практика по този начин да се запазват старите сгради. На много места се случва подобно срутване. При такива стари фасади навремето е нямало бетонни колони. Това прави много трудно вграждането в нова сграда.", коментира Недев. [15] И тук можем да си зададем следващия въпрос: „Защо, след като е много трудно вграждането в нова сграда се издава разрешение?“.

За съжаление това не е единственият случай, в който архитектурен паметник на културата стига до пълна разруха при строителни дейности.

Схемата не е сложна. В продължение на няколко месеца фасадите на стари сгради се укрепват с метална конструкция, създаваща впечатлението, че се полагат усилия за запазването им. През това време останалата част от постройките се премахва докато най-накрая при “възникване на авария” пада и самата фасада. Така паметникът изчезва, а налагането на санкции за унищожаването му става изключително трудно. [16]

Арх. Виктор Бузев, главен архитект на град Варна изказа мнението си, че: “За съжаление при съставяне на протокол за авария ние не можем да направим почти нищо. Още преди година и половина лично внесох в НИНКН актуализирания списък на паметниците на културата във Варна. По различни причини обаче той не е съгласуван и до този момент. В него са включени около 700 сгради и сега

собствениците на част от тях явно бързат да ги съборят преди да е утвърден списъка, изпратен до НИНКН". [16]



Фиг. 11. Сградата преди СРР



Фиг. 12. „Сградата" на 29 Юни 2016 година



Фиг. 13, Строително-ремонтните работи

Според главния архитект на град Варна обаче случаят е твърде сериозен. Изпълнителят на обекта "Възраждане 2004" ЕООД не притежавала лиценз за работа с паметници на културата. "Независимо от това, дружеството строи предимно в централния варненски район "Одесос", който обхваща историческия център на града и където почти всички оцелели стари постройки са паметници", обясни арх. Виктор Бузев. Според него в момента се извършва проверка как и на какво основание на "Възраждане 2004″ са били издавани строителни книжа за работа с НКЦ при липсата на лиценз за подобна дейност. [16]

На 06 декември 2010 година, Галя Стоянова, директор на дирекция "Изучаване и регистрация, документиране и архивиране на паметниците на културата" в НИНКН заявява пред Лили Границка, репортер на www.gradat.bg: „по времето на социализма са се отделяли значителни средства за реставрация - по около 20 млн. лв. годишно. Собствениците са поемали само половината от разходите по възстановяването на сградите, останалото е било за сметка на държавата". Г-жа Стоянова изказва становището, че повечето от сградите: „са строени в периода след освобождението до 30-те и 40-те години на миналия век, когато стоманобетонът не е бил познат и конструкциите им съответно не са много здрави. След промените през 1989 г. голяма част от сградите паметници на културата, бяха реституирани, а след това препродавани многократно. И макар че по документи имат собственик, на практика те бяха оставени да се саморазрушат, действайки по сталинския принцип "няма сграда, няма проблем". Така се разчистваше поредният терен." [7]

За разчистване на терени можем само да предполагаме. До сега няма официално изнесена информация и не са доказани такива намерения и действия, както няма информация да е осъден някой, по простата причина, че унищожаването с действие или бездействие на недвижим паметник на културата не се класифицира като престъпление.

2.6. Наличие на други причини за създаване на опасност

Естествено, съществуват още много причини за създаване на предпоставки за рисковото състояние на много от недвижимите културни ценности. Ако се спрем по-подробно на всяка една от тях ще нахвърлим многократно изискуемия обем на доклада. Затова, те само ще бъдат споменати, дотолкова, че да се добие малко по-пълна картина за ситуацията. За целта ще използваме опита на екип професионалисти в сферата на културното наследство, които ежедневно се срещат с проблемите и са създали интернет страницата **http://heritage.bg**, в която са събрали и систематизирали актуалните проблеми – от нормативната уредба до конкретни институционални дефекти, като целта им е не само да констатират проблемите, но и да дадат предложения за техните решения. Ето някои от тях: [17]

✓ Липсва координация между Закона за културното наследство, Закона за кадастъра и имотния регистър, Закона за устройство на територията, Закона за общините и местната администрация, Закона за земеделието и горите и др.

✓ Множество обекти се изпълняват с разлики спрямо съгласуваните проекти.

✓ Липсват достатъчен брой експерти. Малък брой хора обработват проектите за цяла България.

✓ Липсва стратегическо предаване на опит между поколения колеги, експерти, институции.

✓ Липсват местни териториални звена за проучване на обекти културно наследство и оценка на проекти, на база на знания за даденото място, като единствено в Пловдив има такова звено, което е без права за реална намеса в негативните процеси на място.

✓ Общият брой на недвижимите културни ценности в България е около 40000 Данните обаче не са сигурни, защото не се извършва актуализация. Т.е. днес не знаем в какво състояние са тези обекти.

✓ Липсва специализиран кадастър за културното наследство. Работи се с остарели кадастри за населени места, стари карти, схеми, документи и др.

✓ Деловодните системи на Министерство на културата и НИНКН не са обвързани. Всяка институция използва различна електронна система.

✓ Декларирането и регистрирането на НКЦ са излишно усложнени.

3. Изводи

Всички посочени в този доклад проблеми забавят действията по осигуряване стабилност на конструкциите на сградите, обявени за НКЦ, с което ги правят потенциално опасни за обитателите, преминаващите, работещите по реконструкцията и ремонта им, контролни органи, екипите на Гражданска защита и Пожарна безопасност и защита на населението и други. Дори да оградим всички НКЦ, няма да ги направим безопасни. Необходими са спешни мерки за поетапно (групово и единично) решаване на проблемите, които ги правят рискови.

Екипът, който стои е създал интернет страницата **http://heritage.bg** дава предложения за техните решения и който иска да се запознае с тях, може да го направи на http://heritage.bg/predlojenie/. [18]

Аз ще коментирам само някои от тях:

Специалистите предлагат „Да се създаде дългосрочна стратегия в сферата на недвижимото културно наследство и неговото опазване..“ и „Да се създаде и провежда целенасочена държавна политика за популяризиране на наследството сред обществото: какво е Недвижима културна ценност, защо е ценна и защо трябва да пазим тези обекти. Така ще се създава национално самочувствие и на базата на културното ни наследство.“ [17]

Основата на възникване на всеки проблем е в неразбирането и неосъзнаването му. Ако мотивираш собственика да се гордее, че притежава недвижима културна ценност, то той ще намери начин да положи грижи за нея. Но не мотивация от рода „освободен от данък сгради“ [19], защото инвестицията за поддръжка и възстановяване е много по-голяма от „спестените пари“. Тази мотивация трябва се изгражда още от ранна детска възраст. Изграждането й от страна на родителите е трудно постижимо, защото в голямата си част те самите не са мотивирани. „До голяма степен това е наследено поведение от тоталитарния период, когато обществено-политическата система е подтискала гражданското общество и индивидуалното мнение, личната позиция е безсмислена, дори опасна за индивида. От друга страна в същия период властта залага на културната идентичност в своята

борба с „врага“ на Запад и целенасочено подпомага опазването на наследството със законови и финансови мерки. Така на практика през социализма се постига ефективно опазване на културното наследство без активното изискване (и участие) на обществото за това.“ За съжаление, и след периода на т. н .“социализъм“ се оказва, че „държавните приоритети са далеч както от културата по принцип, така и от опазването на наследството в частност.[20] Докато ръководителите на държавата не преосмислят приоритетите си, няма да може да се постигне особен напредък в областта на опазването и съхранението на недвижимите културни ценности, което е пряко свързано с осигуряване на тяхната безопасност.

Много често се водят спорове дали недвижимите културни ценности трябва да се надстрояват, пристрояват и т. н. Тези спорове са абсолютно излишни. Ако една културна ценност може да се спаси чрез някое от тези действия, и това да я направи безопасна, то това действие трябва да се приложи или изпълни. При вземането на такива решения трябва да се подхожда индивидуално – за конкретния обект, като се включват специалисти от различни области: история, архитектура, археология, строително инженерство, химия, изкуствоведство, реставрация, климатология, пожарна безопасност, гражданска защита и т. н.

Можем да дадем няколко примера за успешни решения:

❖ Град Варна, ул. „Иван Драсов“ № 10 [Фиг. 14 и Фиг. 15]



Фиг. 14. Западна фасада



Фиг. 15. Южна фасада

❖ София, бул. Цар Освободител 2 [Фиг. 16]

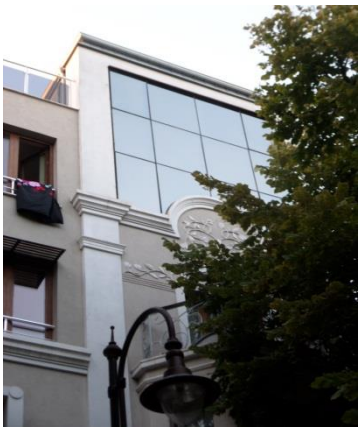


Фиг. 16. Сграда на Банка БНП Париба

❖ Град Варна, ул. „Братя Шкорпил“ № 12 [Фиг. 17 и Фиг. 18]



Фиг. 17. Общ изглед



Фиг. 18. Част от надстройката

Основен принцип при вземането на решение дали една НКЦ да се надстрои или пристрои трябва да бъде, дали това ще осигури безопасността на гражданите.

4. Съкращения

НИНКН - Национален институт за недвижимото културно наследство

ГД ИОКН - Главна дирекция "Инспекторат за опазване на културното наследство"

КИН – Културно историческо наследство

НКЦ – Недвижима културна ценност

ЗКН- Закон за културното наследство

СРР - строително- ремонтните работи

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B0%D1%82%D0%B0%D0%BA%D0%B0-%D1%80%D0%B0%D1%88%D0%B8%D0%B4%D0%BE%D0%B2-%D0%BA%D1%80%D0%B8%D0%B5-%D0%B2%D0%B8%D0%BD%D0%BE/

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VALUE MANAGEMENT IN RESTORATION OF CULTURAL HERITAGE

Eng. Marika Georgieva [1], Prof. Dr. Eng. Fantina Rangelova [2]

University of Architecture, Civil Engineering and Geodesy

***Abstract**:*

The article is considering the innovative technique for achieving maximum value of a project – Value management.

The paper explains the essence and main ideas of this technique. The report considers the applicability of the value management method in the restoration of cultural heritage. The advantages of the method are analyzed. Difficulties that may be encountered during the process of restoration of architectural and engineering heritage assets are also considered. The paper points out different software products that implement this technique.

The main purpose of this article is to make investors and designers familiar with the potential of Value management. The technology is an instrument to define clear objectives, to take optimal decision and to gain the investor's required value of each individual project.

***Key words**: value management, earned value management, cultural heritage*

1. Introduction

Value management is a project management method, which main aim is to ensure that the highest value of a project is achieved. This means that the highest quality and functionality will be achieved and all of the investor's requirements will be met, at minimum cost(funding) and time. When the method is applied in the early stages of the construction process / research and design / it implies the achievement of excellent results. This is due to the basic value management principle: a clear definition of the function of a project and setting of accurate targets for the implementation of the project, which should be clearly prioritized in the very begining. This project management technique also stimulates team work, based on the premise that a team usually performs better than an individual.

Construction projects, which include restoration of cultural heritage are among the most significant and difficult ones for implementation. In order to achieve the highest value/cost ratio, those projects require great precision at financial prediction. Construction sites, which are part of the cultural heritage, require particularly detailed analysis and planning, including in-depth study of their present state, setting clear goals and expectations of the project, a comprehensive and detailed plan for the implementation of restoration of the facility and specific quality of the project. It is necessary to collect a team of competent professionals in areas as civil engineering, architecture and history in order to achieve the objectives of the project. Completely overlapping with the above-mentioned

[1] Marika Georgieva, PhD student, Sofia city, bul. Hr. Smirnenski №1, georgieva.marika@yahoo.com
[2]Fantina Rangelova, Prof. Dr. Eng., Sofia city, bul. Hr. Smirnenski №1, fantina_fce@uacg.bg

objectives, value management is an extremely suitable project management method for restoration of buildings and other facilities, which are part of the cultural heritage.

2. Main techniques for Value management implementation in restoration of cultural heritage projects

A main principle in Value management is a team of multidisciplinary professionals with different background and attitudes to be selected. This gives an opportunity during the planning and design of the project to introduce various points of view and take a better decision for the implementation of the project itself.

There are a number of techniques for value management implementation. The most common one are: function analysis, SMART technology (simple multi-attribute rating technique), cost/worth, value drivers, target costing, value proofing, options selection, creative techniques, value drivers. This article briefly describes these techniques, which the authors accept as suitable for construction projects for restoration of cultural heritage.

In the early stages of a project, Value management is an excellent tool for precise defining of the main requirements for the project. The key objective is to determine the functions of the project, which usually leads to systematization of a few ideas /functional analysis/. The desired result is to define clearly the most essential functions in order to eliminate unnecessary ones. Thus the design of the project is simplified and the requirements and expectations of investors are mostly satisfied. The functional analysis is the means to consider in detail the final results and the functions of the final product. Once the main functions of a project are clarified, variations of solutions for project implementation can be developed. The solution that brings the highest value should have to be chosen.

After defining the main functions of the project, they have to be arranged hierarchically according to their significance. Also a cause - effect relationships between the functions have to be made. This can easily be expressed by a value tree. It helps the communication between stakeholders to be improved. The visualization also provides better understanding of the aims of the project. /SMART methodology/

After creating importance hierarchy for the functions and linking them, the next step is calculating the cost for achieving each function. The team, which is working on the project, should also be able to define what the "worth"/value of this function is, taking into account all the tangible and intangible benefits that it will bring to the project. If the implementation costs substantially exceed the value of the function, alternative solutions requiring lower costs should be developed. /Cost/worth technique/

One of the fundamental ideas of Value management is to stimulate implementation of innovative solutions. Functional analysis can be used to cause and enhance innovation and creativity. /Creative technique/

When the main aims and requirements of the project are clearly determined, the decision how the project should be implemented is easily taken. By using an option evaluation matrix, it is possible to assess the relative benefits of each option using the weighted value drivers as evaluation criteria. The best option will be the one that satisfies the value drivers the most. /Options selection technique/

3. Earned value management (EVM)

The earned value management is a technique for measuring the project performance. With the application of this technique, more accurate forecast for performance problems is provided. The risk management should be a preliminary focus when architectural and engineering heritage assets are due to restoration, which makes the Earned value management method, highly recommended for project management techniques implementation. Its main aim is to report the progress of the project by measuring cost and

time. This gives important information to all stakeholders about technical, cost and schedule performance. The implementation of this technique provides better visibility of the construction process and identifies problematic areas. For the successful application of EVM the following features of a project should be provided: project plan; Budgeted cost of scheduled work, called Planned value (PV); Budgeted cost of work performed, called Earned value (EV).

3. Analysis of the advantages of the Value management and Earned value management and the difficulties that might be encountered during the process of restoration of cultural heritage

3.1. Advantages

The restoration of cultural heritage requires: detailed analysis and preparation of the construction process; a solution that could reach the highest quality and duration by using minimum funding; strict and timely progress measurement. Since these are the main principles of the Value management and Earned value management, by implementing these techniques in the project management, the following objectives of the project might be achieved:

- Clear definition of the project scopes and functions;
- Achieving best value projects, analyzing worth/ cost ratio: improved quality and reduced cost;
- Application of innovative solutions, that are more cost-effective and time-saving;
- EVM gives detailed information about all project stages, time-schedule and cost;
- Control and monitoring of the project performance;
- Analysis and management reports are summarized, which make the process visible and more predictable;
- Reduced risk of delay and over-budget execution of the project;

3.2. Possible difficulties

Value management and earned value management are still new project management techniques. The lack of gained experience and detailed information for the specifics of the implementation of these techniques can result in meeting some of the following problems and difficulties:

- One of the main principles of Value management is developing a number of solutions for the execution, which is time consuming;
- Since Value Management encourages application of innovative methods, there is a risk for unconfident decision making;
- Conflicts between individuals, due to different objectives for the different team specialists /civil engineers, architects, historians/;
- The earned value analysis takes into consideration mainly the budget and the time for execution of the project, the quality issue is usually neglected;

4. Software products, based on Value management

The software products, which are based on Value management are applicable during the execution of the project. They serve as an excellent monitoring tool for the investor. Occasionally verifications and analysis are performed, that measure the project performance and progress. A risk analysis is also performed by the software. Their EVMS components typically include:

- EVM Scheduling Engine
- EVM Cost Engine
- EVM Reporting Engine
- Accounting system integration

Depending on the main objective of the application of Earned value management, some of the following software tools can be used:

EVMS Scheduling Engines

There are plenty of Project Management / Scheduling Engines. However the most typical scheduling engines seen in EVM systems.

- Microsoft Project / Project Server
- Primavera P6
- Deltek Open Plan
- Safran
- Artemis

EVMS Cost Engines

The products, that are listed below dominate the market according to Pinnacle Management Systems Inc. / a leading project management company/. Each of those tools has its obvious advantages and disadvantages. Most of the decision criteria will be based on an organizations current EVM / PM capabilities, existing EVM and PM tool infrastructure, and current and future EVM goals.

- EVMS forProject
- Deltek Cobra
- EcoSys EPC
- Oracle Primavera Cost Manager

EVMS Reporting Engines

wInsight is the dominant EVM reporting product on the market. Another reporting engines are listed below.

- Deltek wInsight
- EcoSys EPC
- DecisionEdge
- Combined EVM Tools

There are a few tools on the market that combine Scheduling, Cost and Reporting into a single product.

- Unanet
- Safran
- Dekker Trakker

4. Conclusion

The value management and earned value management are very suitable project management techniques for projects including execution of restoration of architectural and engineering heritage assets. Their main principles cover all specific requirements and needs of such projects. The techniques for value management implementation encourage team work, which generates discussions and development of solutions that will be taken into consideration for historical, engineering and architectural problems today and in future. The Value Management method is not only stimulating planning, designing and

execution of a comprehensive project, but also achieving the best project value: reached tasks for the lowest cost possible. Earned value management is an excellent tool for investors to perform control and risk analysis, which are one of the most important objectives in the lifecycle of a construction project, and especially for the restoration of cultural heritage. The disadvantages of these techniques could be overcome with implementation in different projects and gaining more experience and information about their detailed specifics.

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SEISMIC RETROFITTING OF CULTURAL HERITAGE WITH TEXTILE REINFORCED MORTAR

Gianmarco de Felice[1], Stefano De Santis [2]

Roma Tre University, Department of Engineering

***Abstract**: Externally bonded composites are emerging as an effective solution for structural upgrade and seismic retrofitting, since their high strength-to-weight ratio ensures significant improvement of mechanical performances with minimum encumbrance and mass increase. This paper shows relevant applications of Textile Reinforced Mortar for the seismic retrofitting of architectural heritage. More specifically, a technique for the extrados strengthening of vaults carried out in the rehabilitation works realized in Italy after 2009 L'Aquila and 2012 Emilia earthquakes is presented. The performances of these system are discussed with reference to the experimental tests carried out in the laboratory and in situ. On this basis, the potentialities of TRMs for this strategic field of civil engineering, with crucial cultural and social importance are highlighted.*

***Key words**: Cultural heritage, Retrofitting, Textile reinforced mortar, Composites*

1. Introduction

The performance of cultural heritage building under seismic action is one of the challenging research topic due to the necessity to withstand safety conditions while fulfilling preservation criteria. In some cases, traditional techniques, that ensure the accomplishment of preservation criteria and also provide the adequate durability, are not sufficient for ensuring a sufficient seismic safety. For instance, recent earthquakes in Italy have shown the high seismic vulnerability of thin in-folio brick masonry vaults. Due to their slenderness, these vaults are particularly vulnerable against unsymmetrical service loads, relative horizontal displacement of the abutments and seismic actions. Therefore, in numerous existing structures in seismic-prone regions, the vaults need retrofitting to ensure an adequate safety level according to current standard codes. To this purpose, externally bonded reinforcements with composite materials have proven to be particularly advantageous [1-3] since they provide high mechanical performances with minimum thickness and mass increase.

[1] *Gianmarco de Felice, PhD/Proff., Roma Tre University, Department of Engineering, e-mail: gianmarco.defelice@uniroma3.it*

[2] *Stefano De Santis, PhD/MSc., Roma Tre University, Department of Engineering, e-mail: stefano.desantis@uniroma3.it*

In the last two decades, most research activities and field applications have made use of composites with polymeric matrix (Fibre Reinforced Polymers, FRPs). Nevertheless, a new generation of composites has been recently proposed that consist of high strength fabrics (made out of steel, carbon, basalt, glass, PBO or natural open meshes) embedded into inorganic (mortar) matrices. Mortar-based reinforcements are named Textile Reinforced Mortars (TRM) or Fabric Reinforced Cementitious Matrix (FRCM) when comprising carbon, glass, basalt, or PBO fabrics, arranged in the form of open meshes, or Steel Reinforced Grout (SRG) when making use of steel textiles. The use of mortar in place of resin ensures the fulfilment of the principles of conservation and restoration, such as respect of authenticity of materials and structural behaviour, minimum intervention, reversibility, substitutability and removability, and compatibility with original substrates and decorative settings. For all these reasons, mortar-based composites appear particularly promising for applications to masonry structures and cultural heritage. However, inorganic matrices may entail lower bond strength than epoxy resins and require proper installation and curing conditions to ensure the bond with the substrate. In the last decade, increasing research efforts have been devoted to the study of TRMs, fostering a fast technological and industrial development. At the same time, several applications have been realized for safeguarding cultural heritage against earthquakes. The TRM-to brick/masonry bond behaviour has been investigated by a number of studies [4-6] that provided fundamental information on bond strength and failure modes, and highlighted the role played by the mechanical properties of the matrix, the layout of the textile, and the roughness of the surface of the substrate. Nevertheless, a better knowledge still needs to be gained, especially on some issues (such as durability, design criteria, installation details, etc.) and, apart from the US document ACI 549.4R-13, no specific guidelines have been developed yet.

In the present paper, the application of mortar-based composites for strengthening brick masonry vaults in the rehabilitation works realized in Italy after 2009 L'Aquila and 2012 Emilia earthquakes is presented and the performances of these system are discussed. The strengthening design for masonry vaults would require that a deeper knowledge is gained on the actual bond behaviour of the composites on a curved substrate and on the key variables that affect it, since in the presence of a curvature, except few recent works [7], the reinforcement-to-substrate bond behaviour has not been sufficiently investigated. To this end, an experimental investigation carried out on the application of TRM systems to the extrados of brick masonry vaults is presented. The tests are devoted to get a deeper knowledge on effectiveness of the reinforcement when applied to a convex substrate. The tests have been carried out both in the laboratory and in the field, allowing for investigating the actual performance of the reinforcement and the resulting increase in load carrying capacity of the vault.

2. Extrados strengthening of brick vaults

Among the different mortar based composite systems that are available in the market, in the present case, a unidirectional fabric consisting in very thin cords of Ultra High Tensile Strength Steel (UHTSS) embedded into a lime-based mortar are used for retrofitting of the vaults. Steel textile have about 3200 N/mm^2 tensile strength and 185kN/mm^2 Young's modulus. They were applied with a lime based mortar having 15 N/mm^2 compressive strength and 22kN/mm^2 Young's modulus. With respect to the fabrics with other fibre materials, steel textiles are stiffer and stronger than glass and basalt and thicker than carbon, aramid and PBO, are isotropic (which provides better toughness), more durable in alkaline environment, and need lower cost and energy for production. Figure 1 shows the installation process of the Steel TRM on the extrados of the vault. Given the one-directional properties of the steel wires that constitute the reinforcement, the

application is carried out in two subsequent phases in the orthogonal directions, according to the double curvature of the vault. The width and the spacing between the strips are designed to provide the requested increase in strength as well as to prevent any local fall of bricks during seismic events. The steel wires are directly inserted into drilled holes at the abutments and injected as to provide a further restraint. Accordingly, if for any reason the bond between the reinforcement and the extrados of the vault deteriorates, the end connections would still allow the reinforcement to contribute as unbonded tendons. The presence of the steel fabric at the extrados of the vault is able to prevent the opening of cracks, thus inhibiting the four hinges collapse mechanism that would take place in unreinforced vaults. Additionally, the retrofitting of the vault with this technique succeeds in preserving decorative settings at the intrados with no changes in the thickness nor increase in the mass of the structure.



Fig. 1. Phases of strengthening brick masonry vaults at the extrados: a) preparation of the extrados of the vault after the removal of the filling; b) application of a primer for enhancing the bond between the extrados of the vault and the inorganic matrix; c) application of the Ultra High Tensile Stress Steel strips; d) end connections at the abutments; e) application of the covering layer of mortar matrix and of a second transversal set of strips; f) construction of brickwork spandrel walls for the backing and filling with granular material.

3. Laboratory tests on extrados strengthening of brick masonry vaults

The tests carried out in the laboratory were designed to simulate as closely as possible the effective behaviour of the vault, including the contribution of the buttresses

and of the filling materials. As it is well known, both these contributions are crucial in the stress transfer and cannot be neglected in the analysis.

Since the activity is currently underway, only some preliminary results are presented in this note, which however are sufficient to show the effectiveness of the strengthening system. As a preliminary activity, several double lap bond tests were carried out aiming at evaluating the bond properties between the composite system and the brick masonry substrate in the presence of curvature (Figure 2). These tests provided the failure mechanisms and the increase in bond strength related to the convex curvature, allowing to design the strengthening of the vault.

The experimental setup was designed to simulate the worst loading conditions that bring the vault up to failure due to the activation of a four hinges mechanism. The load was applied over the filling at about one third of the span by means of an hydraulic actuator. Tests were run under displacement control to follow the whole load displacement post-peak response up to failure.

Only two tests on the vaults have been carried out to date, consisting of two sections of the vaults, with 2800 mm span, 55 mm thickness and 500 mm depth. The first specimen was representative of the actual conditions of the vault before retrofitting, while the second specimen was retrofitted by applying the reinforcement to the extrados, consisting in UHTSS with 8 cord/inch, with 150 mm with, having an overall cross section of 25.2mm^2. The applied load was directly provided by the loading cell of the actuator, while the displacement filed of the vault and of the filling during the test was recorded by means of nonconventional contactless measurement methods, such as the Digital Image Correlation. Strain gauges were also glued to the reinforcement textile to record the stress and estimate the load carried by the steel cords.

The tests (Figure 3) results can be summarized as follow: the presence of the SRG reinforcement led to an increase of the load carrying capacity of the vault of 280% (from 5.7 kN to 15.4 kN. In the unreinforced specimen, a four hinge mechanism activated, while the SRG strips bonded prevented the development of the cracks at the extrados. Failure occurred by a combination of crushing in the masonry and shear sliding between the bricks under the load application point. The SRG strips detached from the substrates in some portions (detachment occurred at the textile-to-matrix interface).



Fig. 2. Bond failure between TRM and brick masonry for planar and curved substrates.

4. Field tests on extrados strengthening of brick vaults

Tests were carried out in an historic building in the city centre of L'Aquila, Italy, badly damaged by a strong earthquake in 2009, and currently undergoing important reconstruction and retrofitting works. Testing setup (Figure 5) was designed to simulate the loading conditions that the reinforcement would experience if a crack develops at the extrados of the vault, due to the activation of a mechanism, in order to investigate the reaction that SRG is able to provide up to debonding. The textile was bonded to half of the vault and subjected to tensile loading at the crown. A 1 m long portion of textile was left unbonded and gripped to apply a horizontal (tangent to the vault) load. Two steel plates were used to clamp the textile. A ∅16 threaded steel bar was welded to the lower plate that transferred the load applied by means of a hollow hydraulic actuator, that contrasted with steel beams connected to the side walls.

The oil pressure in the actuator was provided by a hydraulic pump and measured by a manostat, allowing for deriving the applied load. The relative displacement between reinforcement textile and substrate at the loaded end (slip) was measured by two linear displacement transducers. Finally, two 10 mm resistive gauges were glued to the unbonded textile to record strains and derive a further measure of the applied load. Three tests were carried out. The first cracks appeared near the loaded end of the reinforcement (i.e., its first bonded section) on the upper side of the SRG strip, and orthogonal to the load direction. Longitudinal cracks also developed on the side of the SRG strip. The crack pattern progressively evolved during load application, up to the detachment of the reinforcement from the substrate, which occurred progressively starting from the loaded end, and at the end reached the springing section of the vault and involved the whole SRG tape (Figure 4a). At the springing, the SRG strip was connected to the side wall with mechanical end pivots (SRG connectors placed in inclined drilled holes and injected with grout). Tests were never carried out up to the pull off failure of the connectors. At the end of the test, the entire upper layer of mortar matrix disintegrated and the steel textile detached from the lower layer, which did not debonded from the substrate.

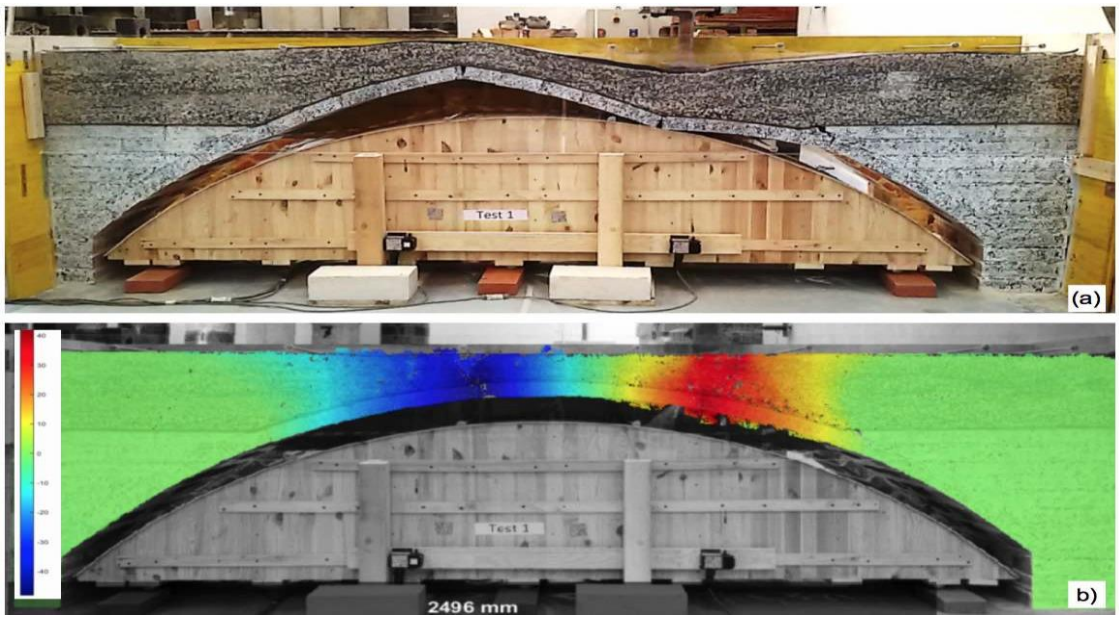


Fig. 3. Laboratory tests on real-scale in-folio vaults retrofitted with Textile Reinforced Mortar: a) collapse configuration and b) analysis of the displacement field with Digital Image Correlation.

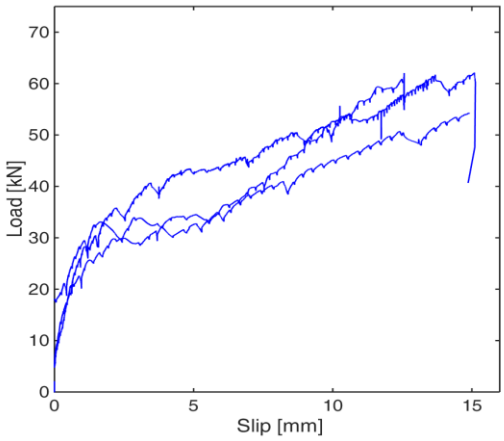
a)  b) 

Fig 4. Field tests on extrados strengthening of brick vaults: a) debonding of SRG strips at the end of the test; b) load-slip responses

The load-slip curves of the tests display a good agreement (Figure 4b), considering the variability of substrate and setup, which is unavoidable in field testing. The response is characterized by three phases associated to progressively reducing stiffness.

The first phase is associated to an un-cracked behaviour of the reinforcement. The measured displacements are related to elastic deformations and small settings. The second phase is related to the crack development of the matrix and the activation of the detachment of the reinforcement from the masonry substrate. The transition from the first phase to the second phase can be identified by the occurrence of the first cracks and the increase of the relative displacement between reinforcement and substrate. Up to the end of the second phase, the bond behaviour of the SRG reinforcements applied to the vault is similar to that observed in laboratory tests on small-scale specimens [6]. The third phase is a peculiar characteristic of the behaviour of SRG reinforcements applied to the extrados of masonry vaults, since it is related to the very large bonded area and to the curvature of the substrate. In this third phase, in addition to the cohesive strength, a friction contribution activates. The former (cohesive contribution) is associated to the bonded textile that, once the debonding process has initiated, moves away from the loaded end. The latter (friction contribution) is mobilized on the detached portion of the reinforcement, as a result of the curvature of the vault. Since the SRG is applied to the extrados, when a tensile load is applied to the steel textile, normal compressive stresses arise at the reinforcement-to-substrate interface. As shown by the experimental response curves, the component related to friction grows with the increase of the tensile load in the steel cords and of the area of SRG that has detached from the substrate, and significantly contributes to the overall strength. Table 1 lists the main results for each test, namely the maximum attained load (F_{max}), the corresponding load per unit width ($F_{max,u}$), stress in the textile (σ_{max}), and exploitation ratio of tensile strength (η), the mean strain (ε_m) in the textile, and the slip (s) at peak load.

Table 1. Results of field tests.

Test	F_{max}	$F_{max,u}$	σ_{max}	η	ε_m	s
	kN	kN/m	N/mm^2	-	10^{-3}	mm
1	62.1	414.3	1631.2	56.2%	5.63	15.09
2	54.2	361.6	1423.6	49.1%	4.65	14.88
3	60.9	406.1	1598.9	55.1%	4.91	12.48
Mean	59.1	394.0	1551.2	53.5%	5.06	14.15

5. Conclusions

Laboratory and field tests were carried out to investigate the effectiveness of mortar-based composite systems for the reinforcement of masonry vaults. Lab tests were performed on full scale brickwork vaults and indicated that the load carrying capacity can be improved by up to about 3 times with steel cords strips applied over the extrados of the vault. In order to reproduce actual field conditions, specimens were provided with buttresses in solid brickwork and filling. Digital image correlation was used to record the displacement of the brick units as well as the strain field in the fill.

Field tests provided information on the shear bond strength of SRG strips applied to the extrados of brick masonry vaults: on average, the maximum achieved load was about 60 kN, corresponding to a load per unit width of 350 kN/m, a stress in the textile of 1550N/mm^2 and an exploitation ratio of the tensile strength of the textile of 53%. The stress attained at failure proves the need of using a textile with particularly high mechanical properties, such as the Ultra High Tensile Strength Steel, for this kind of application. The values of the exploitation ratios are significantly higher (up to 3 times) than those obtained in laboratory tests on plain substrates, indicating the important strength contribution provided by the convex curvature of the extrados surface of the vault. The presence of the end connectors, whose contribution was not mobilized in the tests, could lead to an even higher strength. Failure occurred by detachment at the interface between steel textile and mortar, and not within the substrate as generally occurs with the more traditional FRP reinforcements. Therefore, the result of the test appears basically independent from the mechanical properties of the substrate (strength and stiffness of the masonry of the vault). On the other hand, due to the presence of a friction contribution, the bond strength depends on the curvature of the vault and on the bond length.

It is worth highlighting that the performance of the strengthening system strongly depends on the accuracy of the installation, on the preparation of the surface of the substrate (whose roughness should be ensured), and on the curing conditions of the mortars.

A larger number of experimental results is needed to develop a deeper understanding of the mechanical behaviour of mortar based composites for the retrofitting of masonry vaults, also considering the lack in the scientific literature of analytical/numerical methods for the reinforcement design and the assessment of the strengthened vault. Nevertheless, the studies carried out so far have indicated that SRG can be an effective and cost efficient solution for the safeguarding of historic masonry structures against earthquakes, and, more in general, for the conservation of architectural heritage.

Acknowledgement

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НАПРАВЛЕНИЕ 4

Възстановяване на сгради от културно-историческото наследство, изпълнени от зидария, дървени или метални конструкции-критерии, иновативни решения и казуси; Сеизмична рехабилитация на сгради от културно-историческото наследство; Опазване и съхраняване на недвижими културни ценности; Консолидация, възстановяване и укрепване на исторически структури; Сгради и съоръжения принадлежащи към културно-историческото наследство - след катастрофални събития: пожар, наводнения и взривни въздействия.

TOPIC 4

Restoration of historical masonry, timber and steel structures-criteria - innovative solutions and case studies; Seismic rehabilitation of historical masonry, timber and steel structures; Conservation and preservation of historical masonry, timber and steel structures; Consolidation, rebuilding and strengthening of historic structures; Culture heritage under catastrophic events: fire, flood and blast loading.

PROTECTION AND PRESENTATION OF ARCHAEOLOGICAL SITE MEDIANA

Slavko Zdravković[1], Dragan Zlatkov [2], Predrag Petronijević[3], Ana Momčilović-Petronijević[4]

The faculty of civil engineering and architecture of the University in Niš, A. Medvedeva 14, Niš, Serbia

***Abstract**:The paper presents the overall planning, technical protection, presentation and future role of the archaeological site "Mediana" in the tourism of Nis. The most representative building complex, the Villa with peristyle and nearby structures are presented. In the first phase, the entire space of the Villa with peristyle, including Nimfej was covered. The complex was covered by a space structure, using an arched timber structure of a span of 72.5m with a day height of 11m which was the archaeological and conservational condition. The function of the structure is to protect the archeological remains of the architectural complexes of buildings, and above all of the very valuable floor mosaics and frescoes from the adverse weather effects. The entire concept of protection is designed to allow continued unimpeded research and restoration of all undiscovered archaeological values, as well as to provide realization of the full tourist potential at the highest level the tourist industry requires.*

***Key words**: Mediana, protection of site, arch structure*

1. Introduction

On the territory of the Republic of Serbia there are 189 archaeological sites that have the status of immovable cultural property, of which 19 have a category of exceptional, and 25 of great importance [3]. Only five archaeological sites have built protective structures over some of their parts, and they are: Lepenski Vir, Drenovac, Sirmium, Viminacium, and Mediana. Design of such protective structures is a very complex and currently topical issue. Protective structures are mostly used for the protection of archaeological sites with mosaics, but they serve to protect other sensitive structures, which either cannot survive outdoors or their maintenance and presentation is difficult [5]. So far, seven protective

[1] Dr, Full Professor, Academic of Serbian Royal Association of academics, innovators and scientists, Expert of the Federal Ministry of science, technology and development in the field: Civil engineering, Aseismic engineering, Bridge stability, The Faculty of Civil Engineering and Architecture, University of Niš, A. Medvedeva14 Niš, Serbia, slavko.zdravkovic@gaf.ni.ac.rs
[2] Dr, Professor, The Faculty of Civil Engineering and Architecture, University of Niš, A. Medvedeva14 Niš, Serbia, dragan.zlatkov@gaf.ni.ac.rs
[3] MSc Predrag Petronijević, Assistant, The Faculty of Civil Engineering and Architecture, University of Niš, A. Medvedeva14 Niš, Sebia, predrag.petronijevic@gaf.ni.ac.rs
[4] Dr, Professor, The Faculty of Civil Engineering and Architecture, University of Niš, A. Medvedeva14 Niš, Serbia, ana.momcilovic.petronijevic@gaf.ni.ac.rs

structures have been built in Serbia, three of them are raised above the buildings with mosaics [7]. The protective structure with the largest surface area of the mosaic that is protected, was designed and implemented at the archaeological site of Mediana.

2. The archaeological site Mediana

Mediana archaeological site is located in the area which covers 80 hectares. It is positioned east of Niš, a few kilometers from the present town center. The northern part of the site is declared the immovable cultural heritage and has a category of great importance, and the southern part enjoys the prior protection. The Villa with the peristyle is the most important discovered building in Mediana so far. This is a complex architectural structure of several buildings which are spread over a total area of about 7000m^2. The direction of the villa is approximately north-south. It is composed of a central part, which contains an entryway, a large inner courtyard - atrium with a pool and a porch that surrounds it, and from which residential areas are accessed. On the north side, the porch leads into a large two-part representative hall "triclinium with an apse," which is separated from the porch level with three stair heights. On its eastern side a small hall triclinium with a fountain is located, and symmetrically to the west another structure of similar purpose, "stibadium" is positioned. On the northwest, the villa is with a single longitudinal corridor connected to the thermal spa, Representative rooms of the villa were heated by the hypocaust system. The floors of the rooms were treated differently. What makes this villa prominent is a large floor area decorated with mosaics, around 1000m^2. A large number of rooms had wall surfaces decorated in the fresco technique [1].

The villa with peristyle is the central and most important structure of the archaeological site Mediana. The significance of this building is that a large area is under mosaics, very well preserved,too.. Floor mosaics were intended as decorations for the porch, triclinium, nimfeum, stibadium, thermal spa and a corridor between the spa and the villa.



a) b)

Fig. 1. a)) The mosaic of the apse triclinium, from [4]; b) The villa with peristyle, the presentation of the river deity (photo P. Petronijević)

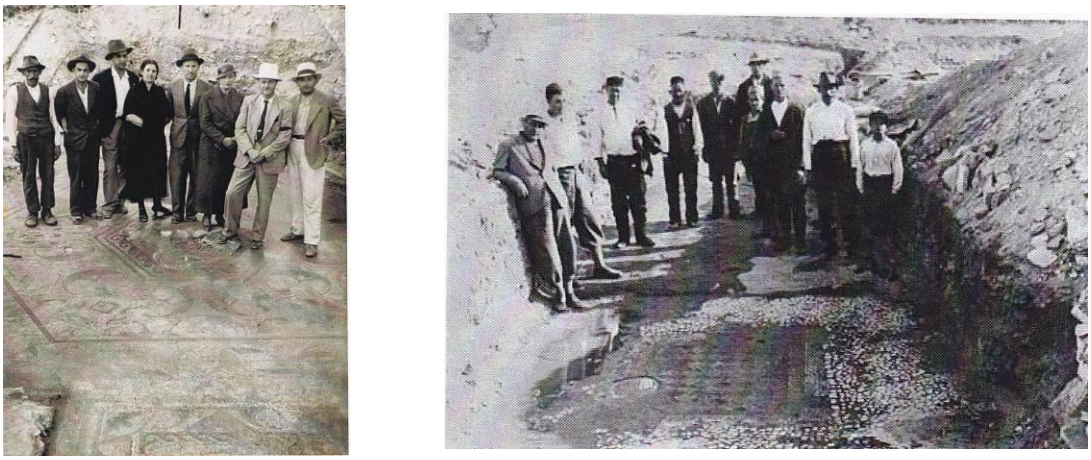
The best preserved mosaic ensemble at Mediana is in Nimfeum (triclinium). The central hexagonal room and attached niches on four sides have mosaic floors with different geometric designs. Seen as a whole, this mosaic has a central scheme dominated by a complex composition of hexagonal mosaic. In the peristyle of the villa there is a number of mosaics with geometric patterns and a panel with a figurative representation. Peristyle had a mosaic surface 471.5m^2, of which about 70% was saved. Various geometric motifs were used for decoration. The northern part of the porch is distinguished by numerous and

complex motifs. In its middle part is the panel of total area about 10m^2 which contains a presentation of a river deity in the form of a strong male figure in a sitting position. In the apse triclinium of the Villa is a dominant mosaic with the image of Medusa [4].

3. Research history and site protection

Mediana is first mentioned as a human settlement in IV century in the writings of the Roman historian Marcelius Armius. Two centuries later, it is mentioned in a list of cities that were restored by Justinian the Great. As a suburb Naisa it is assumed that it flourished under Constantine the Great. The first archaeological excavations started in 1930s. The museum building over Nimfeum with extremely well preserved mosaics was built in 1936. The first serious research in the area of this archaeological site began in 1961. Then, about 250 probes were done, thus establishing the spread of the settlement, its borders and its character. The following year, a thermal spa and a villa with peristyle were discovered and preserved. During the 70s, along with intensifying the works on the central villa, at the same time research was carried out on "Horeum", on the route of the Niš-Niška Banja road. In the area of the factory complex EI Niš in 1980s a large water tank for water supply of the village was discovered [1].

In the period that followed, research works continued. On several occasions the conservation and reconstruction of some parts of the building was performed. A total of about twenty structures were explored and the same number was only confirmed by probes. Of the total number, seven buildings had mosaic floors.



a) b)

Fig. 2. a) the discovery of mosaics in Nimfeum, 1935; b) a corridor between the Villa with the peristyle and thermal spa, 1935.(Documentation: National Museum in Belgrade, from [4])



a) b)

Fig. 3. a) raising mosaic in one piece, 1973; b) work in the western part of the peristyle, 1973. (Documentation: National Museum in Belgrade, from [4])



a) b)

Fig. 4. a) Stibadium; b) works on mosaic conservation (photo P. Petronijević)



a) b)

Fig. 5. Mosaics in the Peristyle; (Photo P. Petronijević)

4. Protective structure

The research carried out in Mediana during 1930s was focused on the structure of the orthogonal layout with an exceptionally well-preserved mosaic (Triclinium - Nimfeum). Recommendation of the researchers was to protect the mosaic by erecting a hard material structure above it. In the previous period only research activities were carried out and the findings were backfilled for protection . One of the first protective structures in this part of Europe, and certainly the first in Serbia, built to protect and present the part of archaeological site was constructed right here, way back in 1936. The opening ceremony of the Museum of Mediana, with a small exhibition setting was performed on Vidovdan, 28th of June, 1936 in the presence of citizens and authorities. Mediana then became the most visited site and museum [6].

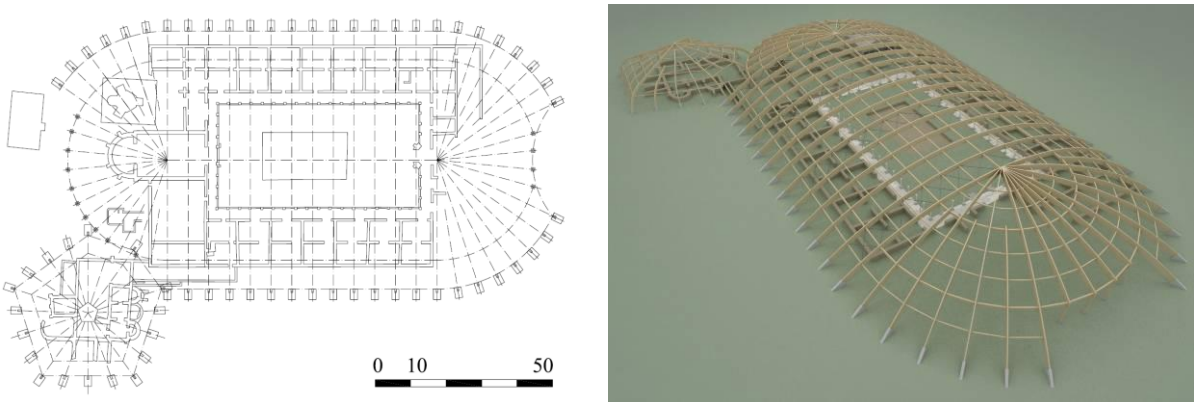
The Villa with peristyle has not been fully explored. The idea of its presentation by covering was launched in 2009. In 2012 the presentation and protection project was launched for the second time, which included the construction of protective structures over all the parts explored so far, and which would allow the presentation of mosaic floors and other preserved architectural elements. Implementation of protective archaeological research had preceded the making of protective structures.

Short before the celebration of 1700 years of declaration of the "Edict of Milan" it was planned to cover the archaeological site Mediana, which would permanently solve the problem of protection of the villa with peristyle and at the same time mosaic floors would become available to general public and visitors to the site. The most common form of this

type of protection is in the form of light, transparent LLD construction that was already implemented in many locations such as Limassol in Cyprus, Viminacium near Kostolac and others.

Protective structures at archaeological sites are much more than what their name suggests. These structures must satisfy a number of very specific requirements, for which engineers and architects are not prepared by their standard education. Design of the greatest number of protective structures built in our country is initiated and conducted at the National Institutes for Cultural Heritage Preservation, because their professional staff combines engineering and conservation knowledge [8]. Realization of projects themselves is very often entrusted to the same institutions. In these endeavors, participants in the design and construction phase should be aware that their word is not decisive or most important, and that they would meet the experts whose knowledge and views on the issues are diametrically opposed. Not understanding the construction, the way of design and other technical issues is a big problem for archaeologists involved in research of archaeological structures. Use in tourism and visitors needs further complicate the task of designing. By sublimating all requirements, significantly better results are achieved relative to protection structures with predominantly only one mentioned view [9].

The construction of the building is composed of two parts: the central capsule and the annex which have been designed as spatial linear systems with a PVC covering membrane with taut cable network. The total building area is 10300m^2. High-quality fasteners, industrial production of supports, high resistance to fire, light and easy installation, unambiguous economy are just some of the parameters that influenced the choice of materials and structural system. Application of the arched LLD roof system has been established as the optimal solution for covering this type of structures [10]. Research in the field of timber structures in the recent decades in the world and in our country made it possible to design a very bold construction. The main project included the global statical analysis of the construction composed of linear elements. Given the considerable span of the construction (L=72.50m), we started with the detailed analysis of stress and strain relationships and the supporting joints in characteristic nodes. The analysis was performed using the finite element method (FEM), and nodes and supporting links were modeled specially.



a) b)

Fig. 6. a) the base of the structure; b) axonometric projection of the protective construction

According to the concept of architectural design the object consists of two independent structures. A central "capsule" with dimensions 138.4x72.5m and a pentagonal hall with a side of 25.6 m. The system is prefabricated constructions. For architectural reasons, the height of the arched construction (arrow) is limited to 11m so that the compression of the arch is f/l=1/6.6. The selected double-hinged arch is aesthetically

pleasing and is slightly sensitive to relative vertical settling of support. Due to the nature of the site location, for archaeological reasons, excavation works and foundation had to be reduced to the lowest possible level. Taking into consideration the type of the arch construction with a relatively small chord in relation to the span, it is the least favorable combination of a large horizontal force with a small vertical reaction (Hmah/Vmin). By varying the degree of restraint for the relevant frame, closest to the asymmetric calotte in which for the symmetrical constellation of loading the asymmetrical field of force is also formed, the iterative redistribution of static forces was carried out. As the optimal choice of the restraint degree in terms of the construction economy, we obtained the value of α=0.25 which corresponds to the footing and the main support beam, dimensions b/d=2.0/3.8m and b/d=20/150 cm. Thus the chosen level of restraint improves the state of stress in the cross section of the field, somewhat reducing the length of arch buckling in its level and foundation dimensions have the minimum increase. Stability analysis showed that the structure has a satisfactory safety factor, greater than 10.5 for the major support beams in the central span, and the critical buckling force of N_{kr} = 4486kN [10].



a) b)

Fig. 7.: a) north entrance; b) museum building (photo P. Petronijević)

According to the project request of conservationists, it was necessary to build a classic foundation structure with minimal engagement of mechanisation. Application of alternative solutions in the form of deep foundations on piles or geotechnical anchors could not be considered. In the underground part the limitation was the devastation of archaeological layers. A special request was that in the future the possible removal of the basement construction should be enabled. On the aesthetic side, such a solution required reliance on arches to harmoniously fit into existing historic neighborhood, which required that the visible part of the foundation is minimal, that the only visible part of the foundation is its neck [11]. As far as authors of this article know, this is an extremely rare design of the arch with a shallow foundation and with a relatively large span in flat terrain.

For frames foundation the pad foundation of dimensions 2x3.7m was adopted, based on the depth of founding of 1.50m (recommendations from the geotechnical report). The terms of foundation have required replacement of the soil and making significant gravel cushions in order to improve capacity and reduce deformability of the ground. The "neck" of the foundation is 40cm wide and is adapted to the conditions of supporting the lamellar arched wooden structure. The foundation of doubled end bearers is 3.0x5.0m. To prevent slipping and overturning of the foundations, a joggle 60cm wide and 2.20m deep is designed on the inside, which ensures the activation of the passive earth's pressure for the most unfavorable combination of reactions.



a) b)

Fig. 8.: a) foundation of the support beams; b) newly found remains of the structures in the place of foundations (photo P. Petronijević)



a) b)

Fig. 9.: a) northeast appearance; b) south appearance

5. Conclusion

In the design and construction of protective structures at the site of Mediana there were special requirements at all stages of the project. The structure was built in the area which had a category of great importance as immovable cultural property, but the structural span exceeded 50m, which in line with current legislation entailed specific licenses for individuals and legal entities in order to access planned works and activities [8]. The fact that the site is located in the first zone of sanitary protection of sources areas and infiltration lakes for water supply of the city of Niš further complicated the works of founding the structure.

Although not fully complete, largely for financial reasons, the protective construction has multiple positive impacts on the site and buildings that it protects. After a few decades of the last conservation, the conditions for continuation of mosaics conservation and their presentation are once again created. Recently at Mediana there was an exhibition celebrating 80 years of building the museum at this site - the first protective construction we discussed. The original design planned for the demolition of the museum building, but because of its historical significance that idea was given up. The new protective structure has already covered the museum building.

1700 years old mosaics were uncovered, they have been so far under the sand, and finally made available to the public. 80% of mosaic floors are available to visitors. All mosaics located in the villa are presented and all the elements of architecture together with underfloor heating systems are available in several rooms. The visitors can now for the first time also see one of the most beautiful mosaics located in Stibadium, 72m^2 of area. Construction of this protective structure has greatly contributed to the popularization of

this site. Visitors to Niš have recently been able to enjoy all the beauties of the archaeological site of Mediana. Under the protective structures numerous meetings, lectures, visits of domestic and foreign experts were held. Mediana is now available to the public.

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COLONIA ULPIA OESCENSIUM /OESCUS/ TEMPLE OF FORTUNA – ANASTILOZA, RECOVERY OF ARCHITECTURAL MEMORY

***Arch. Julii Farkov*[1]**
***Arch. Vladislav Kolarov*[2]**

" F-DECO"Ltd, city of Kjustendil

„The art of memory works with imaginative spaces,
The culture of memory – with signs in natural space"
/Jan Asman/

Abstract: *Twenty six meters of two double-breasted latin building sign with traditional font „ capitalis monumentalis " in the fields of eleven frizarhitravs from Corinthian architectural order of the southern portico towards dekumanus maximus ,read and precision dated by prof.dr.Theofil Ivanov, come us back towards strong years of rebuilding the temple of Fortuna – 190-192 year at the time of roman emperor Avrelius Komodus Antoninus Augustus /180-192/. The temple is situated in the southeast end of Forum architectural ensemble of Ulpia Oescus and its southeast façade is open towards the main street– dekumanus maximus. Porticos of three sides are forming peristil around big inner yard,built with stone plates. The real temple is buit on podium with four column portico, celle and preserved marble statue of the Godess of Lucky fortune. The architectural research and the project for conservation, restauration,anastilosa and socialization, in general, is based on exhaustive catalog from 293 architectural fragments with monumental plastic decoration,stilometric analysis analogues, comparative analysis, research of proportions, facilities and properties of architectural composition, refers to the place of the monument in the scale of linear time. A long way from artefacts towards modelling the first image,towards decoding of creative efforts and excitements of Ancestors, of architectural creation – scene of everyday life on generations and vicissitudes of Fortune!*

Colonia Ulpia Oescensium /Oescus/ is the biggest antique city from the Roman Empire in today Nortern Bulgaria, placed in the country area Dolna Mizia on the right bank of the river Danube /Istros, Hister, Danubios, Danuvios/. The beginning of the city tradition is established with the revealed relicts of the Thracian invasion of Tribaldi from the late Bronze age and Early iron ages ,the permanent war camp of IV Scythian legion /first half of I century/, of V Macedonian legion /I century and from 271 AD till the end of IV century/, and from the near camp village of veterans /roman citizens, free people and slaves/ - canabae. Raised up in a rang of Colonia in 106 year after Dakian wars with administrative reforms of Emperor Marcus Ulpius Traian /98-117/ like a main structural element of the defense system of Danube limes of Roman empire. [2]

Oescus is main structural element, sector of the first defensive line of Danube limes, placed between Hemus /Stara planina/ and river Istros, build up of network horizontal and vertical military strategic and communicative roads, and supportive spots – war camps of the legions, castels and ali, kohorts and supportive wars units, burgi and frurii, road stations – mansio and mutacio, fortified villas and villages of veterans, ranked according the cannons of the Roman fortification and strategy of defence. Oescus marks crossroads of the neardanube road /road and sea/, that connects all villages on the right bank of river

[1] Julii Farkov, Architect, "Dimitar Granchsrov"str., City of Kjustendil, e-mail: f_deko@abv.bg
[2] Vladislav Kolarov, Architect, "Parizka komuna" str.. city of Kjustendil., e-mail: vladislav.kolarov@abv.bg

Istros from Singidunum /today Beograd /till its delta, with roads Filipopol –Augusta – Meita - Oescus through Trojan pass – connections of Danube road with the Central road /Singidurum-Serdica-Filipopol-Adrianopol-Bizantion for Anatolia/, so as a comfortable place for crossing the river Istros for Sukidava /near today village Chelei near Korabia /Romania/ and Dakia.

The position of Colonia Ulpia Oescus in country Dilna Misia is reproved in the time of emperor Konstantinos the Great in 328 year. With the building of Konstantinos bridge above river Danube on the road of White sea and Tracia towards open spaces of Dakia and the treasures of Karpati mountains. The bases of the bridge are registered by Luidgi Marsili at the end of XVII century.

In relief from Arc de Triumph in Benevento, Italy, raised up in honor of the victory on daki tribes, is modeled the realization of standards /flags/ of the five cities, honoured with the father's name of the emperor –Ulpii in 106 year, among that nis Ulpia Oescus. [3]

Oescus forum is distinguished creation of roman city planning with three temples of Capitolia triada – of Jupiter Optimus Maximus, Junona and Minerva, area with three monumental gates, kuria /local senate/, citizen bazilika /basilica civilis, forenzis/ with universal functions – bazar, tribunal, common citizen meetings, with build up area 1,8 acres. In the sacral geometry of the forum architectural ensemble avgury and agrimensory are coded the birth date of the roman emperor Mark Ulpius Trajan – 18 september, in traditional tracing of the base axis – decumanus /east -west/ and cardo /north-soth/, of fundamental coordinative system, established by the movement of the sun [4]

In the southeast end of forum architectural ensemble, tangered by dekumanus maximus – the main street of the city in east west direction, is placed the temple of the roman goddess of Lucky fortune – Fortuna, sky protector of the Ancient city.

Colonia Ulpia Oescus Oescensium – spacious lined mown meadow… and few archeological windows with hundreds faned from lichens and mosses white stones architectural fragments, recumbent in the chaos of ruins. Unploghed celery of opportunities in this stoned in misery heaven part of modern Bulgaria near lush banks of eternal Iskar and Danube!

Route! Participation in a project for European programme for transborder cooperation for development of cultural tourism Bulgaria – Romania, that included investment project for conservation, restauration, anastilosis, exhibition and socialisation of the temple of Fortuna,that entirely is based on results from archeological research of scientific team from National archeological institute and museum at Bulgarian Academy of science and Regional historical museum – Pleven with research guided prof. dr. Teofil Ivanov.

The beginning! Detailed catalogue of revealed 293 architectural fragments, stilometric analysis of architectural structures, architectural research due to method of mental reconstruction, based on the results of interdisciplined team, to space and time connections between separated artefacts, tracks of building up and ruins. Building up of architectural vision in the spirit of Place and Time!

Architectural reconstruction stands on the border between results of scientific work of interdisciplined team and the project for coservation, restavration, anastilosis and socialisation. Corrective of hypothesis for reconstruction of first image in the structural analysis, comparative analysis, analogues, metric analysis, measuring of proportions, tools and features of architectural composition, due to place of the monument in the cliff of linear historical time! One long way from the artefacts towards the very first image, towards decoding of creative efforts and excitements of Ancestors, processes of building up, destructions, rebuilding of architectural demand, scene of everyday life and vicissitudes of Fortune!

Architectural research:

Architectural ensemble of temple of Fortuna is built up of four main objects:

A/. South gate with two lined latin iscription towards decumanus maximus
B/. Peristyle yard
C/. Base temple
D/. Facilities in the north part of the yard – warehouse

A/. South portico has rectangular plan with length 28,80 m and width 4,70 m. The south side towards dekumanus maximus is limestone monolite colonnade from 12 columns with entrance in the middle, released outside towards the street. North wall of portico, with width 90cm is built up with double face kvadrova masonry and emplekton with crushed stones, coupling with mortar and pieces of crushed bricks Krepidona was lined with rectangular limestone plates.

Twenty six meters of double-breasted latin constructional sign with traditional font „capitalis monumentalis" in the fields of eleven frizarhitravi of Corinthian architectural line of the south portico towards dekumanus maximus, read and precision dated by prof. dr. Teofil Ivanov comes us back in the strong years of upbuilding the temple in the time of roman emperor Avrelius Komodus Antoninus Augustus /180-192/. With the decision of Roman cenate name and titles of the emperor are erased after 31 December192 year – „damnacio memoria" –„a curse of mind" in the whole Roman empire. In the constructional sign of the temple they are damned clumsily, that afford inscription to narrow the dating of upbuilding in narrow time frames from 190 – 192 year.

One detail from art order creates work hypothesis for dating finishing works on part of relief to frizarhives of peristilium and apart of south fronton in the real temple with two goddesses of victory – Victories, holding lavrov crown, that are different strongly in quality of realisation and art value. It is possible, that these reliefs are entrusted on mediocre stonecutters after attempt on the emperor, who have submitted and damning the names and titels on the mentioned building sign, as well as on the column, fallen apart on three parts on the ground of dekumanus maximus from the opposite portico of pretorium. This assuming the final completion of temple of Fortuna according to 193 year in the time of political destabilisation in the reign of emperors Pertinax /I – III.193/ and Didii Julian /III – VI.193/, prelude towards establishing the absolute power above Rome from Septimii Sever /9.VI.193 – 4.II.211г./.

Elements of Corinthian architectural order:

a/. Krepidoma (podium) – Stereobat (stripe fundament) is wide 215 cm and deep 310 cm. The distance from road line till south wall of temenossa is 705 cm. The whole hight of krepidoma is 118 cm.

b/. Silobat-rectangular limestone plates with width 70 cm and width 30 cm, that step on stereobata and are base of antique base.

c/. Column:

- Base with hight 27 cm, atique type, made by limestone. Plinta 63x63 cm.
- Body of the column with hight 350 cm. Lower diameter – 53 cm, upper diameter – 43,5 cm.

- capitel, corinthian, column with hight 62 cm, diameter 44 cm. Slimness 62:44=1,41.

d/. Antableman :

- frizarhitrav with high 69 cm. Double-breasted building sign on the frieze on the whole south colonnade of dekumanus maximus is in the base of reconstruction of architectural fragments on frizarhitravs on south portico.

I row:
Block№1: [[IMP.CAESARI M.AVRELIO COMMO
Block №2: DO AVG. PIO FELICI SARMATICO
Block №3: GERMANICO MAXIMO BRITANNICO
Block №4: PONT.MAX., TR.POT.XV, IMP VIII
Block №5: COS VI, P.P.DIVI MARCI
Block№6: ANTONINI PII GERMANICI, SARMATI FIL.,
Block№7: DIVI PII NEPOTI; DIVI H
Block №8: ADRIANI PRONEPOTI, DIVI TRAI
Block №9: ANI PARTHICI ABNEPOTI, DIVI
Block №10: NERVAE ADNEPOTI]] [GNAEO SU
Block №11: ELLIO RVFO, LEG AVG PR. [PR.PROV.]

II row:
Block №1: [MOESIAE INFERIORIS ……]
Block №2: [……]
Block №3: [……II VIR] Q.Q. COL. ET M.C……
Block №4: [……] LVS DEC.
Block №5: [……],
Block №6: PRAEFECTI ET PATRONI COLLEGI FABROR.
Block №7: OB AMOREM PATRIAE ET C
Block №8: [IVIVM TEM] PLVM FORTVNAE A SOL
Block №9: [O CVM PORTICVS ET COLVMN]
Block №10: IS ET STATVIS LOCIS EM [PTIS OM]
Block №11: NIQVE INPENDIO SVO FE [CERVNT].

In Bulgarian the sign claims:

I row: „To emperor Cesar Mark Avrelius Komod August, Pius, Felix, Sarmatik, Germanik Maxim Britanik, suprime leader, tribune for 15-th time, emperor for 8-th time, consul for 6-th time, father of the fatherland, son of divine Markus Antonius Pius Germanius, Sarmatik, grandson of divine Pius, grand grandson of divine Hadrian, grand grandson of divine Trajan Patrik, grand grandson of divine Nerva, when Gnei Suelii Rufus was rulling the country.
II row: Lower Misia ……/ …. ……../ ……duumvir kvinkvenal of the colony and Matk K /…….. lus dekurion/ …… prefects and patrons of association of craftsmen, due to love towards the country and citizens built up the temple of Fortuna from bases with porticos, columns and statues on bought lands entirely by their own assets."

- cornice – h=37 cm with adhering palmets of simata

e/ the entrance towards the southern portico is issued on 0,75m, south of the façade of the portico. It is consist of four columns, as the frontal two steps on limestone postaments

with the hight of 86 cm. Between them were placed three steps with average hight 28,33 cm and width. Frizarhitrav above the entrance is destroyed on four fragments with whole lenght 2,975 m. Behind side is consist of two parts, as well as upper part has a bed (0,33x0,15 m) for cassette ceiling above the entrance. Rectangular plate of the cassette ceiling is with reconstructed length 220 cm, width 64 cm and thickness 23 cm, secondary made up from reused frizarhitrav. In the both cassettes are modelled heads of Meduza, and in the middle a head of bull.

g/. Triangular fronton above the entrance

- Timpani consist of three blocks. Middle block has a form of pentagon with length of the base 1,93 m and hihgt 0,73 m. Fronton is lined with so called rider and pedestal for statue or akroterii.

h/. Covering facility with teguly and imbriks, finishing with artefacts on cornicrs.
i/. kalimata – stone cassette ceiling above south entrance.

Metric analysis:

Ik – interkolumnii – 211cm 181cm
Ax –wheelbase - 260cm 230cm
D –lower diameter of column - 53cm
D –upper diameter of the column – 43,5cm
KH –hight of column – 439cm
AH –hight of emblem – 106cm
PH –hight ofkrypydoma – 118cm
OH – hight of colonade – 663cm
d:D –conicity of column – 43,5:53=6,566:8
D:Ik –attitude between thicknessof colonnade and width of the hole –
53:211=1:3,98 53:181=1:3,415
D:KH –value of colonade – 53:439=1:8,28
PH:KH –attitude between foot and hight of column – 118:439=1:3,72

From east and west portico is formed with two intercolumns and palistrov transition towards south wall of temenos. In the architectural reconstruction of the entrance of portico are shown results from research of roof wooden construction, based on the tracks from the beams on existing frizarhitravs and cornice.

B/. Peristyle yard – has rectangular plan with sizes 29,70x19,80 m with longitudinal axis, oriented north-south, with deviation 24,18˚ towards northeast-southwest. Paved with limestone plates, where are fallen architectural fragments from order of colonnade porticos and the temple. Three masonary canals near east, south and west three stepped podii of yard lead atmospheric waters towards central canal of dekumanus maximus .

Porticos of peristyle yard:

Placed on the three sides without northern – monument colonnades in Corinthian style. Wall plates of porticos were paneled with thin white and grey marble plates with profiled marble sockets and cornices.

Elements of architectural order:

a/. krepidoma (podii) with hight 59 cm. Stereobat has width 130 cm. Width of west portico is 350cm.

b/. column

- athic base with hight 27 cm
- body of column with hight 350 cm
- Corinthian capital with hight 62 cm

c/. antableman

- Frizarhitravs with hight 69 cm, with heads of bulls and garlands, and plastic symbols between them. Each frizarhitrav block has Sofitel ornament with plant motive. Relief images above garlands (sertae) are reflection of everyday life, nature and religion.

Solving the problems of southern portico of peristil is connected with architectural reconstruction of middle field, underlined in hight with triangular fronton between axis 7 and 8.

- Cornice with hight 37 cm with ligature palmets

Porticos are covered with onelevel roof. Along the longitudinal axis of peristalic yard above southern portico, entrance is marked with triangular fronton.

Metric analysis:

Ik –intercolumnii – 200cm 167cm
Ax – wheelbase - 249cm 216cm
D –lower diameter of column - 53cm
D –upper diameter of column – 43,5cm
KH –hight of column – 439cm
AH – hight of antableman – 106cm
PH –hight of kripidoma – 59cm
OH –hight of colonade – 604cm
d:D – conicity of colonade – 43,5:53=6,566:8
D:Ik –attitude between thickness of colonnade and width of the hole –
up53:200=1:3,77 up53:167=1:3,15
D:KH – slimness of column – 53:439=1:8,28
PH:KH –attitude between foot and hight of column – 59:439=1:8,28

C/. Real temple – situated on 12,30 m from stilobata of southern portico of peristilic yard (till first step of monumental stairs). On the level of cript longitudinal walls are thick in 2,10 m, and the northern side 1,55 m. Built up by limestone quadras and only the sheets of southern entrance are with mixed masonry (opus mixtum) with two and three rows of roman bricks. The construction of ceiling of kripta is with cilindric arck, that holds the floor of paranaos and celle.

a/. Kripidoma (podii) – celle and the open hall-pronaos are placed on a common podii with hight 216 cm (from the ground of peristaltic yard). The difference in the levels is overcome with 9 steps 37,7/24 cm, as a part of the first two steps are preserved on the place. Parameters of podium prissume portico with 4 columns – tetrastyle.

b/. column

- base athic type with hight 28,5 cm

- body of column with hight 385 cm, with lower diameter 57 cm and upper diameter 47 cm
- capital, romancorinthian with hight 66,5 cm

c/. antableman

- Frizarhitrav with hight 79 cm and plastic decoration on the frieze with eroses and garlands /formind inner corners/
- Frizarhitrav with hight 79 cm,without plastic decoration on the frieze, with a bed for cassette ceiling, is replaced on the right wing of the west façade of the temple
- Frizarhitravs with hight 79 cm and plastic decoration on the frieze with heads of bulls and garlands, with a bed for kalimata or girder – whole lenght 17 m
- Cornice with hight 40 cm, with ligature palmets on simata

d/. southern fronton, on the frontal façade on the real temple - central part of timpan is with pentagonal form and with length 1,72 m, maximum hight 1,47 m, width 0,60 m. Decorated with two flying Victories (goddesses of Victory), holding lavrov crown (d=1,33 m), where is situated umbo on shield (d=0,73m). On the top of cornice is situated so called „rider" and postament for acroterii or sculpture
- both corners of fronton were lined by postaments and acroterii with hight 1,02 m, base 0,82 m and thickness 0,18 m
- door towards celle of the real temple – preserved are sheets, decorated with kima and astragalli. On the bottom of celle is raised the statue of Fortuna, that today is placed in the exposition of National Historical Museum - Sofia.

e/. northern fronton, preserved are fragments from timpan and acroterii

Achievment of architectural research of the architectural order of the temple of Fortuna, and more-specifically on outside and inside architecture of celle, is discover and research of frizarhitrav – frizcornice, with plastic modelling on frieze with eroses and garlands, finished with a head of ram (northeast corner of open hall).

Metric analys:

Ik – intercolumnii – 234cm 187cm
Ax – wheelbase – 177cm 130cm
D – lower diameter of columnдолен - 57cm
D –upper diameter of column – 47cm
KH – hight of column – 480cm
AH –hight of antableman – 119cm
PH – hight of podii – 216cm
OH – hight of colonade – 815cm
Ax:KH – proportion of rhythm of columns – 177:480=36,88% 130:480=27,08%
KH:AH – attitude between hight of column and antableman –
480:119=24,79%
D:Ik – attitude between thickness of column and width of hole –
57:234=1:4,11 57:187=1:3,28

D:KH – slimness of column – 57:480=1:8,42

Elements of architectural order of interior to celle (naos):

a/. socket, cladding, marble with hight 20 cm. Probably with such kind of hight, suppose to be and lower part of postament of cult statue of Fortuna.
b/. wall plate, cladding with marbel plates, with hight 369,5 cm
c/. horizontal streak with one row akant leaves, capital, that crowns the wall plate, with hight 40 cm – element of monolite block of capital - arhitrav
d/. arhitrav streak with hight 265 cm
e/. frieze with heads of bulls and garlands with hight 23 cm
g/. Cornice with ligature palmets of simata – hight 35 cm, after that follows a bed of girder and decoratyive ceiling with whole hight 514 cm

D/. Facilities of temple architectural ensemble

- inside sizes 26,50 м x 4,7 m under common roof. Their purpose is monstrance.

The project of conservation, restauration, anastylosis and socialization presumes:

- research and conservation of canal system of peristile yard, dekumanus maximus and the two tangiraci kardines from east and west ot temenos.
- partly rebuild and nivelation of the original street ground from limestone plates of dekumanus maximus and both kardines
- conservation and rebuilding of the steps towards krepidoma (podii), as well as the ground of lime stone plates of portico
- anastilosa of existing architectural fragments of Corinthian order of portico, to part of roof construction and roof covering. The beds of beams in the back side of frizarhitravs define their sections.
- Conservation and rebuilding of sacred threshold, the sheets of entrance gate of the temple towards inner yard space through anastilosa of original architectural fragments.

Anastilosa of Corinthian architectural order of colonades porticos of peristelium to base on preservation original fragments – base, body of columns, frizarhitravs, cornice, as well as on the elements of the entrance with triangular fronton

- rebuilding of fragment in the roof construction and covering with teguli imbrics and antefix in existing model in the southeast part of temenos, where is presumed to be placed museum trakt with lapidarium, multimedia information stellas, places for visitors, protected from harmfulll atmospheric influences
- rebuilding of ground with limestone plates in peristalik yard and three stepped podii of porticos

- conservation and restauration of brick wall of temenos with two faced quadra masonry
- partly anastilosa of portico of pronaos in the temple with monumental triangular fonton with original timpan with plastic disk and flying Victories holding lavrov crown, as well as frizarhitravs and antov capitals.

The temple of Fortuna has lived two earthquakes – political, with the change of religious doktrina – monotheism, christianity, and probably an earthquake with epicenter „Vrancha" (today Romania), proof for the last is the place of architectural fragments in the frames of themenos – deintergration of architectural language. After „God intervention" recumbent architectural fragments are buried and we are witnesses of continuity and development of cult place. On the temenos and cellae – the real temple as contra mark is built up Christian church. This way the temple of Fortuna, of the Lucky fortune is preserved from the fads of Fortune. The analysis of the architectural masterpiece, whole or in ruins, on one architectural text is „Elite activity, protected from cosy alibi of specific /Rolan Bart/. The imagination of sign. C.1991. c.442 „ , visible, obvious ! But to finish **second way**, the way towards spirit universe of Ancestors, Fifth demention of Place and Time, Time and Number, to skip dimentions and overlive woken nights of Creativity, giving a birth of ideas, curiosity, creative inspiration, imagination, intuition, is purely human and criminal saga of Theatre of Mind!

Space, Time, Numbers!

The space, that we catch through our imagination, is not insignificant space that is used by the measures and the mind of geometry /agrimensor/. It is a space, that is living. And it is not in its positivness, but with all preferences of imagination/ Gaston Bashlar/. Poetry of the space Sofia 1988, C. 34 /

Anastilosa of distructed architectural fragments – words, phrases, discursors of archaic architectural text in researched reconstructed architectural novel with only new easthetics, lighten up by the nostalgic taste and poetry of ruin, from one unfinishness of the sense , measured enigma, that provokes movement of imagination and overwhelming desire for overbuilding of knowledges for relics on cultural memory of blessed Bulgarian land!

GRATITUDE:

Thanks for cooperation in project for conservation and restotation of "Temple of Fortuna" to Eng. Anton Maleev – constructions, Eng. Lilia Aladjem - lighting effects, Georgi Penchev – technologist, Arch. Teodor Iliev, Arch. Simona Lazova, Milka Farkova – designer.

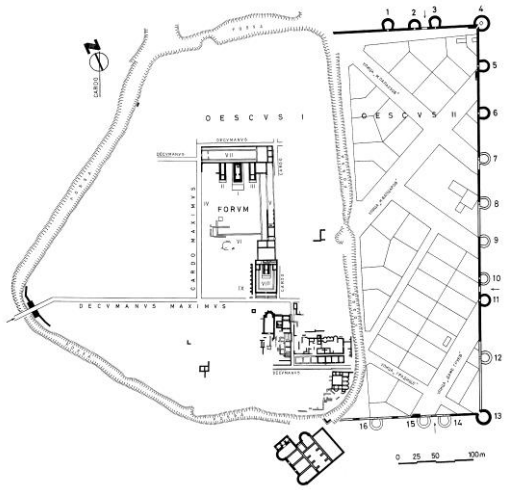
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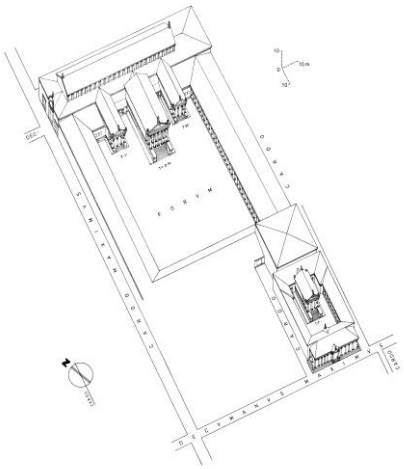
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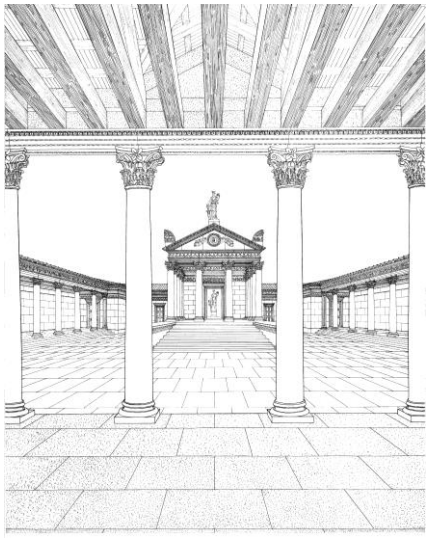
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1. Colonia Ulpia Oescus-Plan of the city
2. Colonia Ulpia Oescus-Forum-Izumetriya

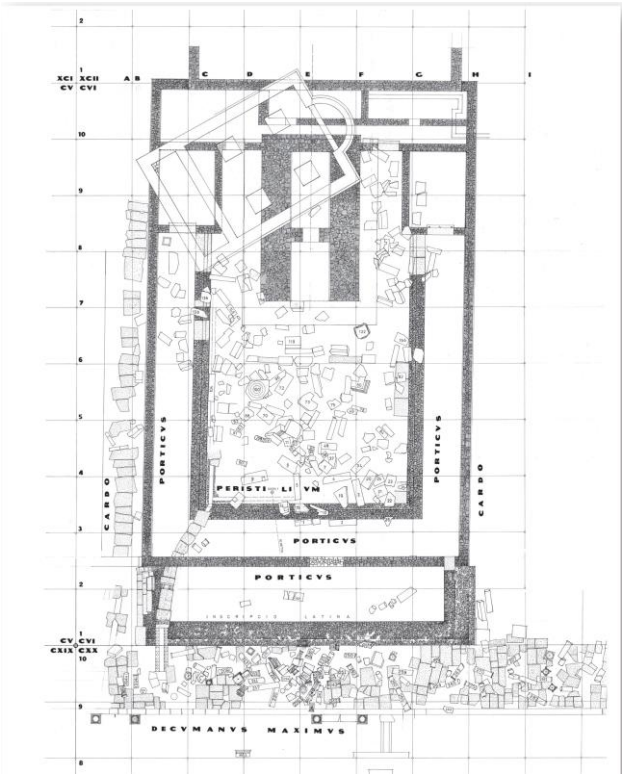




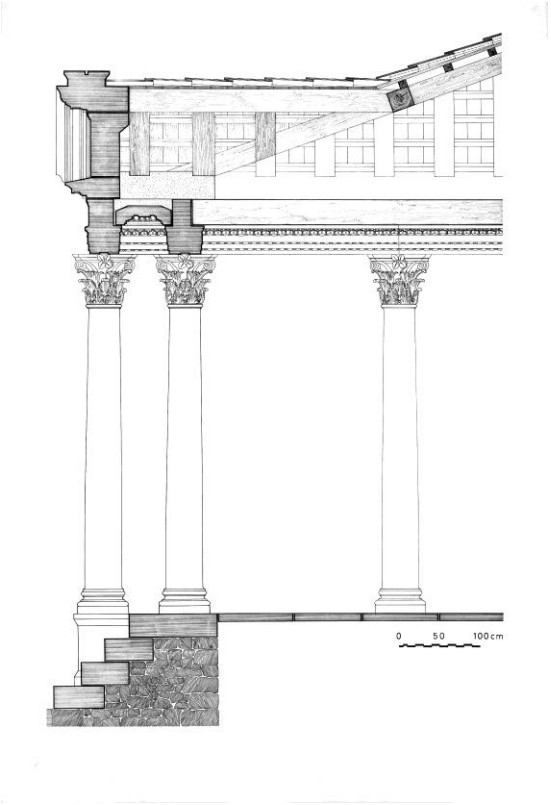
3. Temple of Fortuna, Forum, Reconstruction 4. Temple of Fortuna Peristilic yard-Perspective

5. Colonia Ulpia Oescus – aerial photo

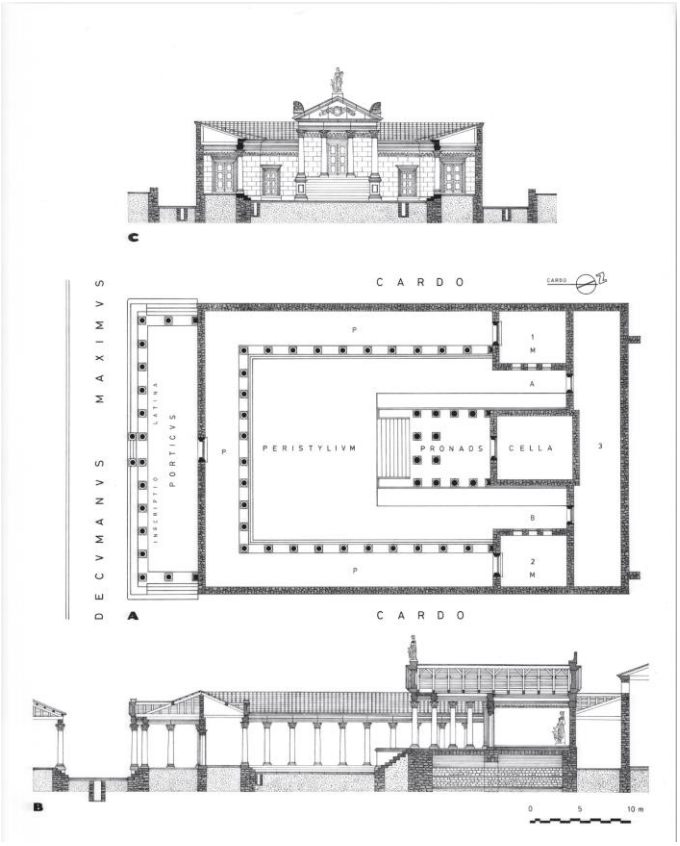




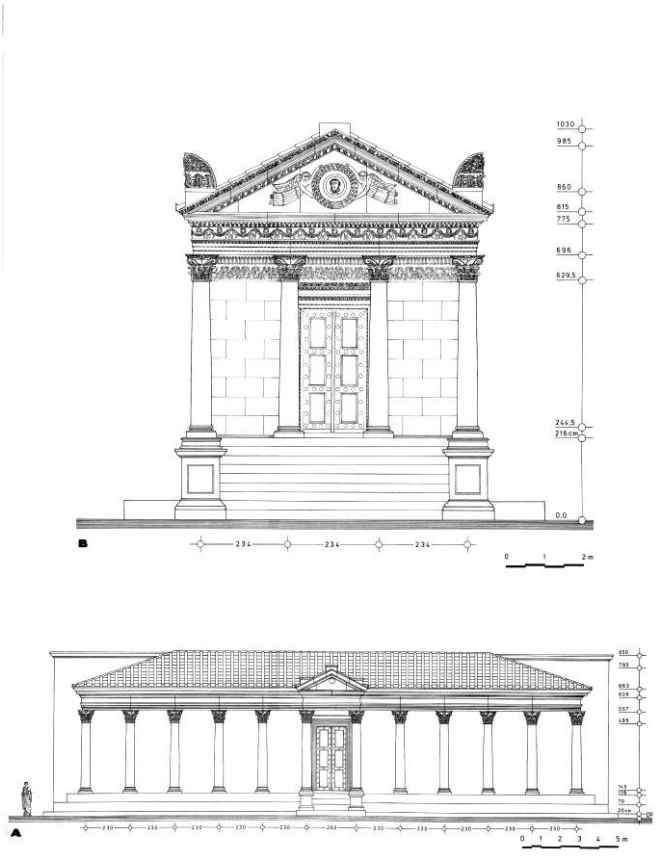
6. Colonia Ulpia Oescus- Plan of layout to arcitectural fragments



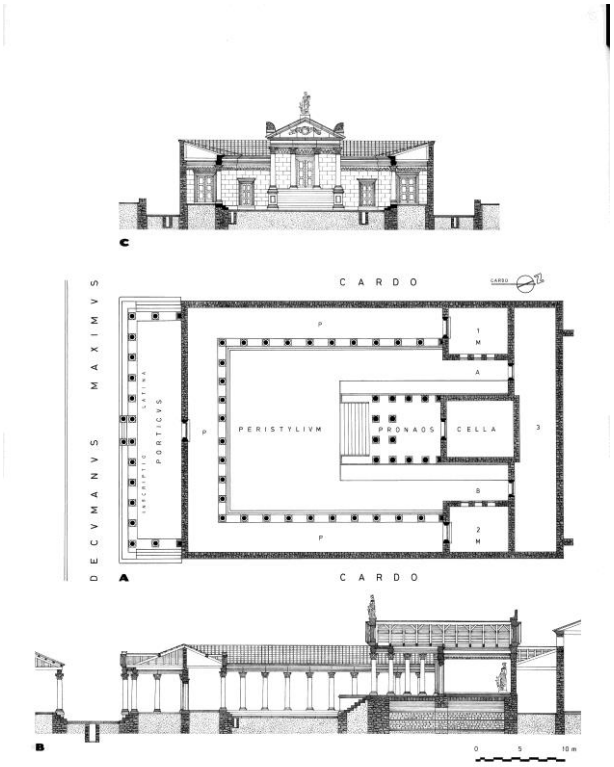
7. Temple of Fortuna-South entrance with sign-Vertical section



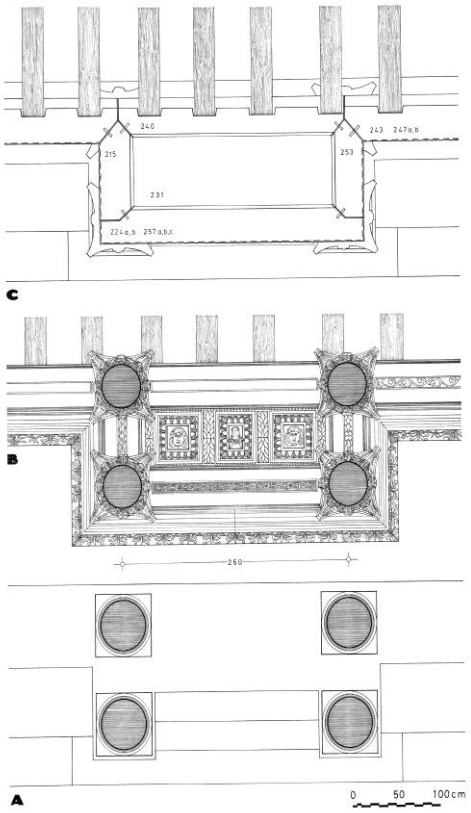
8. Temple of Fortuna – plan and sections



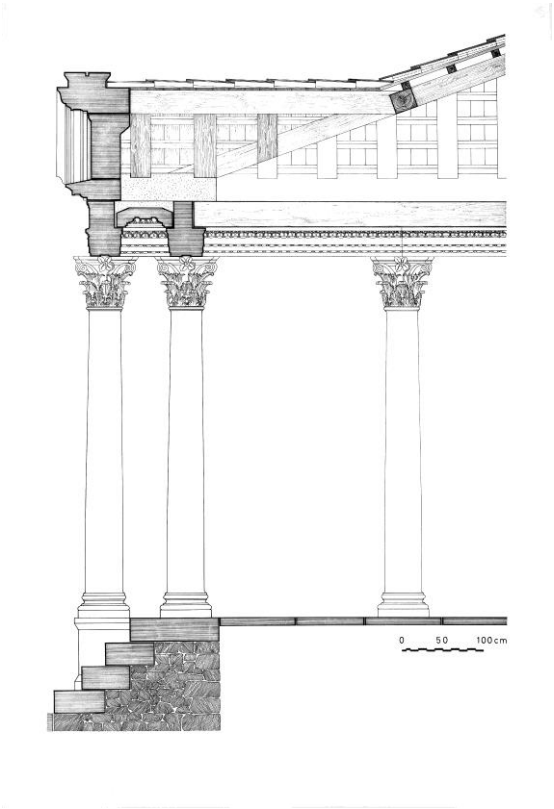
9. Temple of Fortune-South portico with sign-South facade of the temple



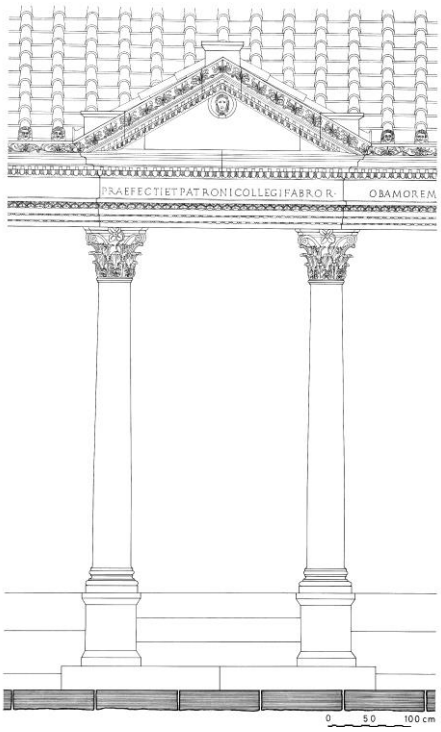
10. Temple of Fortune- Plan.Sections



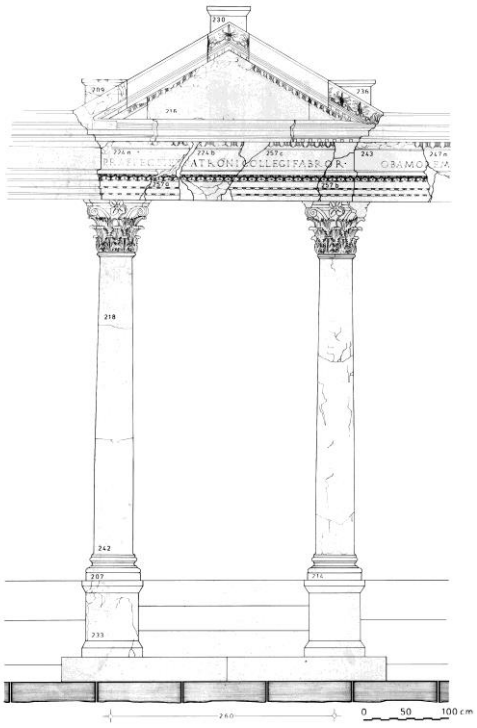
11. Temple of Fortuna-South entrance with sign-Plan-Spotlights-Plan of arhitravs



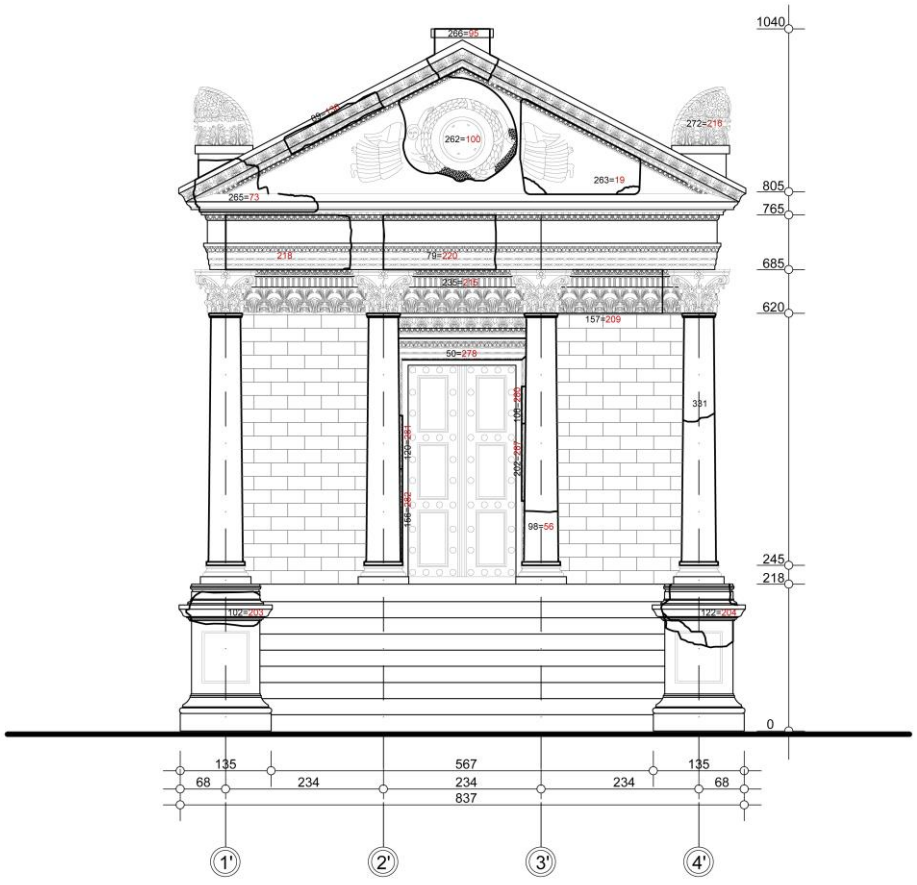
12. Temple of Fortuna-South entrance with sign-Vertical section



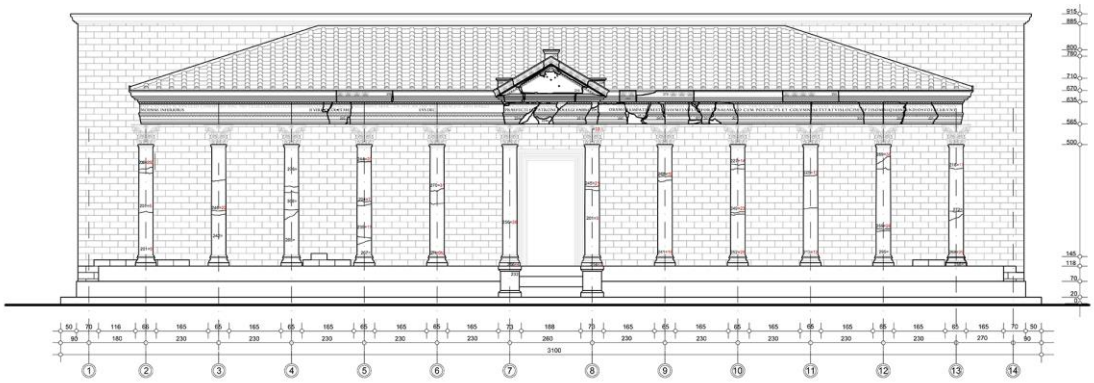
13. Temple of Fortuna-South entrance-Architectural reconstruction



14. Temple of Fortune-South entrance with sign



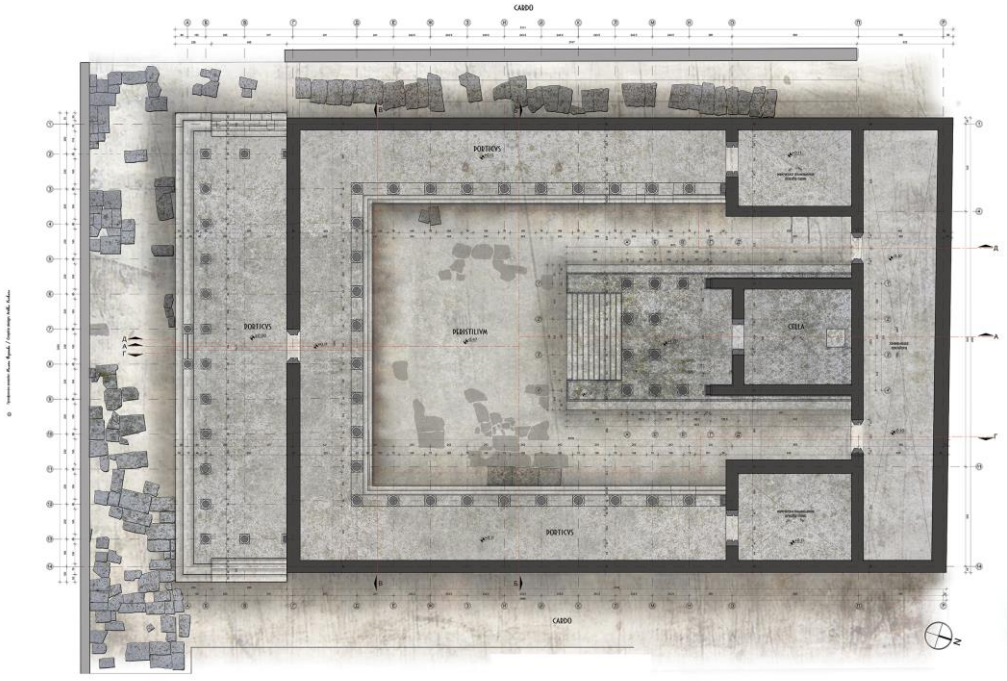
15. Temple of Fortuna.View from south.Archeologicai research



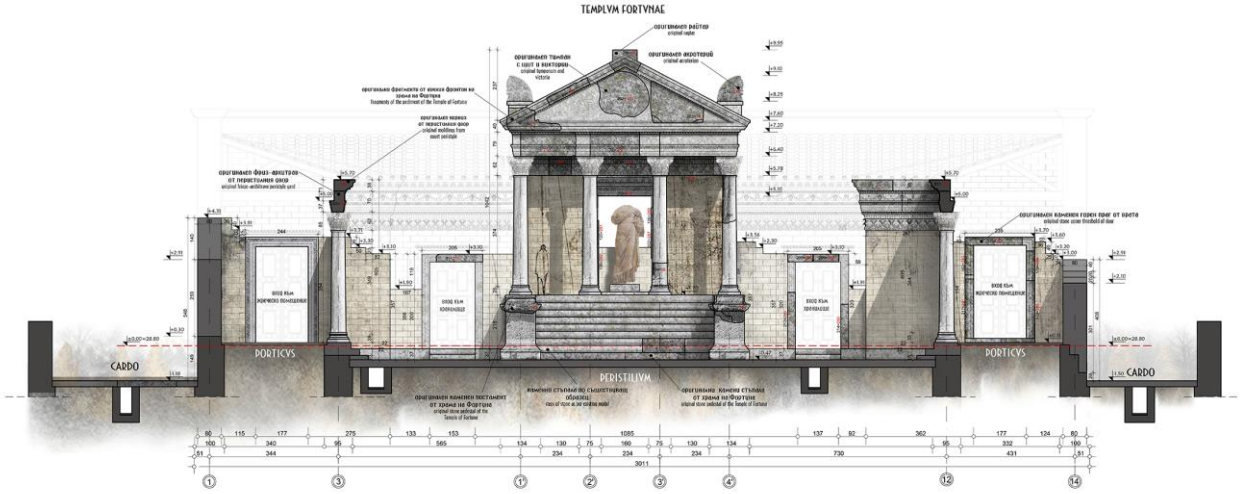
16. Temple of Fortune-southern portico shilouette towards dekumanus maximus-Archeological research



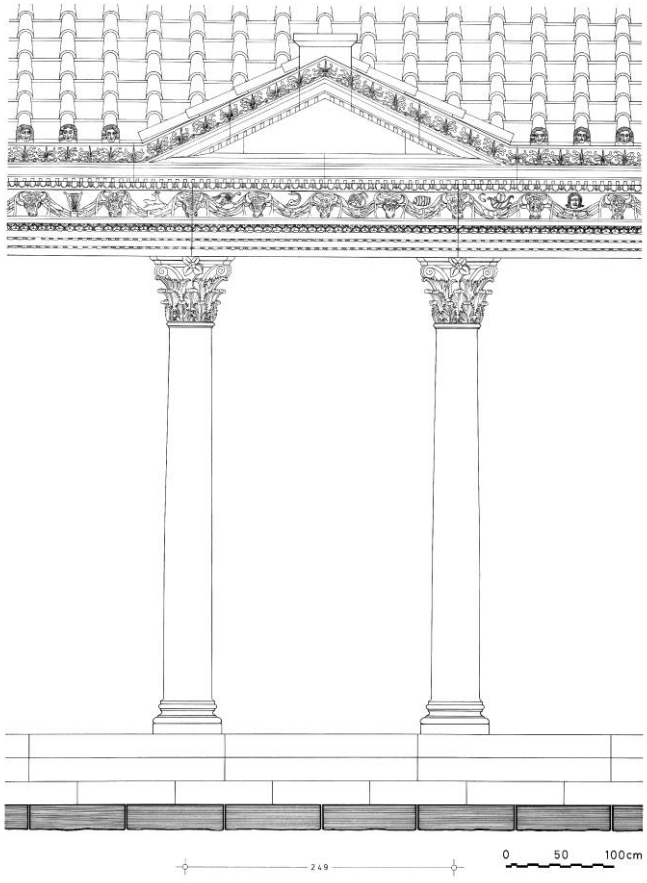
17. Colonia Ulpia Oescus.Temple of Fortuna



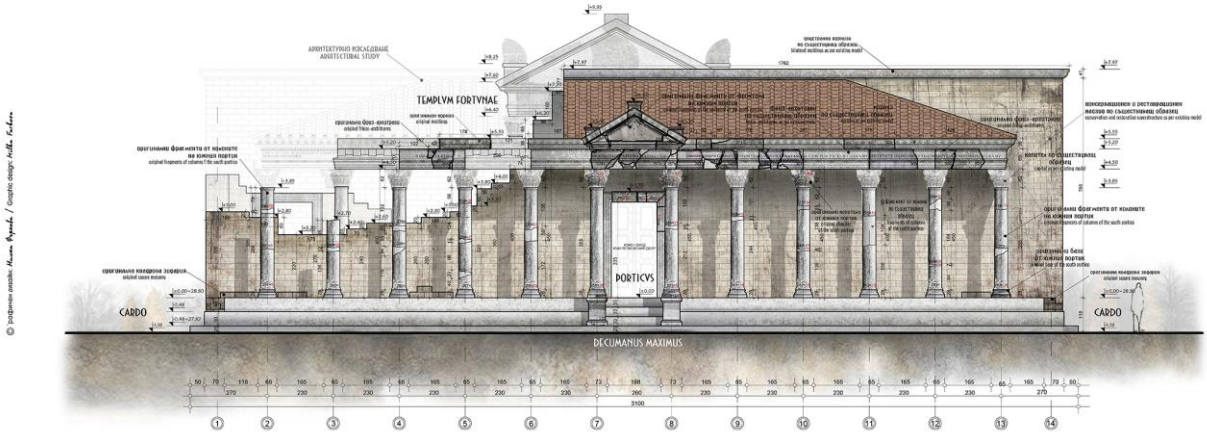
18. Temple of Fortune.Plan



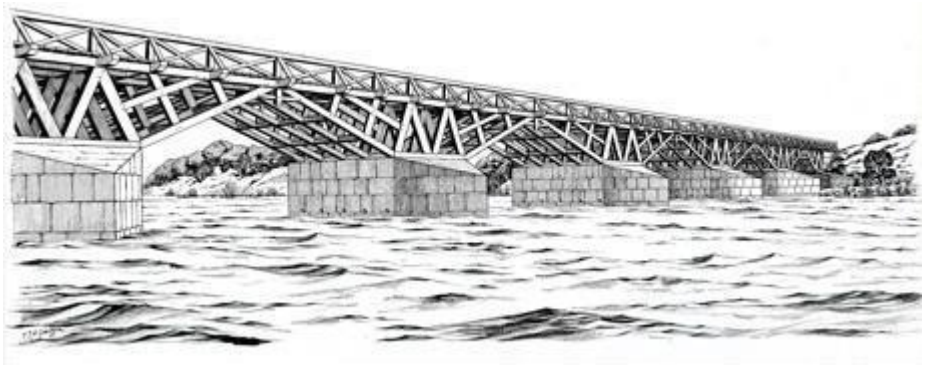
19. Cross section-view towards the temple of Fortune



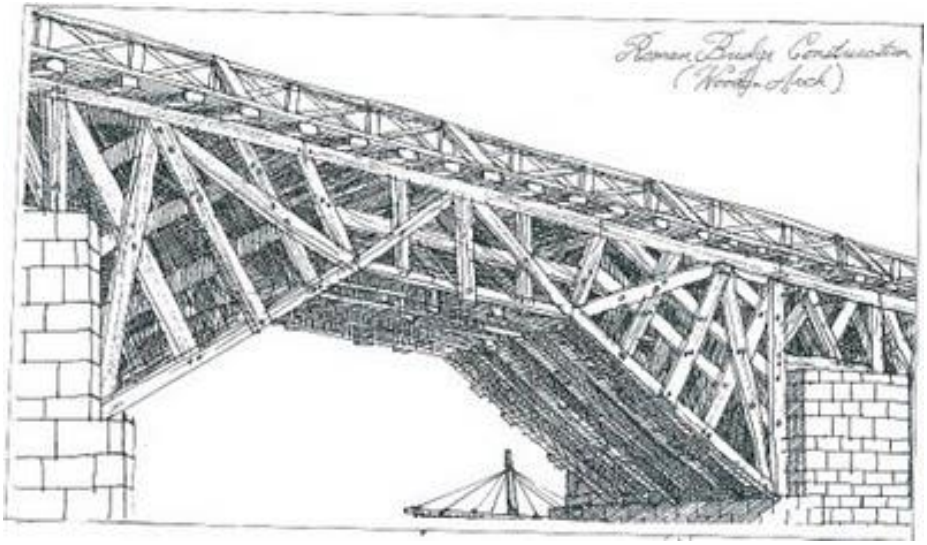
20. Temple of Fortune - Peristalic yard



21. Temple of Fortune-South portico-shilouette towards dekumanus maximus



22. Konstantin bridge above Danube near Oescus



23.Konstantin bridge-Design

QUALITY ASSURANCE DURING RECONSTRUCTION OF THE OLD BRIDGE MOSTAR, UNESCO HERITAGE

Damir Zenunovic[1], Kenan Mandzic[2], Adnan Ibrahimovic[3], Enver Mandzic[4]

Faculty of Mining, Geology and Civil Engineering, University of Tuzla, Bosnia and Herzegovina

Abstract:
The Old Bridge Mostar was demolished in the recent war, in September 1993. The city of Mostar signed an agreement of financing the reconstruction of the Old Bridge with the World Bank in 1997. The project was included by UNESCO. The reconstruction of the Old Bridge finished in 2004. The reconstruction was a challenge for engineers because of a mix of demands of the modern civil engineering and the traditional way of construction. Some execution details were given in the paper. The paper presents the overview of quality assurance plan and specific tasks during reconstruction of the Old Bridge Mostar with the aim to presents some experience and challenges of reconstruction UNESCO cultural heritage, which was completely destroyed.

Key words: *demolishing, investigation, reconstruction, quality assurance*

1. Introduction

The development of building bridges in Bosnia and Herzegovina began with the arrival of the Turks. Ottoman Empire declares state interest of building bridges, which leads to expansion of construction. In particular it can mark off the sixteenth century, when they built the largest and most important bridges. In this period all bridges were built of stone and wooden bridges. Wooden bridges are not preserved, because of their durability and they are only data based on stories that are transmitted for generations. The most significant bridges of this period are the stone arch bridges: Mehmed Pasa Sokolovic Bridge in Visegrad, built by Koca Mimar Sinan in the period from the 1571 to 1577, Goat Bridge, near Sarajevo, the bridge at the mouth of Zepa, Arslanagica bridge in Trebinje, the bridge in Plandiste, Seher-cehaja bridge in Sarajevo, the Latin bridge in Sarajevo, Old Bridge in Konjic and Podgradska bridge in Stolac built in the sixteenth century.The most famous is Old Bridge in Mostar, which is located in the old part of Mostar, listed on UNESCO's World Heritage List (Fig.1).

[1] Damir Zenunovic, PhD, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina, damir.zenunovic@untz.ba
[2] Kenan Mandzic, PhD, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina
[3] Adnan Ibrahimovic, PhD, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina
[4] Enver Mandzic, Academician, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina



Fig. 1. Old Bridge in Mostar (*used with www.mircorp.com*)

"Old Bridge" on the Neretva River in Mostar was built in the period from 1557 to 1566, and to this day represent a symbol of the city of Mostar. The bridge was built by Mimar Hajrudin Aga, a student of the greatest Ottoman architect Koca Mimar Sinan, and by order of Sultan Suleyman the Magnificent. The bridge was built of limestone with the abutments in rock. Abutments are 6.53m from the summer water level of the Neretva River, and at that point is the span 28.70m with an arch arrow12.02m (Fig.2).

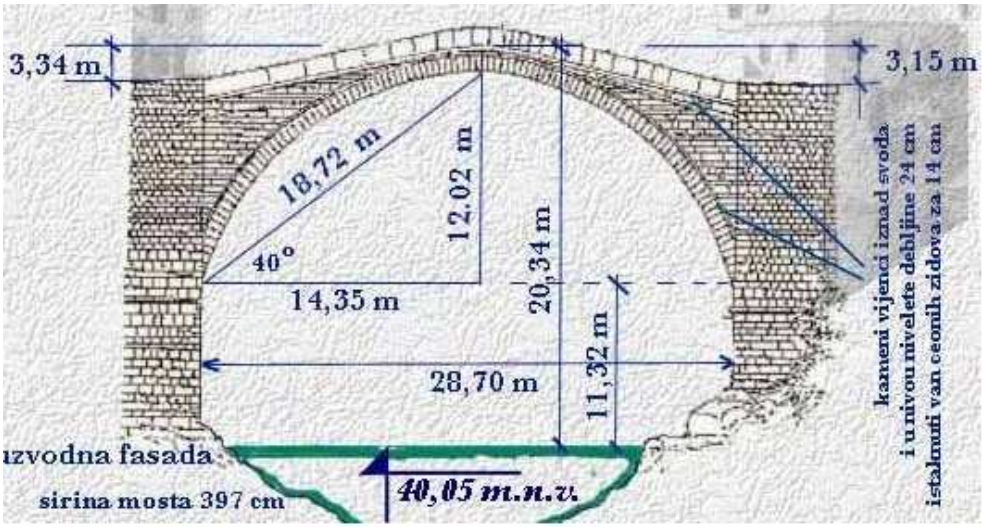


Fig. 2. Cross-section of Old Bridge in Mostar (*used with www.avlija.me*)

The thickness of the arch at the crown is 77cm, a width of 397cm. With its harmonious shape of the white stone arch over the green river and the unique atmosphere in which there is "Old Bridge" is a centuries impressed observers from around the world. Unfortunately, the "Old Bridge" was demolished in 9th September 1993, during the recent war. The city of Mostar has signed an agreement on financing the reconstruction of the Old Bridge with the World Bank in 1997. The basic requirement was to build the bridge with same material as was built five hundred years ago. The project was included by UNESCO. Special attention was given to creating designs for the reconstruction of the bridge. Selection of appropriate scaffolds for the reconstruction of the bridge was given special attention. Selected heavy metal scaffolding of the elements of a massive structure, which is support on temporary cantilever of concrete columns, which were later removed (Fig. 3).



Fig. 3. Scaffolds for the reconstruction of the Old Bridge

The opening ceremony of the reconstructed Old Bridge and Tower on the banks of the river Neretva was on July 23rd, 2004. After expending great effort and knowledge of all participants in the reconstruction of old (new) bridge has excelled in all their glory to the delight of Mostar's citizens and many visitors from around the world (Fig. 4).



Fig. 4. New Old Bridge

In this paper were presented some directions for preparation and application of Quality Assurance Plan (QAP) for such specific reconstruction, accompanied the requirements of the standards EN ISO 9002 [1] and EN ISO 9003 [2]. The QAP should include an organizational diagram, description of jobs, information on the distribution of responsibility and authority, and description of internal working relations between the key personnel. Here is presented overview of the Plan.

2. Reconstruction procedure

Detailed and all-including visual overview of the structure is normally the first and basic step, and also a condition for efficient and rational structure. Visually we can preliminary observe the general structure state, as well as its weak «points», where particular attention has to be paid. It is important to emphasize here that this particular attention has to be paid to so-called weak points on objects which are of great importance, due to avoid of great direct and indirect damage. According to detailed visual examination it is needed to create a rehabilitation program, which should contain chapters as on figure 5. Details were described in papers [3] and [4].

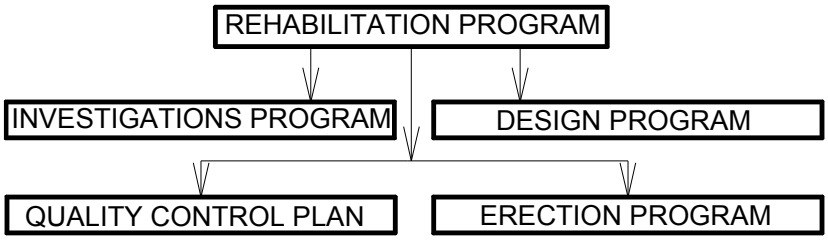
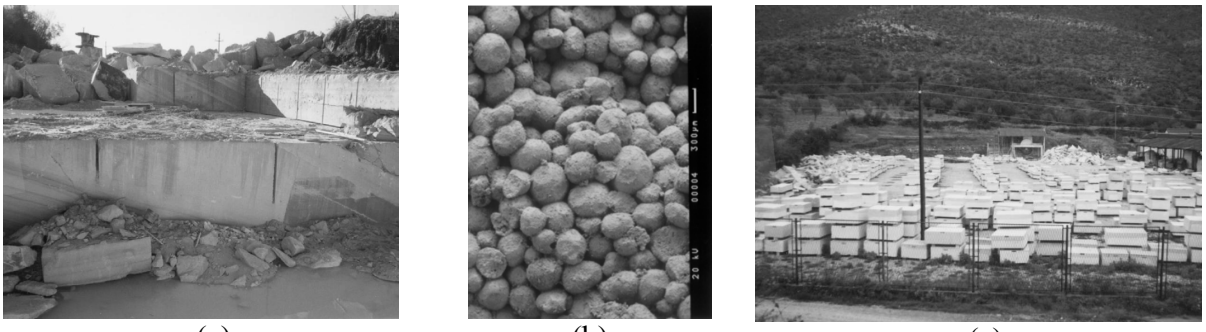


Fig. 5. Structure of rehabilitation program [3]

Scope and content of investigations program should assure the reliable mark of the bearing structure state with aim of choosing and undertaking other measures of rehabilitation program. The determined degree of structure damage represents the input data base for making of economic analysis justification of structure repair.

The bridge is built from Eolithic limestone of the local name „Tenelija", used for voussoirs, cornices, spandrel walls, parapets and repair of the walls. „Tenelija" was obtained from the quarry Mukoša, south of Mostar (Figure 6a). „Tenelija" is local oolitic limestone with uniform grains (visible grains), whitish ebony color, or light and warm color, with compressive strength most often from 20 to 26 MPa (Figure 6b). For the reconstruction was used the same type, color and resistance as the old one which was originally used for construction of the bridge, most probably extracted from the same quarry where the original old stone was extracted (Figure 6c).



(a) (b) (c)

Fig. 6: (a) Quarry Mukoša; (b) Oolitic structure of „Tenelija"; (c) „Tenelija" blocks for the reconstruction of the bridge

The arch blocks were connected with iron dowels, poured with led connecting the structure in such way (Figure 7). Also, the blocks were connected with the iron cramps on the extrados, which are again poured with led. Bind between the stone blocks was traditional lime mortar. Pavement of the bridge was constructed from the hard marble limestone, which becomes polished through time. The pavement was placed in layer of red soil (terra rossa) and lime, so called Turkish insulation. The iron fence on the bridge, dated

from Austro-Hungarian period, was renewed in accordance to the original receipts of metal and building methodology, as well as dowels and cramps.



Fig. 7. Structure of rehabilitation program (*used with www.litosonline.com*)

Marble limestone was used for voids covers, repairs of walls, masonry filling and pavement. The massive Eocene limestone blocks, rich in petrification of numulite and alveoline which become visible due to walking causes its abrasion, was obtained from the field Opine, southern part of Mostar (Figure 8). The limestone has compressive strength of 170 MPa.



Fig. 8. The Old Bridge pavement

In this case the object is completely destroyed. The investigation program was reduced to diagnose the condition of certain parts of the bridge structure and the individual blocks. On this occasion, the remains of the bridge were removed from the river Neretva, delayed on the coast and tested. Quality control was performed using echo method and ultrasonic test.

The blocks was re-used if cracks was not obtained during visually and sonically investigations. If damages were purely esthetical nature the authentic block was not rejected.

Results of tests on site and in laboratory represent the input data for analysis of preliminary and detailed technical documentation. In this phase of rehabilitation program it can be influenced the most on the final sanation balance, and that is why very detailed and study approach is important, including:

- Possible rehabilitation solution analysis and choice of optimum solution – it is important to optimise the rehabilitation efficiency and rationality, but at the same time design engineer should take care about the rehabilitation suitability considering the aspect of rehabilitation material purchase and technical equipment of the local firms for construction works;
- Analysis of construction technology within the detailed documentation – if it is possible and acceptable, the solution with flexible approach to construction technology should be chosen during designing, i.e. such technology which enables specific shifts during construction, without influence on work dynamics.

It is important to make construction works specification within the rehabilitation plan. In specific example of The Old Bridge rehabilitation following operations was performed:

- Removal of damaged structure (blocks);
- Injection of cracked blocks and preparation of a new blocks from the same quarry as the authentic blocks;
- Execution of scaffolds structure;
- Execution steps according to specific requirements for craft works procedures used during construction of the original bridge.

3. Quality control plan

Contractor should establish and maintain an appropriate Quality Assurance (QA) System for rehabilitation works. Quality Assurance Plan (QAP) has to be submitted to the Project Manager-Supervisor for approval. During the performance of the works, Contractor produce documentary evidence proving that the QA System is respected and that consistent and required quality of works is ensured. Quality Assurance Plan include an organizational diagram, presented in figure 9 [5].

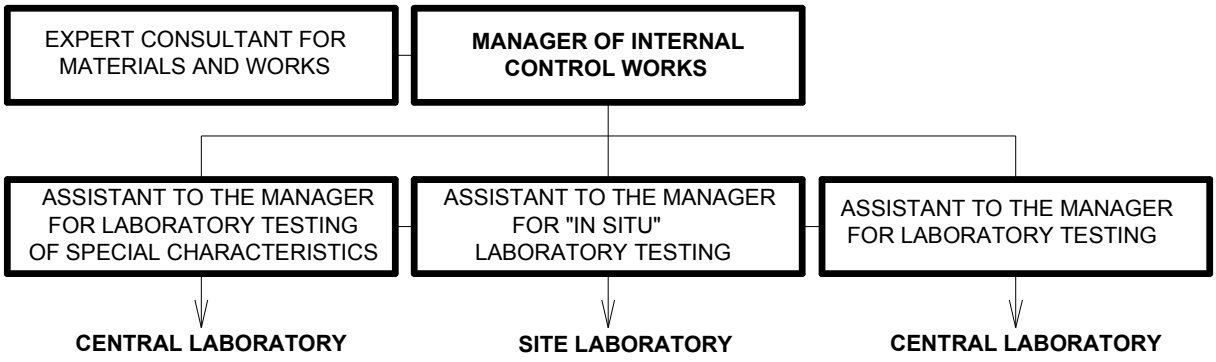


Fig. 9. Organizational chart of a team for internal quality control [5]

Contractor appoints a senior person to the position of Quality Assurance Manager. He is authorized to liaise with the Project Manager-Supervisor in any quality assurance matter.

The Quality Assurance Plan must as a minimum include:

- Note about the Site organization;
- Book of procedures that defines the execution of tasks;
- Documents for follow-up of the execution of the Works by the Contractor;
- Quality control Plan.

The quality control of materials has to be conducted in the way presented in figure 10.

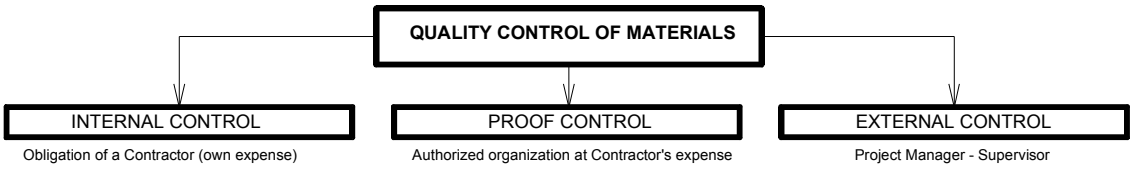


Fig. 10. Quality control of materials

The Control Plan must include:

- Definition of control sections;
- Specification of the internal control measures and list of all required quality control documentation;
- Description of hold points that need to be inspected by the Contractor within the scope of the internal control and within the scope of the external control;
- Identification of type and number of tests in each control sections;
- Description of sampling and testing methods;
- Description of the Contractor's responsibility for the conduct of inspection, sampling and testing and for the assessment of testing results;
- Description of reporting procedures and of the report format.

The Quality controls presented on figure 10 include:

- Control of basic components,
- Production control,
- Quality compliance control,
- Control during execution,
- Control after execution.

The control of the basic components relates to the following:

- Tenelija for for voussoirs, cornices, spandrel walls, parapets and repair of the walls;
- Limestone for voids covers, repair of walls, masonry filling and pavement;
- Conglomerate for repair of masonry walls and masonry filling;
- Lead for sealing dowels and cramps;
- Metal for cramps and dowels;
- Laying mortars and mortars used for filling;
- Wearing course under pavement;
- Mortars used for the joint;
- Grout mixtures for injection of masonry walls;
- Products for injection of micro cracks in voussoirs;
- Basic components for mortars such as limes, sand, gravel, additives;
- Products used for the patina.

Production control includes all testing that needs to be conducted during the production of different mortar types and grout mixtures. Production control must to be done at the Contractor's expense. If the material is produced at the construction site, the control is done at the location of the batching plant or grout mixer.

Quality compliance control takes place upon the completion and approval of the production control test by the Project Manager-Supervisor. Quality compliance control consists of carrying out specific tasks under the conditions of real execution in order to test the procedure, assess the conditions of execution and possibly improve them.

Quality compliance control includes the following:

- Definition of procedures for the course of the execution of specified tasks;
- Agreement on the control testing (during and after the execution) and the execution of the tests;

- Definition by the Project Manager-Supervisor of the hold points;
- Tracking of events in the course of the Works execution;
- Preparation of testing reports;
- Preparation of conclusions, recommendations and corrections of the procedures for the purpose of the execution by the Contractor;
- Acceptance by the Project Manager-Supervisor.

The following quality compliance tests were done:

- Assembling of the arch;
- Pavement (new and restoration);
- Injection of the masonry walls;
- Repair of the walls, ashlar walls and its cornices;

The control during the execution encompasses all visual, in situ and laboratory testing which will be carried out by the Contractor and approved by the Project Manager-Supervisor during the execution of the tasks.

It includes more specifically:

- Control of the respect for tolerances;
- Visual control and ultrasonic tests on ashlars during the Works on platform;
- Testing of laying mortars (mechanical characteristics, setting time, creep, workability);
- Testing of masonry filling and its components;
- Testing of wearing course under pavement;
- In situ testing of grouting (inspection of boreholes, mechanical characteristics in situ, permeability, endoscopy in boreholes).

The aim of testing after the execution of works is to guarantee to the Contractor and the Project Manager-Supervisor that the objectives defined in Technical documentation have been reached. If results indicate that the objectives have not been reached, the Contractor will in agreement with the Project Manager-Supervisor and at his own expense undertakes the appropriate measures or complementary works in order to meet the objectives. The control after the execution mainly consists of visual inspection and control of the geometry – intrados, positioning of the joints, level of pavement, level of cornices and parapets. It also includes possibility of loading tests.

The Contractor has to establish site laboratory to carry out all the tests on the site that are required in Technical Specifications. Installation and equipment of this laboratory, as well as the technician who will be responsible for a correct execution of the tests, have to be approved by the Project Manager-Supervisor. This laboratory must be fully accessible to the Project Manager-Supervisor who will use it for the execution of his own control tests. Final approval will be given by the Project Manager-Supervisor after trial period. Quality control dates must be record and stored in digital and paper version.

4. Final remarks

Since the reconstruction of historical heritage is specific construction work, which is regularly financially demanding, detailed plan for quality assurance is very important. The aim of this paper was to present the experience of the elaboration of the quality assurance system at the demanding reconstruction of the destroyed historical heritage. The experience shows that systemic approach is necessary to achieve rationalization of demanding and expensive construction work.

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RECONSTRUCTION OF THE LOAD CARRYING SYSTEM AT THE LEDNICE CHATEAU, CZECH REPUBLIC

Miroslav Bajer [1], Jiří Kala [2]

[1] *Department of Metal and Timber Structures, Brno University of Technology, Faculty of Civil Engineering,*

[2] *Department of Structural Mechanics, Brno University of Technology, Faculty of Civil Engineering.*

***Abstract**: The aim of this article is to approach the reconstruction method of the load carrying system particularly decorative column. The priority of the monument care of the bearing steel structure in the greenhouse at the Lednice chateau was to protect the greenhouse vegetation. For this reason, the special and complicated technologies were chosen. The timing of the works respected the health of the vegetation.*
First came the analysis of the actual condition of the monument and conservators prospecting report. The preparation of the design documentation and conservators project followed. In the second stage the monument care project was realized. The structure of the greenhouse and its interior was reconstructed, then the exterior reconstruction was realized. The final task consists in reconstructing the catacombs, the burial place under the greenhouse.
The restoration of the Lednice greenhouse was awarded by GRAND PRIX prize of architectural associations.

***Key words**: Monument care, Lednice Chateau, GRAND PRIX prize, greenhouse bearing system*

1. Introduction

The greenhouse at the Lednice chateau in the Czech Republic is part of the Lednice-Valtice complex, a UNESCO monument. The structure, which was built in 1845, was proposed by the architect Geore Wingelműllerem on behalf of Alois Joseph II of Liechtenstein. It is one of the oldest and largest historical greenhouses on the European continent. The restoration was supervised by The Heritage institute in Brno. The company OK-DESIGN, Ltd. was both the provider of the design documentation and the general constructor, the authorized conservators were in charge of the actual reconstruction works.

The monument care process went in three phases. First came the analysis of the actual condition of the monument and conservators prospecting report. The preparation of

[1] Assoc. Prof., Ph.D., Veveří 95, 602 00 Brno, Czech Republic, e-mail: bajer.m@fce.vutbr.cz
[2] Assoc. Prof., Ph.D., Veveří 95, 602 00 Brno, Czech Republic, e-mail: kala.j@fce.vutbr.cz

the design documentation and conservators project followed. In the second stage the monument care project was realized. The structure of the greenhouse and its interior was reconstructed, then the exterior reconstruction was realized. The final task consists in reconstructing the catacombs, the burial place under the greenhouse. The final task consists in reconstructing the catacombs, the burial place under the greenhouse. For this, the documentation has already been prepared.

The priority of the monument care of the bearing steel structure in the greenhouse at the Lednice chateau was to protect the greenhouse vegetation. For this reason, the special and complicated technologies were chosen. The timing of the works respected the health of the vegetation.

2. The chateau palm greenhouse – historical context

The history of cultivating foreign thermophilic plants in Lednice reaches back to the 17th century. The chateau in Lednice boasts many fascinating features that illustrate the fame and ability of its builders, the Princes of Liechtenstein. The chateau itself ranks among the masterworks of architecture. The palm greenhouse, however, is unique. The Lednice-Valtice area, therefore, has quite properly been placed on the UNESCO List of World Heritage Sites. In 1642 Prince Karl Eusebius of Liechtenstein (1611-1684) began to built first know orangery. The orangery, described also in period literature, was the pride of the Lednice garden.

In 1715 Prince Anton Florian of Liechtenstein (1656-1721) preparations for building large wooden greenhouse with northern wall of masonry; it was built on the site of today's palm house. The orangery became an integral part of the presentational areas of the chateau after 1817. Prince Johann Josef I (1760-1836) had a new wing designed by architect Josef Körnhäusel (1782-1859) added to the chateau. The new arrangement reduced the size of excellent transition area to the landscape park built not long before (1805-1811). The orangery was repaired several times, and ceased more and more to satisfy the requirements of the growing assortment of warm-climate plants. Prince Alois Josef II (1796-1858) decided finally to tear the orangery down and build a modern greenhouse. English architect Peter Hubert Desvignes started working for the prince in 1838, among other jobs, Alois Josef II entrusted him with the task of drawing up plans for the renovation of Lednice chateau. Why Desvignes' design was never realized is unknown. Part of the plan – evidently a fragment of the overall plans – is on deposit at the Vienna family archive of the ruling Princes of Liechtenstein. English construction principles, as transmitted through P.H. Desvignes, were put to use in the new design, the author of which was Georg Wingelmüller (1810-1848). The plans for building the greenhouse date from 1843-1846. Wingelmüller's drawings of the layout, cross-sections, front view, and roof structure, show the date 1843. The architect Poppelack implemented the plans without major changes.

The first step (1842) was to tear down the Baroque orangery, the Temple of the Muses, and the chateau theatre; the actual construction started in 1843 and was finished in1845. In 1937 (date of design] the upper part of the structure was replaced according to plans by Opava engineer K. Wiche. The elongated structure of the greenhouse is made to point east-west. This is quite an interesting fact. That is how greenhouses with half roofs are usually oriented, with the northern side formed by a wall, often of extra thickness, the better to protect the greenhouse against the north wind and accumulate the sun's energy. All-glass greenhouses with ridged roofs like the Lednice greenhouse usually point north-south, so that both sides are equally exposed to the morning and afternoon sun. Facing north and south with the narrow and prevents passive cooling and overheating.

2. Steel bearing system

44 load-carrying columns form the structure bearing system. The columns support the half-cylinder vault made from steel ribs. Both columns and steel ribs form the arch bearing system, the part of which is the glass tile cladding. The number of glass tiles is approx. 65000.

The bearing columns are located in the interior in two longitudinal rows, the longitudinal distance between them is 3900 mm, in the lateral direction 4300 mm, see figure 1.

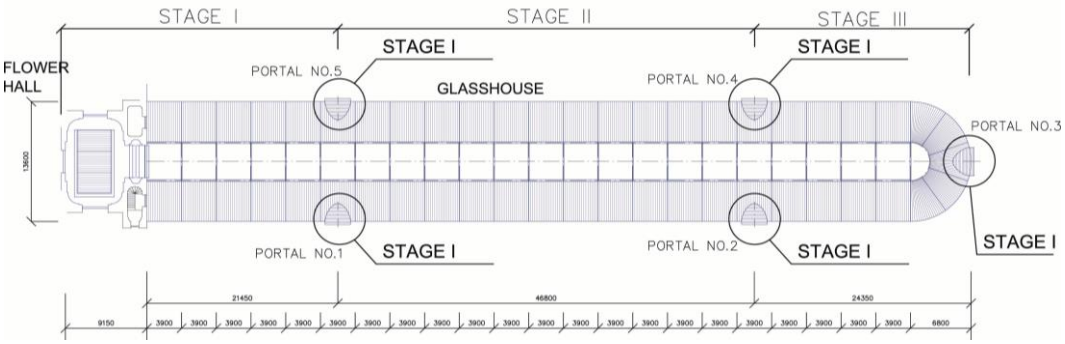


Fig. 1. Ground plan with stages of reconstruction

As part of the conservator prospect, one column was extracted from the system and mechanically divided. The shape of the decorative bamboo tree was respected. This column (7072 mm high, octagonal shape footing) is bold anchoraged into the 600x600x400 mm marble block. The block is surrounded by brick deck with calcareous plaster, see figure 2.

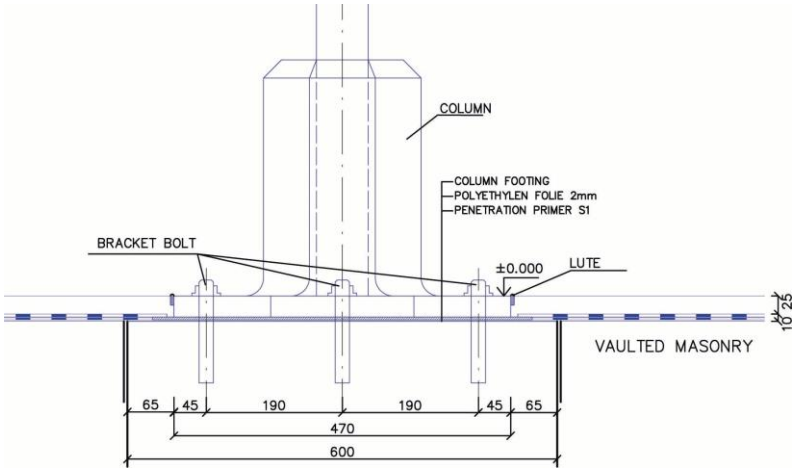


Fig. 2. Column footing

The bearing column center is countersunk into the cast iron footing. The wrought iron center is of circular cross section, its diameter is 72 mm, and the upper end head serves as the connection with the vault, see figure 3.

The column head is hinge joined to the longitude truss girders. The center is cladded by six cast iron members imitating the bamboo tree shape. The bottom shaft part is covered by zinc banana tree foil; unidentifiable foils and flowers cover the head.The space between the bearing center and the cladding was filled by gypsum. Wrought iron ribbing made by smithing forms the half-cylinder vault bearing system. The distance between the double ribs is 3900 mm, see figure 4. These profiles are fixed into longitude girders. In the bottom side, they are anchored through the portal in the brick base.

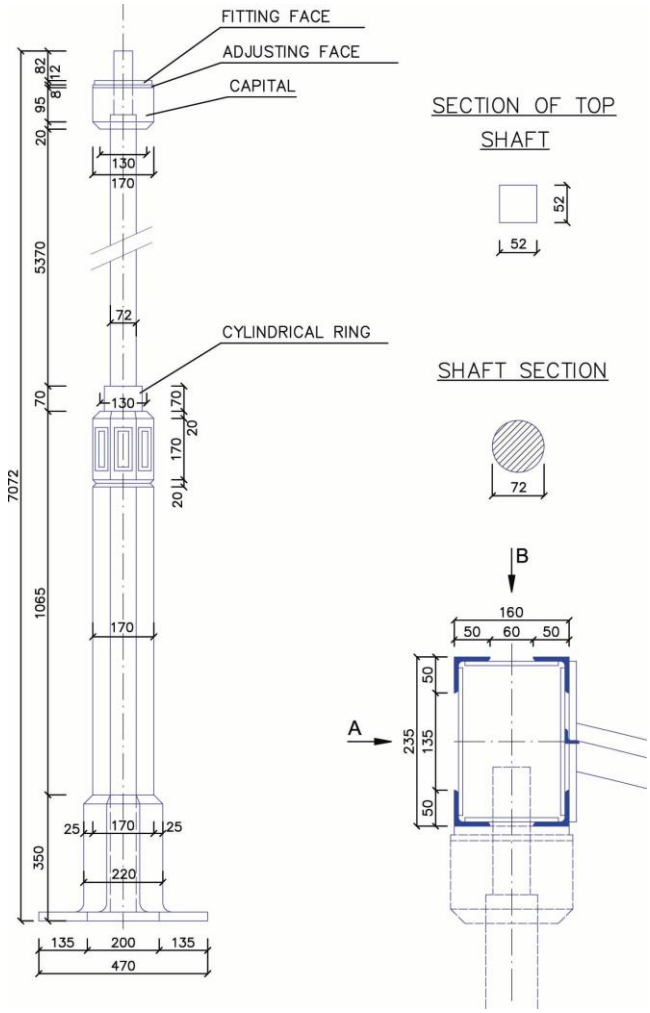


Fig. 3. Column detail

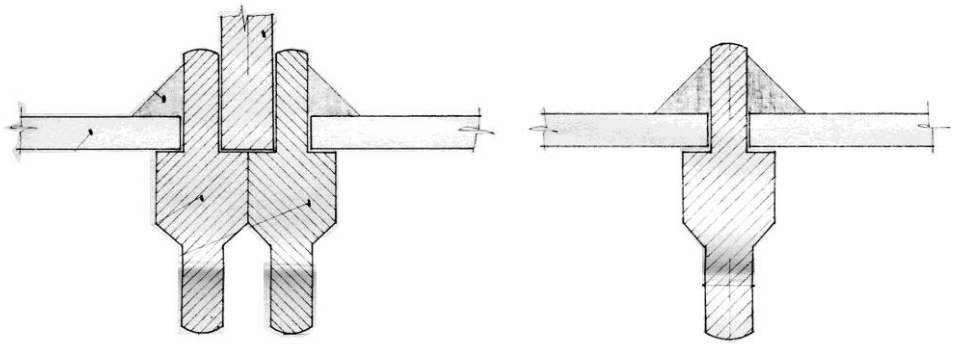


Fig. 4. Vault steel ribs section

The single ribs are put between the doubled ribs in the distance of 250 mm. The ribs support cladding glass tiles by jigger and pin connection. The tiles prevent the ribs from lateral buckling. In the lateral direction, the upper longitude girders are joined by the timber cross member. This connection is made in the place of the double ribs. The timber greenhouse loft structure lies in this system. The participation of each member can be seen in figure 5.

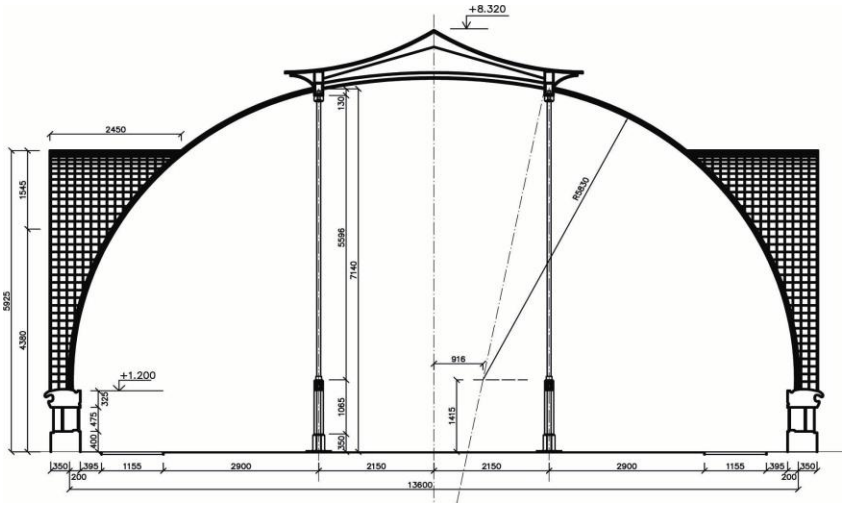


Fig. 5. Typical greenhouse section

3. The rehabilitation of the load bearing column

Primarily, the greenhouse was used as the orangery. The plants grew in containers and the columns stood freely in the air, not exposed to humidity and subsoil weight. When the orangery was converted into a greenhouse, the subsoil was spread in a layer of the height of up to 750 mm. Since the columns were not insulated from the subsoil humidity, the water crept up through gypsum the whole column height, creating - together with air humidity - conditions for the shaft and cladding corrosion.

After the columns were taken away from the greenhouse and replaced with temporary supports, the cladding had to be carefully removed from shaft. The steel pole was heated in a tempering furnace to loosen the rust and burn off the original filling material. Then, the sleeves were gripped, and using a hydraulic device, an attempt was made to strip them from the shaft. As the shaft and the sleeves were solidly bonded together by corrosion, this procedure failed. For this reason, a reverse procedure had to be used. The columns were submersed in a 10-15% bath of hydrochloric acid for 12 hours. Afterwards, they were sprayed with water under high pressure, and stabilized. In this way, the gypsum softened. Then the column was gripped and the bearing shaft was pushed out in a horizontal direction and the undamaged cast iron sleeves were freed. Against the primal theory, all shafts could be used without change. As the gypsum did not prove to be a suitable filling material, it was substituted by a two-element epoxy laminate resin Ebalta AH-110 with filler F-B (modified chalk). The resin has good mechanical characteristics. The adherent is designed to be removable – in case of need the resin is heated to the proper temperature and the sleeve is removed. After the corrosion was removed mechanically, the original coat was blasted, galvanized, and four times painted by Hempel colors. Originally, the material used to connect the sleeves was tin, now the sleeves were glued.

3.1 Non destructive experiments

Non-destructive experiments were applied on load carrying columns shafts in Královopolská strojírna in Brno. The testing was done by the magnetic dust method and by ultrasound. The magnetic dust method shows surface flaws, while ultrasound finds inner flaws in the material. The magnetic dust method is founded on principle of the flow of the magnetic field through material. In the case of damage to the tested material, the flow of the magnetic flow is disrupted. The shape of the magnetic field in the tested material is found by magnetic suspension (in this case water was used as the support medium, and a concentrate as the electromagnetic material). The concentrate is colored with fluorescent dye. While the magnetic filed is going through the tested sample, it is submersed in a

magnetic suspension that copies the shape of the electromagnetic field, which is visible under ultraviolet light. The size of the disruption shown by the magnetic suspension corresponds exactly to the size of the disruption in the tested material. The electromagnetic field was introduced into the test sample by a horseshoe-shaped electromagnet – type TS 230 S TESTIMA running on alternating current of 220 V. The detection element in the magnetic suspension was type FLUOFLUX (TIEDE). Water as a support medium was used because of its relatively harmless effect on the test sample. The purpose of the test was to show that the test sample did not reveal linear cross indicators (faults) of more than 3 mm in length. The ultrasound waves were introduced into the test sample by means of a B 2 SN probe, with a frequency of 2 MHz. The readings were taken on a USM 2 MT (KRAUTKRAMER) instrument, the range of which was set at 100 mm. The purpose of the test was to show that the tested sample did not reveal internal indicators (flaws) longer than 7 mm.

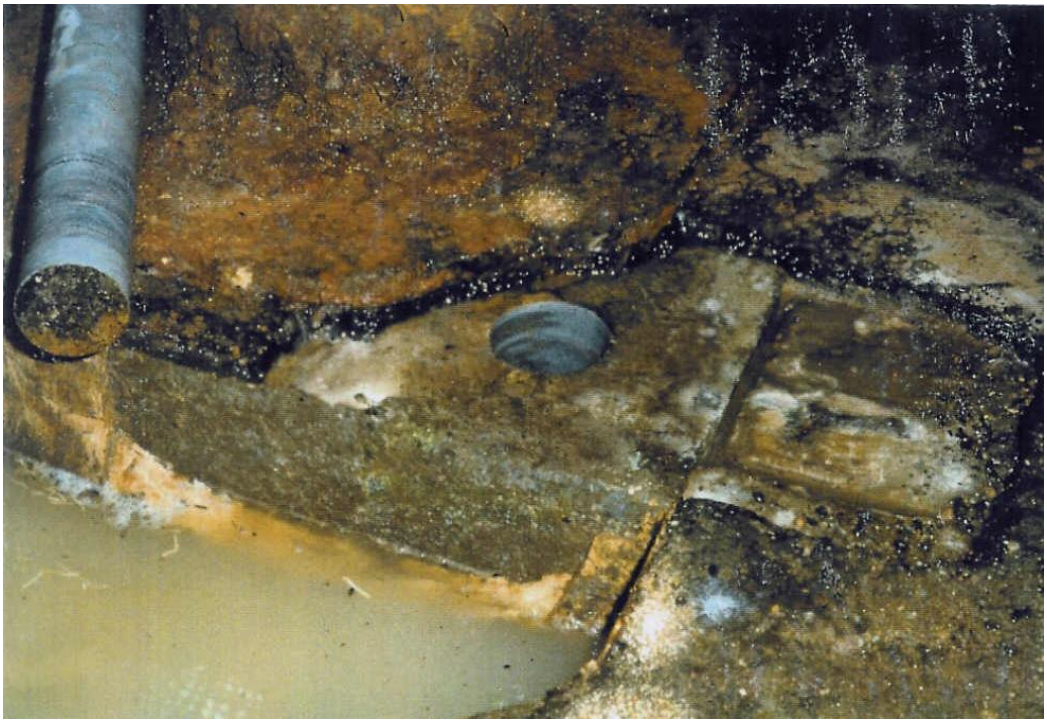


Fig. 6. Specimen for strength laboratory test

3.2 Numerical simulation

As a part of the project documentation "Monument care of the greenhouse" the static analysis of a stand-alone shaft was made. Since the slenderness of this member (of the length of 7072 mm) is too high, it was necessary to consider the participation of both the iron shaft and the sleeve. In this way, the slenderness ratio is 200. We assumed that the shaft is loaded by the axis force of 28,9 kN and that the cladding prevents the column from buckling. The shaft damaged during the conservators project was replaced by the stainless pipe 73/7.1.

The load carrying capacity was recalculated by the ANSYS program system. The detailed model where the participation of each member of the column (shaft, sleeve, epoxy laminate) was exactly defined. The anchoraging and the connection by the longitude girder were also taken into account. This control calculation approves the statical reliability of the columns in the greenhouse at the Lednice chateau.

4. Conclusion

The greenhouse is a very special structure requiring great efforts in creating an interior microclimate. The primary task of the greenhouse is to protect the plants against the negative effects of the exterior environment, and provide optimum conditions for growth. For this reason, the special and complicated technologies were chosen. The timing of the works respected the health of the vegetation.

The restoration of the chateau greenhouse in Lednice may for many reasons be called a unique event both Czech and world monument preservation. Above all it was extraordinary standing of the greenhouse among other structures of its kind from the historical and technical aspects, and the maximum effort devoted to preserving its authenticity on the creative and material level, which compelled everyone who took part in its restoration to search for new solutions to its problems, and select the best of them. All work was undertaken with consideration toward the plants, which for the period of the reconstruction remained in the greenhouse in order that their vegetative cycles be interrupted as little as possible. No small problem was the handling of the other plants including transplanting, as some of them have been growing here since the greenhouse's founding, and were brought here already as adult specimens, meaning that some of them are over 200 years old. It was also necessary to use technology and materials in such a way as not to endanger the plants during the reconstruction or after.

The process of the monument care can be seen in the figures. The restoration of the Lednice greenhouse was awarded by GRAND PRIX prize of architectural associations.



Fig. 7. Column head before and after reconstruction



Fig. 8. Side portal before and after reconstruction



Fig. 9. Greenhouse interior after reconstruction

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CASE STUDY: DESIGN FOR CONSERVATION, RESTORATION, EXPOSURE AND RETROFIT OF CHURCH "ST.ATANASII", BOBOSHEVO TOWN , KUSTENDIL REGION

Ivan Geshanov[1]

EQE Bulgaria AD, Sofia, Bulgaria

Abstract:.
Current paper aims to present structural measures and design solutions for restoration and structural upgrade of Church "St.Atanasii", Boboshevo town , Kustendil Region.
Church consists of three structurally independent parts, erected in different historical periods.
The oldest one according to written text on the south wall, had been constructed around 1600 year.
At the end of 19th century and beginning of 20th century an open narthex has been added and later – around 1927 year, new narthex with refectory have been erected.
Technical conditions of all parts currently are creating certain risks for valuable wall paintings inside of the oldest part and for human safety and normal service of all parts.
Therefore, according to approved by Bulgarian Orthodox Authorities architectural and restoration design, certain structural solutions have been adopted to put the bearing masonry and timber structures into adequate condition with regard to restored and increased bearing capacity, durability and stiffness.
The vault arch of the oldest part has been structurally upgraded by unloading and installation of protective new steel covering structure, together with replacement of broken and in poor condition tension elements.
The old narthex timber structure, in poor condition, has been replaces by a new timber structure with increased bearing capacity, stiffness and durability.
The most recent part – additional narthex with refectory and clock tower has been generally retrofitted and structurally upgraded by new RC elements and new timber roof and clock tower. Again the new structures have been designed with adequate bearing capacity and stiffness for the intended use.
Finally, structural strengthening and retrofit measures have added additional and sufficient bearing capacity, stiffness and durability to the existing building structures, thus allowing preservation and protection of the valuable historical, architectural and art elements.

Key words: *conservation, restoration, repair, historical masonry, timber structures*

[1]Iv. Geshanov, PhD, M.Sc.Str.Eng, EQE Bulgaria, ihg@eqe.bg; ivgesh@gmail.com;

1. Introduction

The Church is declared as architectural- construction monument of material culture, category of local importance and architectural-artistic monument of material culture category of national importance (now immovable culture value).

1.1. Historical reference

Church "St.Atanasii" is located on a wide terrace at the city's cemetery and is determined as a small, one single hull church with half-circle apse.

According to hardly readable text at the south wall the temple has been erected during 1590 year. Until year 1862 this church is the main temple of the city (village). The building is 9.16 m long and 4.9 m wide (external dimensions). The walls are 0.70 m thick, made of stone masonry. The church has been painted fully from inside, and also outside on the western facade according to established canon.

During 19 th century and beginning of 20th century an open narthex has been added and later – around 1927 year, new narthex with refectory have been erected. Thus total length of the church is 20.22m and the width of the western part is 12.44m, external dimensions.

During year 2009 church is partially renovated (external insulation and painting, PVC window frames have been installed), but without coordination with responsible Authorities, and as a result the general authentic view of the building has been substituted.

General view from eastern apse can be seen in the next pictures (**Figure 1**).



a) General view before 2009 renovation

b) Apse view after renovation

Fig. 1.a) View before renovation; b) Current view

Wall paintings inside of the church are in poor condition, covered with thick layer of dust and soot. No restoration and repairing works have been performed.

1.2. Technical condition of the building structures

17th century church

Structures of the vault and walls are in generally stable; long cracking is observed along vault key resulting from improper loading from the new roof – see **Figure 2**.

One of the two tension elements at the base of the vault is missing; the other is in poor condition.

Floor cover has been repaired by cement putty not complying with certain requirements; and due to this capillary moisture raise can be observed.



Fig. 2.Cracking in the vault key

Old narthex

Massive masonry 19 century walls are in stable condition, but the loose ramshackle timber structures at the upper parts of the walls and roof are in close to failure status. See the next **Figure 3**.



Fig. 3.Old narthex condition

New narthex and refectory

Similarly to the old narthex structure, wall and roof ramshackle structures are in a poor condition and close to failure status – see **Figure 4a)** and **4b)**.

External walls to the cemetery park are built from 60 cm stone masonry and at least 150 cm are embedded in the ground. Due to lack of draining system, adequate waterproofing and protection as well as permanent earth pressure on a vertical cantilever walls, closing walls of the refectory are in emergency state – see **Figure 4a)**.

Bell tower is also in close to failure condition – see **Figure 5**, also refer to **Figure**

It can be concluded that wooden supporting structure of the Bell tower is in very poor status, damaged, rotten and suffering big deformations; in result Bell tower is visually tilted to one side and close to full collapse.




a) General view b) roof structure

Fig. 4.New refectory status

1a).




Fig. 5.Bell tower status

2. Architectural conceptual design

2.1. Introduction

Based on determined in architectural part theoretical, methodological and legal criteria and requirements, the following measures shall be applied:

Regarding 17th century church

-Removal of facade insulation and restoration of authentic roof level and covering;

-Restoration of original facade texture- stone masonry at equal joint; restoration of authentic late medieval floor cover from hexagonal ceramic tiles;

- Restoration of authentic window openings and closing of additional openings.

Regarding narthex and refectory

-Reconstruction, replacement and structural upgrade of near to failure ramshackle structures of walls, ceilings, roofs and bell tower;

-Exposure of original stone masonry texture and architectural details; improvement of service conditions and design solution providing optimal possibilities for protection and exposure of old wall structures dated from 17th century;

2.2. Architectural layouts and sections

Figures 6 and **7** depict general restoration and reconstruction measures according to architectural design solutions.

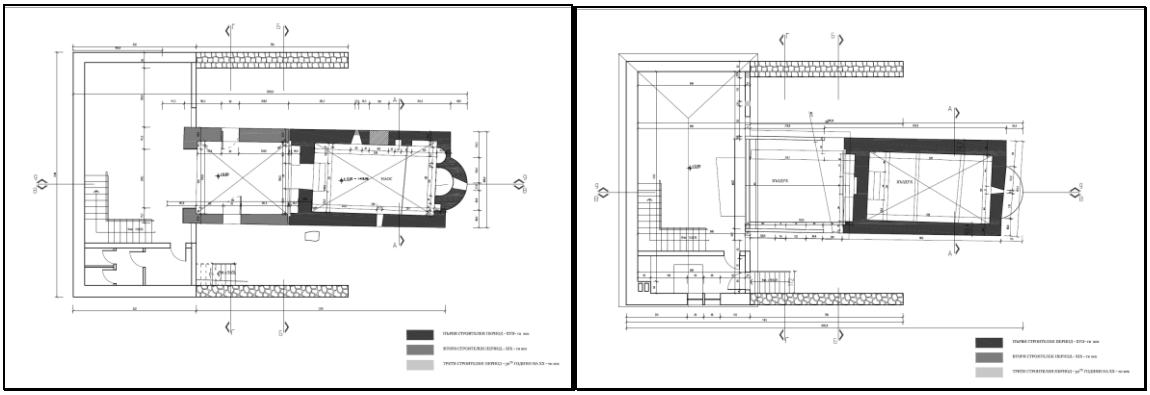


Fig. 6.Reconstruction of ground elevation (±0.00) and elev. +3.00

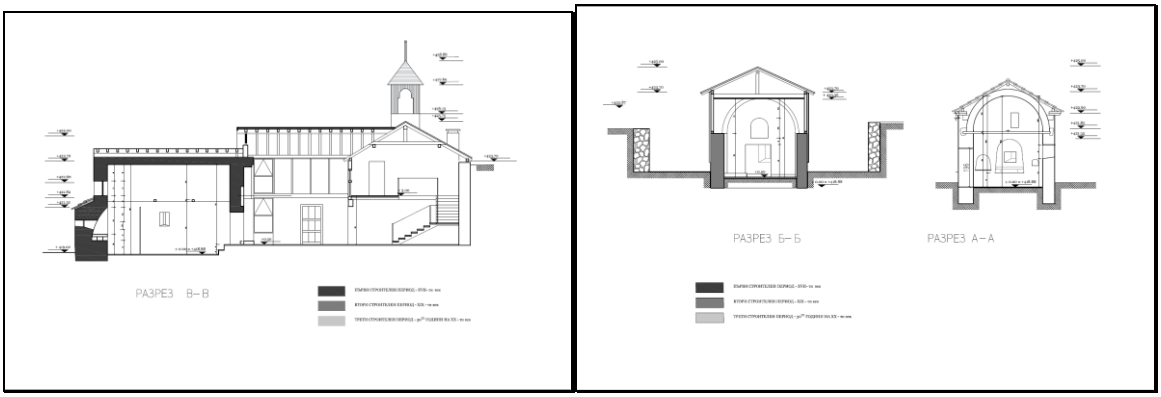


Fig. 7.Longitudinal and cross sections

3. Structural upgrading design for 17th century church

3.1. Technical solution

Based on conceptual architectural design objectives and observed problems in some structural elements, the following measures have been chosen:

a. Removal of existing roof and unloading of stone masonry vault from unnecessary materials and coverings;

b. Injection of cracks with suitable compound/ resins ;

c. Installation of new tension elements instead of old ones; these works shall be realized through execution of anchoring pockets in vertical direction from the top surface of existing walls. Anchors (tension elements) are designed from round steel rod with d20mm and shell be installed hidden in timber strut 100/100mm;

d. Execution of strengthening RC lintels on the top surface of existing walls with the purpose of safe anchoring of the tension elements and support of the new roof structure. Before pouring of fine grained concrete, internal surfaces of the pockets and grooves for lintels are covered with lead sheets.

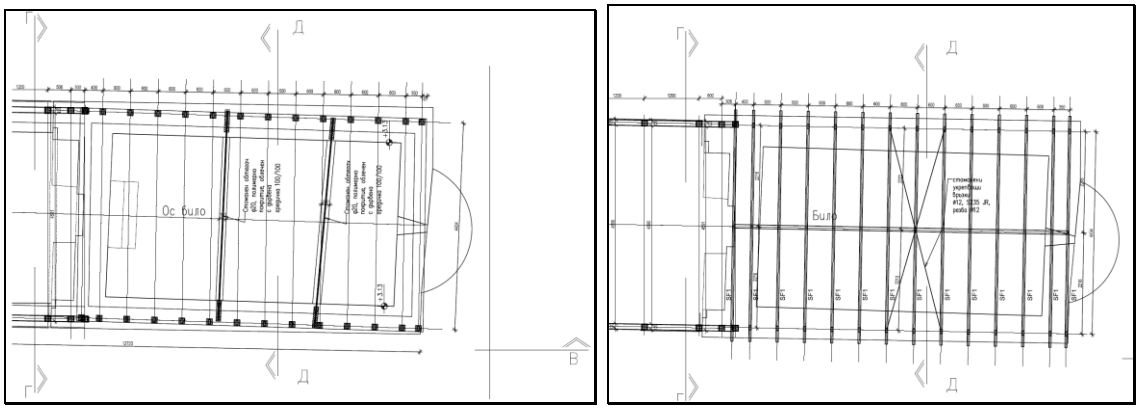
e. Execution of protective and conservation coverings on the top surface of the vault;

f. Installation of new roof steel frames by glued anchors to the concrete lintels, leaving at least 30 mm gap between them and vault top face; installation of steel braces and struts for spatial stability;

g. Istallation of separation bitumen membrane layer (5 mm) on the top face of the steel roof frames; mounting of timber laths and sheeting by mechanical fixing; installation of waterproofing and other insulation layers as per architectural details;

e. Installation of final stone roof plates covering as per architectural details

3.2. Graphical presentation of structural upgrade design



a) New RC lintels and anchor pockets at +3.63 b) New roof steel frames at +3.81

Fig. 8. Installation of new RC lintels, anchor pockets and roof steel frames

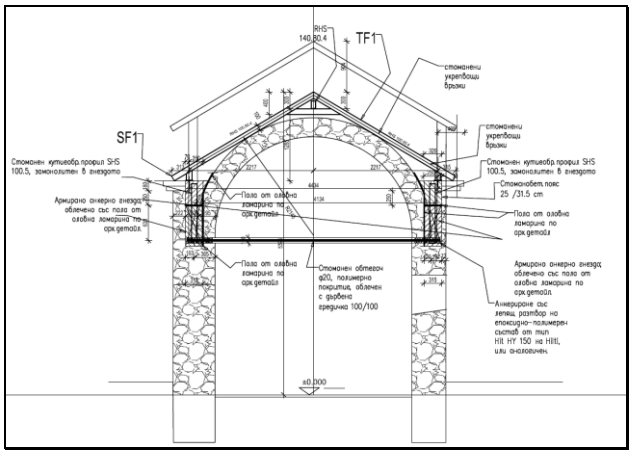


Fig. 9. Typical cross section

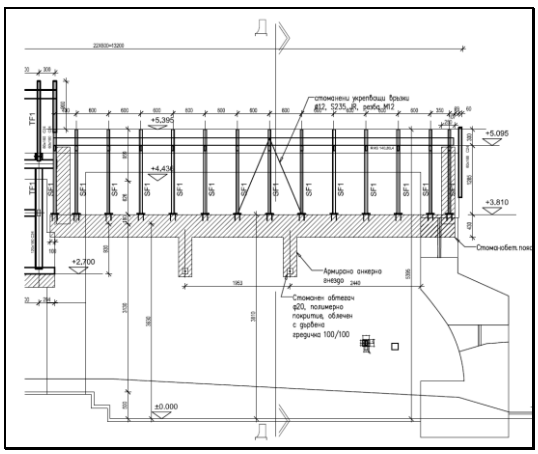


Fig. 10. Longitudinal section

4. Structural upgrading design for new narthex

4.1. Technical solution

Based on conceptual architectural design objectives and observed problems, the following measures have been chosen:

a. Removal of existing wall and roofing timber structures;

b. Execution of strengthening RC lintels in grooves on the top surface of existing walls with the purpose of safe support and anchoring of the new wall and roof structures;

New bearing timber structure is designed as a row of timber strut frames space at 1200 mm and roof trusses between. Global stiffness and stability are achieved by properly located and designed bracing elements from round steel rods, ridge beam and timber struts.

4.2. Graphical presentation of structural upgrade design

5. Structural upgrading design for new refectory and bell tower

5.1. Technical solution

Based on conceptual architectural design objectives and observed problems, the following measures have been chosen:

a. Removal of existing building and excavation to reach the existing floor level of narthex;

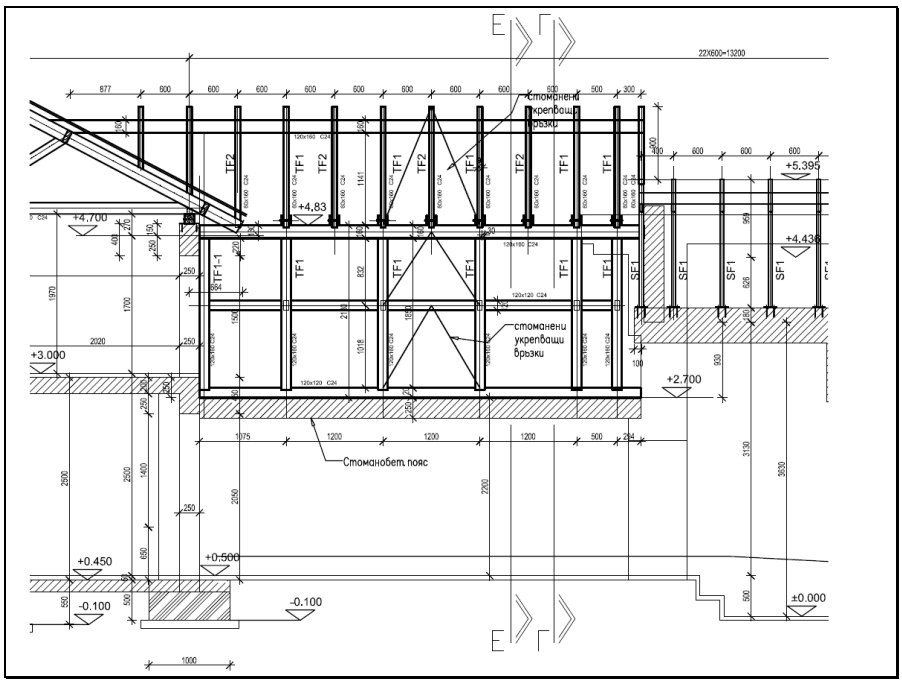


Fig. 14. Longitudinal section

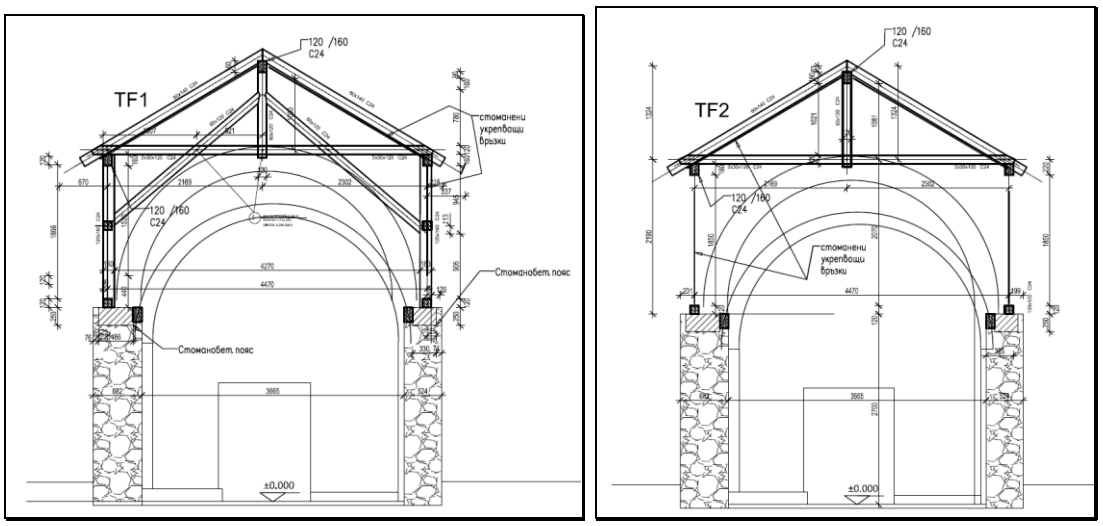


Fig. 15. Cross sections

b. Execution of draining external system, RC strip foundations and bearing retaining walls of the new two story building;

c. Execution of new floor flat slab 20 cm thick, serving also as lateral support to the retaining walls;

d. In order to execute new vertical elements (columns and walls) at the edges of existing stone masonry walls special grooves are foreseen. In these grooves required reinforcement shall be installed and concrete poured. In this manner new structure of the3 refectory shall stabilize existing walls of the new narthex.

e. New roofing structure of the refectory is designed as a row of timber trusses, bound by system of ties and struts in one stiff and stable spatial structure. New timber structure is supported on the new RC structure;

f. New bell tower is an integral part with new timber roof structure and is supported in vertical direction on edge bearing wall and on the other side on a specially designed RC beam.

5.2. Graphical presentation of structural upgrade design

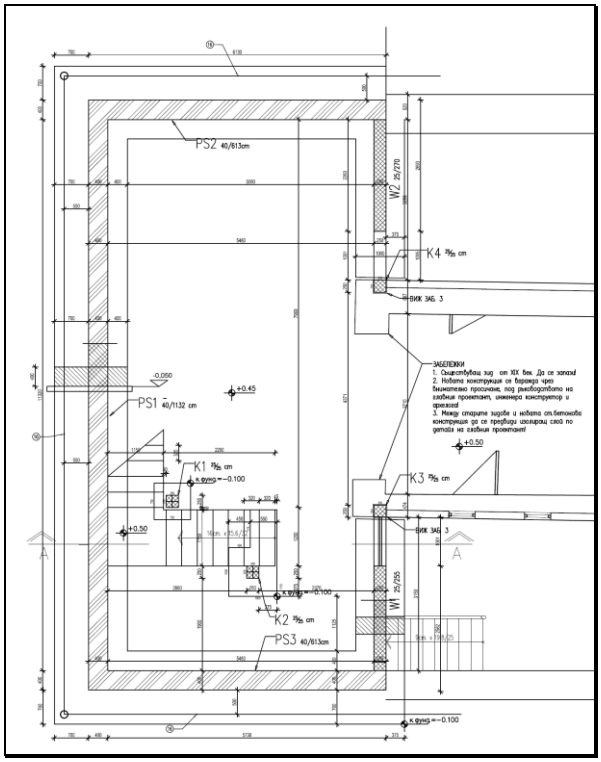


Fig. 16. Foundation plan

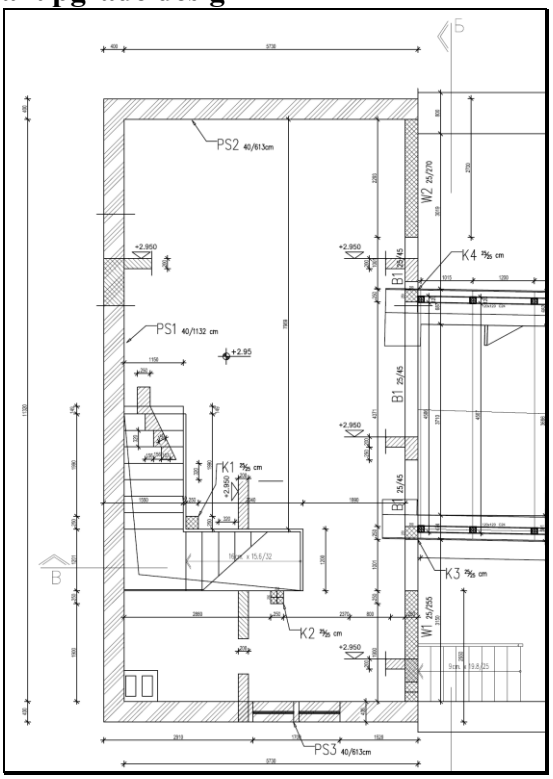


Fig. 17. Formwork of floor elev.+3.00

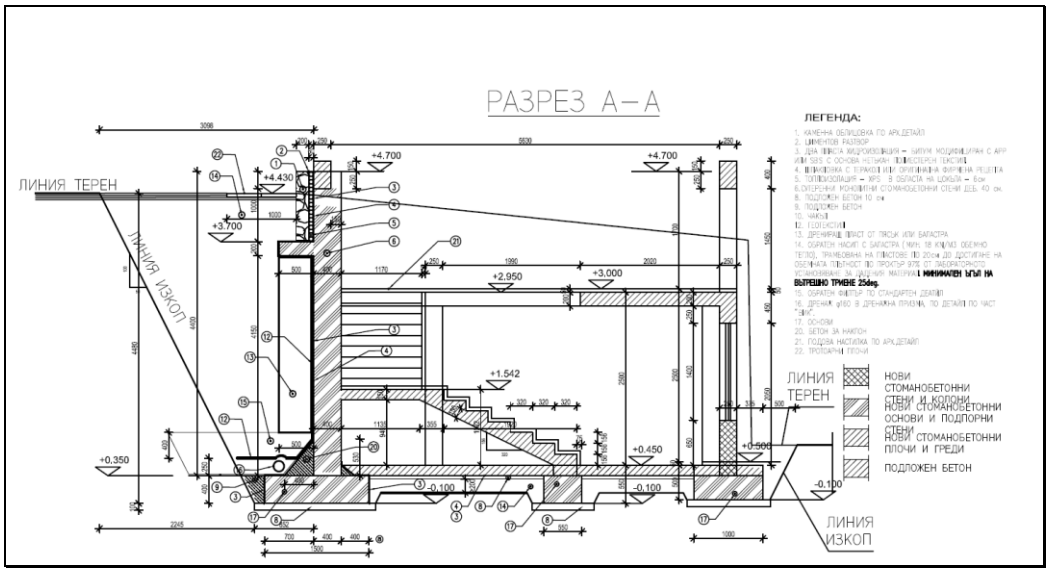


Fig. 18. Cross sections through retaining wall, floor slab and stair

6. Main design parameters

Structural design has been performed according to [1], all applicable parts and main requirements of [2] and [3].

Timber material

C24 according to БДС EN 338; Timber and wood-based materials shall either have adequate natural durability in accordance with EN 350-2 for the particular hazard class (defined in EN 335-1, EN 335-2 and EN 335-3), or be given a preservative treatment selected in accordance with EN 351-1 and EN 460.

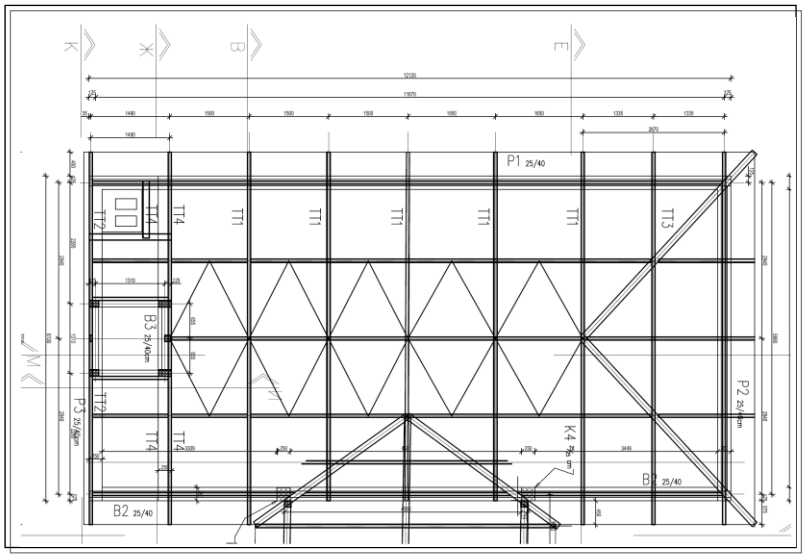


Fig. 19. Plan view of roof and bell tower timber structure

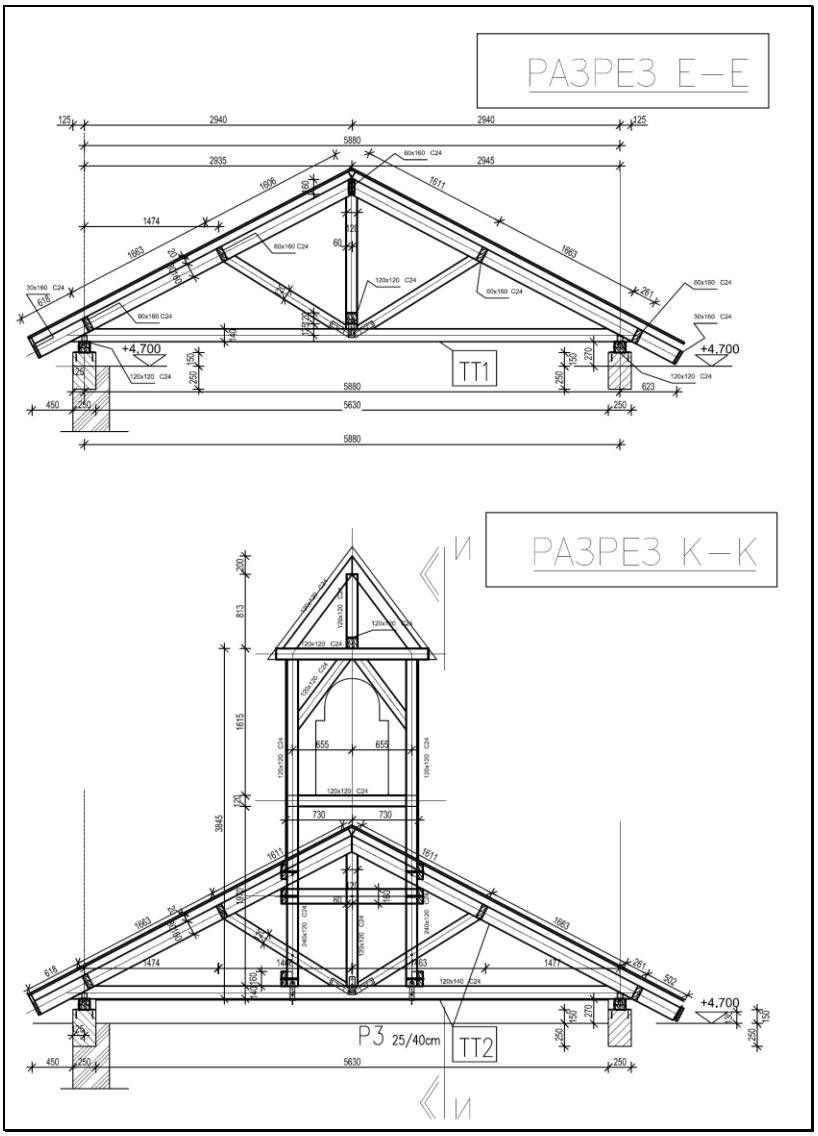


Fig. 20. Cross sections of roof and bell tower timber structure

Fixing elements
Screws for timber, DIN 571, hot dip galvanized;
Plates and connectors, S235 JR, hot dip galvanized 150 μm;
Structural steel
S235 JR, hot dip galvanized, 150 μm;
Concrete
C20/25 according to БДС EN 206-1;
Exposure class for foundation and underground structures: XC2;
Exposure class for above ground structures: XC4;
Concrete cover (minimum):
-foundations: 50 mm;
-beams (to stirrups): 35 mm;
-slabs: 20 mm;
-columns (to stirrups): 35 mm;
-walls (to external rebar layer): 25 mm.
Reinforcing steel
B 500B, according to БДС EN 10080;
Ground base and backfill
Foundations and ground base are designed for allowable bearing pressure 200 KPa.
Backfill material shall be compacted to 97% Proctor density and shall posses at least 25^{o} angle of internal friction.
Geometry tolerances for execution, control and acceptance
-Concrete structures: БДС EN 13670;
-Steel structures: БДС EN 1090-2;

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STRUCTURAL SOLUTIONS FOR PRESERVATION AND REHABILITATION OF MASONRY ARCHES

J.Tsenkova[1], E.Abdulahad[2], F.Rangelova[3]

UACEG

Abstract: *Masonry arches are an important structural element in many buildings, treated as architectural and cultural heritage. Due to various reasons, many representatives of these elements are compromised and at risk of destruction. This raises the need to be sought methods for rehabilitation and / or strengthening, on the one hand to ensure their safety and safe exploitation, and on the other to ensure their compliance with the original, constructive function and aesthetic appearance.*
This article discusses different options for protection, restoration and strengthening of brick masonry arches, as this is the basis for the preparation of an experimental project, which will be investigated for effectiveness and applicability of some of the reviewed methods.

Key words: *rehabilitation, strengthening, masonry arch*

1. Introduction

The architectural heritage in the world and their preservation for the next generation is crucial. The exact definition of architectural heritage is given in the UNESCO Convention in 1972 and it states that the architectural heritage includes architectural works, elements or structures of an archaeological nature, and groups of separate or connected buildings. The masonry arch is often a structural element in structures that are treated as architectural heritage. An arch structure can be structural elements in churches, sports halls, bridges and buildings of architectural heritage because it combines structural and aesthetic functions. The stability as well as the safety of curved structural members under a given loading condition is strongly dependent on the geometry of the structures and on the mechanical characteristics of the constituent material.

According to the geometry of arches are divided into several types. Common representatives are the segmental (parabolic) and semi-circular (Roman). According to the geometry

2. Define the necessity of preservation of architectural heritage in particular masonry arches

Rehabilitation of heritage buildings has become an issue of great importance around the world. It is the result of the need to improve existing buildings for new conditions of

[1] Jolina Tsenkova, PhD student, jolina _cenkova@abv.bg ;
[2] Emad Abdulahad., Assoc. Prof. Dr. Eng., UACEG,Dep. of Reinforced Structures, FCE, Corpus B, study 430; georgosing@gmail.com ;
[3] Fantina Rangelova, Prof. Dr. Eng., UACEG, Dep. of Construction management and Economics, FCE, Corpus B, study 1038, fantina_frp@abv.bg ;

sustainable development of the World, and of the recognition of the importance of conservation of the architectural heritage.

One or more of the following reasons usually, motivate the need for structural rehabilitation of heritage buildings:

- The visible defects in the building;
- Damages after natural disasters and accidents;
- The change of the use of the building for most severe conditions;
- The movements in the abutments;
- The change of the static scheme;
- The erosion of the materials;
- The need to be in accordance of the Requirement of regulations for construction (Euro codes);

A basic point in considering structural rehabilitation of a heritage building is establishing the performance level to be fulfilled, particularly, the requirements in terms of structural safety and the level of the structural safety.

3. Choice of the intervention

Many historical structures continue to offer services and historical values; and as such, it is important to understand their structural behaviour and collapse mechanism when developing a plan for their preservation and retrofit. New restoration and retrofitting methods should be preferred where traditional methods are insufficient. New technologies that can be appealing to historical structures are emerging with current advancements in materials and construction techniques.

An important part of any intervention is: *first*: understand the structure; how it was built, materials it was built from, geometry, properties of materials, condition of the materials, past interventions, structural behaviour and loading conditions. The whole documentation for structure, such as any past documents, drawings and photos must be investigated. The basis of all this information it can be considered various options for strengthening and repair. According to the different problems there are developed various techniques for strengthening and repair. The particular choice is not an easy task. When selecting and designing an intervention, it is recommended to taken into account the following requirements specified by S. W. Garrity [4]:

• Respect the authenticity. Aesthetic appearance should be maintained or improved;
• Increase load-bearing capacity;
• Provide a compatible and durable intervention;
• Avoid over-strengthening or over-stiffening;
• The intervention should improve resistance to cracking, developing hinges, material degradation and other damages or faults;
• Avoid significant increases in dead load;
• Create a safe working environment. Many strengthening methods may create temporary instability during construction;
• Accommodate multiple types of defects;
• Accommodate previous interventions;
• Avoid local stresses from applied interventions;
• Minimize the impact on the environment;
• Provide methods with rapid gains in strength; This is important for safety and stability during construction and prevents unpredictable phenomena from occurring during a slow strengthening technique;
• Be cost-effective within these requirements

4. Different Strengthening Techniques

Masonry has a well-known negligible tensile strength. The stability of masonry arches is provided by the coincidence of the line of thrust and funicular polygon and the line of thrust is kept in the section of the arch itself. The formation of cracks and the increasing of deformation happen, when the resultant of the internal forces outside the central section. This results in the formation of a plastic hinge, which exhibits the crushing of a limited portion of the masonry at the compressed edge of the arch. If sufficient hinges form to turn the arch into a mechanism, then collapse is possible. The aim of the methods of rehabilitation and strengthening is to protect the structure from collapse by increasing the load-bearing capacity or modifying the failure mode.

4.1. Traditional techniques for repair and strengthening

a) *Saddling* has proven to lead to an adequate increment in strength and stiffness, but is labour-intensive. This technique has some significant advantages: low cost, no visible effect and effectiveness for multiple defects. The concrete saddles may be variable and constant width of the cross section. It is important to connect the new arch and the existing arch, to transmit the forces. This will increase the effective thickness and improve distribution of loads. Recently, this technique is improved by the addition of fibers in concrete. Polypropylene fibers give resistance to surface shrinkage cracking, where stainless steel fibers give considerable strength and structural ability to unite arches and to bind cracks.

b) *The shotcrete* or single or double-sited jacketing with cast in-situ reinforced concrete increase the thickness of the arch in an effort to increase load capacity and to stabilize and protect weathered masonry. Usually, these techniques violate the aesthetic conservation and restorations requirements.

c) The injection fill can increase load capacity by improving load distribution to the arch. It can also be a preventative measure to slow further deterioration of the structure.

d) *Anchoring* (Fig. 2) *and radial pinning* (Fig. 1) are suitable for longitudinal cracks and also can be used to restore the ring separation and to prevent further separation. Anchoring and radial pinning will increase the stiffness and the elastic properties of the arch and limit movement. It can be an economical alternative to methods requiring extensive dismantling like saddling and is invisible after completion. The major disadvantage is risk of corrosion.

e) *Iron tie-rods* used in the arches of many historical structures (Fig.3) The main purpose of tie-rods is to prevent the increase of tensile stress on the arch [7]. The tying increases the bending capacity and limit movement. The method is cheap, but corrosion is possible. Other significant issue is that a single steel rod or cable may cause too high bearing stresses.

4.2. New techniques for repair and strengthening

a) *Retro-reinforcement or Near-surface reinforcement* (Fig.4), a cost effective method of increasing the tensile strength in near surface zones with the higher tensile stresses from external loads and ductility of existing masonry using stainless steel reinforcement The reinforcement also helps improve lateral load distribution and increases the transverse flexural strength of the arch**.** By this method, the corrosion is possible. It is recommended to place many smaller sized bars to avoid the corrosion.

b) In the last years L. Jurina developed a new method called "*RAM—Reinforced Arch Method"* (Fig.5). This technique consists in modifying the loads acting on the structure through the placement of post-tensioned steel cables, either at the extrados of the arch or at the intrados. The main purpose of the RAM is to modify the distribution of loads acting on the arch.

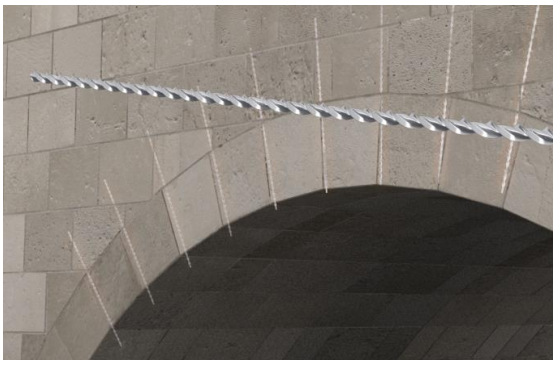


Fig. 1 Radial pinning

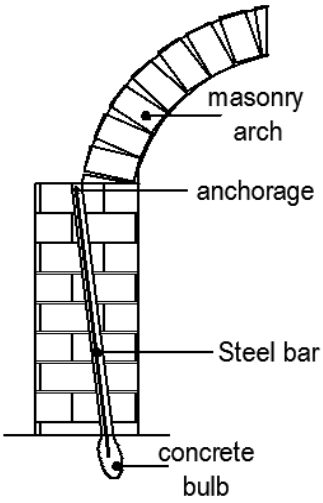


Fig. 2 Anchoring of a vault (EU-India cross program)

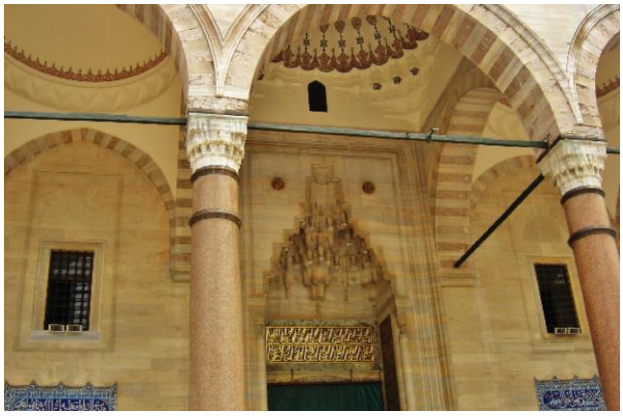


Fig. 3 Example of the use of tie-rods in historic structures (Suleymaniye Mosque in Istanbul)

This new load distribution induces a pure axial compression between the blocks and, consequently, the thrust line is re-centered, avoiding or, at least, retarding the formation of plastic hinges [5]. The method has no visible effects and no significant impact on the weight of the structure. The experimental tests have shown that there is an increase in ultimate load. Compared to the traditional system, which makes use of concrete layers, the RAM reinforced arches showed a higher ductility and a lower residual inelastic deformation, when discharged.

c) Other innovative method is the applying *fiber reinforcement polymers (FRP).* FRP sheets can be applied extrados and/or intrados. The FRP's can be applied by one of the following three different systems: *pre-cured, wet lay-up, or prepreg*. Each system can provide slightly different mechanical and geometric properties. Application of each system is quite easy and only requires a simple bonding to the surface at the pre-defined locations. The application of FRP sheets to an arch modifies the classical mechanisms of collapse in masonry arches, this modification depends on the location of the FRP (extrados, intrados or both) [2]. To assure the maximum load-bearing capacity of the arch, the reinforcement must prevent a fourth hinge from occurring, only allowing the following failures: (1) crushing, (2) sliding, (3) debonding, or (4) FRP rupture. These failure modes are dependent on the limits of strength of the constituent materials and on the structural interactions of

them at a local level [8]. FRP strengthening is simple and lightweight method, and is not labor-intensive. The technique is more expensive than traditional, but has longer life.

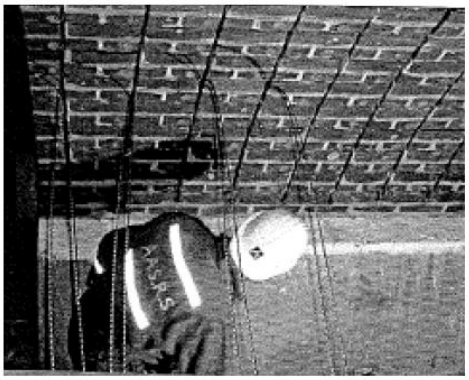


Fig. 4 Placing bars in pre-drilled holes



Fig.5 Intrados reinforced arch method applied at San Cristoforo Convent in Lodi, Italy. (L. Jurina, 2000).

d) *Prefabricated liners* are typically made of corrugated metal or glass reinforced cement and attached to the intrados of the arch. The space between the liner and arch ring is filled with concrete or grout. The liners provide an increase in load capacity by supporting the arch and giving it more resistance [2]. The liner must be manufactured in compliance with the shape of the arch. This method is simply and quick, but is inappropriate for arch with historical or cultural value to which the appearance is important.

e) *Steel reinforced polymer (SRP) and steel reinforced grout (SRG),* based high strength steel filaments twisted to form cords and embedded in either an epoxy or mortar matrix, are fairly new technologies. SRP/SRG composite materials are easily applicable and adaptable to different surfaces. Subsequent to the experimental studies, A. Bori at et. [3] conclude that, steel cords performed better than CFRP in terms of ultimate load capacity and ultimate deflection for both intrados and extrados strengthening applications, in spite of their lower mechanical properties versus carbon fibers.

5. Conclusions and future work

With the development of technologies and materials, each of the proposed methods are improved and modified. All methods have advantages and disadvantages. Their successful application in a particular case depends on the expertise of the team of the detailed information about the site and circumstances of the environment.

The actuality of the problem of strengthening and rehabilitation of the buildings of cultural heritage gives to us reason to prepare one experimental work at the UACG for evaluating the strengthening techniques of masonry arch structures with application of the traditional and advanced FRP materials and systems. Comparison between the two methods will be made and recommendations will be given.

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REHABILITATION AND RECONSTRUCTION OF OLD DORMITORU OF BOGOVADJA MONASTERY (BUILT IN YEAR 1858.)

Nenad Krstivojević[1]

Construction Company ,,Greda"

Abstract: *Old dormitory Bogovađa monastery was built in 1858. in the form of the Cyrillic letter ,,П,, length of 31.50 m, up to 11.60 m central nave, a parallel ships are 21.00 m/ 8.40 m. It has 1/3 basement height of 3.20 m and ground floor height of 3.80 m. It was built in brick without reinforcement. Since the earthquake caused significant damage to the walls of the ground floor, foundation, roof structure and roof cornices. Completed the project of rehabilitation and reconstruction of the building: reinforcing the existing roof structure by introducing new elements to existing real new wooden roof truss and replacing bad beams, concreting of shallow foundations and rehabilitation of damaged walls dormitory introduction of new reinforced concrete ring beam level with a wreath under the attic and rehabilitation of damaged walls network with anchors and new mortar. The works on rehabilitation and reconstruction were carried out in 2013 and 2014.*

KEYWORDS: recovery, new wooden roof truss, concreting under the foundations, reinforced concrete ring beams, cracks

1. Introduction

Old dormitory Bogovađa monastery was built in 1858. Structure is under protection Organization for monuments protection of Valjevo city. That is jagged building shaped in Cyrillic letter ,,*П*,, and it is height is 1/3 basement and ground floor. Tall facade walls make it impressive, especially north-west view. In constructive sence that is brick crafted structure with rock foundations. Floor, atic and roof construction is made of wood elements. Roofing is done by interlocking tiles, except on one section where smaller angle where asbest pannels were placed.

Usable height in basement is 320cm and at the a ground floor 380cm, while on attic there is jamb wall of only 40 cm. Structure was built in mid XIX century in style of masonry walls without steel reinforcement in ring beams.

Building is recorded in detail on start of October and at the end of December of 2011, because is was damaged during earthquakes 1999. and 2010. Research work were done by opening three probes by south-east wall and then it was established that depth of foundations is only around thirty (30cm) centimeter from upper level of sidewalk. Foundation is being done with crushed or squared stone. Width of brick walls in basement goes from 65cm to 90cm, and in ground floor goes from 35 to 60cm. Floor constructions are wooden with massive joists and filled charge on laths and boards. Joists above basement wasn't possible to measure, but wasn't even real need for doing that, because

[1] Nenad Krstivojević, B.Sc.Civil eng., *Construction Company ,,Greda", street Karađorđeva 165, Valjevo, krstivojevicn@sbb.rs*

floors undamaged, and basement ceilings as well, what indicates on good condition of that construction.

Joists above ground floor are on a main carrier with dimensions 19/19cm to 20/25cm on axle distance from 63cm to 83. On the rest parts are with dimensions 12/14cm and 16/16cm on axle distance from 78cm to 106cm. On some areas there are beams above joists with dimensions 15/12 cm with distance of 5.30m. Ceiling construction above ground floor is made of mortar on reed wich is hitched with laths.

Roof wooden construction is made with levels, with slope of 35 degree. Rafter rely on truss plate with straining beams and these on pillars wich are with their roof tie and roof truss are an integral part of double hangers.

At the top are rafters without peak beam, and on the bottom aren't relying on wedges, but on wooden element here called „paroške" which lays on jamb wall from wedges. Hangers are placed on facade walls over attic's jumb wall and pillows – pilars made of bricks above supporting walls.

Originally dormitory was built in shape of Cyrilic letter „Г" and later was added south-east part, what is visable at dilatation and cascade at foundation at the spot of extension, diference of stone during building of stone foundations, diference at attic leveling of older and newer section, as well at diference of roof surfaces and roof tiles.

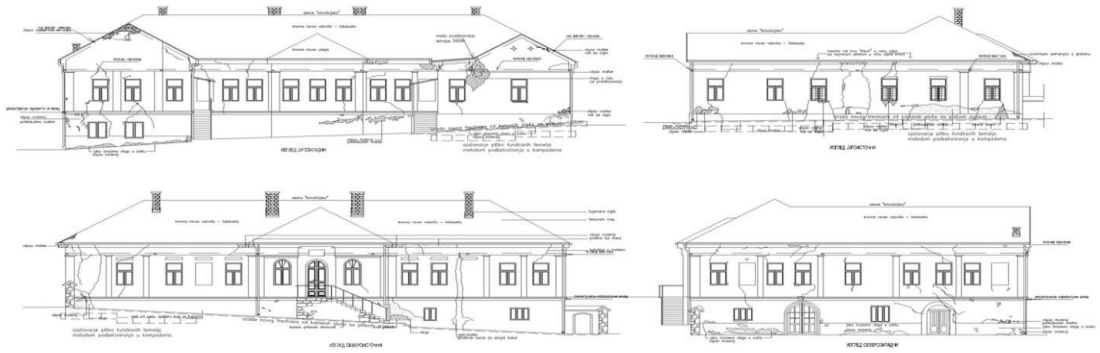


Fig 1. Schematic view facade of the dormitory with disabilities

2. Condition and Description of Building Damage

Roof and roof construction: outside tiles skidded on some spots and some of them are cracked. Roof purlins are damaged a lot, but there are and broken ones. On some of edge rafter ridges skidded and left without mortar, sheet metal on cove are dilapidated and rusted. Some of rafters are very small cross-section, with significant deflections and damages. Rafters above south-east area of dormitory have layers of soot because it seems like they were burning during fire. Roof on three levels over main nave of dormitory (south side) has deflection along the entire surface.

Walls: Most damaged are facades walls facing south-east part of structure, where foundations are founded very shallow. Cracks on that wall are mostly slantwise above window to the horizontal gutter. There are also and cracks at the parapet part of the window. At the joint of south-east and north-east wall there are vertical cracks. All the cracks are mostly wide in a range of few millimeters to a centimeter somewhere. There are cracks all over walls in height above window to wreath of jamb wall. In north-western facade wall there are number of

cracks under and above ground floor windows. At the joints of facade walls there are significant cracks at the joint it self, especially at the wright height and over hanged part of „Sims" in which „parošci" are placed for acceptance of rafter landing. In south-west facade walls most numbered are vertical slantwise in gable walls which are brick-worked by placing half brick. At all inner supporting walls there are numerous slantwise and vertical cracks, which at some places forming earthquake crossed „X„ cracks and significant cracks are facing above the doors as well. There are numerous cracks at the joints of walls and ceiling mortar, which are on somewhere covering whole surface in room cracked.

Floors and ceiling construction: mostly are visible cracks in mortar of ceiling of attic on joint with walls and on some areas thru entire room. There aren't spoted any cracks on the basement ceiling. All of those cracks which aren't indicate that base wooden construction is somewhere damaged floor neither ceiling. Mortar from reed mostly felt off because of humidity or earthquake influence.

Foundation construction: With opening probes on south-east side of building it's being seen that from that side founded and it's been notified existence of old and new section of stone foundations which indicate on already mentioned that building have been upgraded sometime in the past. On the rest sections of the structure there aren't visible cracks or damages of stone foundations.

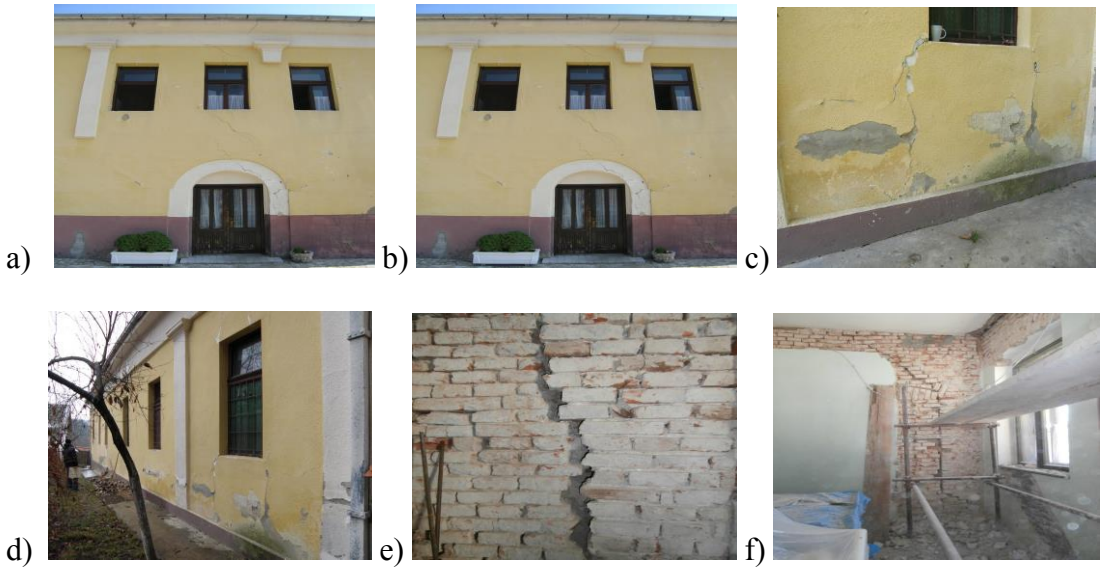


Fig. 2. a, b, c, d, e, f Photos of damage to the dormitory of the earthquake

3. Measure of the Static Constructive Rehabilitation and Reconstruction

3.1 At the roof construction:

Because lack of means Organization for monuments protection decided to change only damaged and static misfit roof elements replace namely not to change entire roofing timber and roofing tiles.

Rafters: By static calculation it comes that is necessary for rafters to be on larger distance than 3.00m and to be in dimensions 10/12cm, and on smaller distance than 2.30m in both cases be in dimensions 10/10cm. Rafters with misfit dimensions for given span and rafter damaged and with big deflection need to be changed with new ones with different dimensions according to static calculation.

Purlins: carrying rafters between hangers and they have webs. By static calculation that for smaller distance (at the end on south-east wing and north-western wing) from 2.60m need to

be 14/14cm, but mostly there are already purlins 12/14cm and it is acceptable to satisfy demanded conditions.

By static calculation for larger distances, (on middle main nave) from 3.30m needed to be 14/20cm, so it's needed to replace misfit purling with new specified cross section. According to larger distances of existing purlings 12/14cm misfit dimensions according to static calculation, whose is't impossible to replace with new ones with right dimension matching without taking complete rafters, roofing felt and roofing tiles. So it is best to use existing purling as upper zone, existing web as starting diagonals, existing queen struts as start support verticals for new form grid with add of new bottom zone 2x6/12cm, new middle verticals 12/12cm and new diagonals 2x6/12cm in all according to static calculation and drawing details. All connections of new elements and existing elements of wooden grids achieve with nails, screws and iron plates.

a)  b) 

c)  d) 

Fig.3. a, b, c , d Photos of damage roof construction

Tie-beam: for shorter distances from 5.30m it's needed according to static calculation 16/16cm, to meet existing tie-beams 16/16cm For larger distance than 6.50 ml by calculation 20/20cm are needed ,to achieve existing tie-beams 20/25cm and 19/19cm with binders.
It is necessary just eventually to replace burned tie-beams and rooten roofing felt under tie-beams from humidity.

Hangers: through the static calculation of hangers 1; 2; 3: 4 achieving existing collar beams, struts and bridles as elements of hangers. It's necessary to add new collar beams 14/14cm where missing. Through static calculation of hangers 6; 7; 8; 10; 11; 12 they are not achieving existing collar beams so it's needed to place a new set of double tenon joints 2x8/12cm and struts and bridles as elements of hangers achieve requirements.
Through static calculation hanger 9 achieving existing collar beam, double tenon joints and bridles as elements of hangers. Through static calculation of hangers 13; 14; 15 achieving existing collar beam, double tenon joints and bridles as elements of hanger.
Replacing of damaged elements and adding of new wooden elements need to be done with conifer timber. Timber need to be dry and protected with adequate impregnation coating to prevent rotting and insects.

3.2 On the walls:

Model of structure have been made in program Tower 6 to get on easiest way to total vertical load at the ground level and total seismic capacity at the ground level. By calculation of main tensile stress at ground floor it comes to little bit value than it allowed, because walls of ground floor are massive enough. However, walls of ground floor are 380cm tall and that is great height without any reinforcement, according to that on a top of walls need to be added reinforced concrete beams b/d= 15/15cm through all outer facade and main carrier inner walls in level of collar beams, according to details from static calculation. Bond beams are reinforced with 4Rø12, Uø6/20. First holes need to make in one wall to make space for bond beams section by section, than section by section being reinforce, concreting and anchorage with next wall and connect into a unit. Alternately that way it's possible to work at more than one place parallel .It's necessary to provide continuity of rebars to accept tensile force with overlapping with min 60cm. All perpendicular bond rings is necessary to connect with anchorage. During constructing provide needed support wall mass above bond ring. Also, bond rings need to be done on a top of gable end wall b/d= 20/20cm with 4Rø12, Uø6/20.

Most spottable cracks are above and around windows at façade walls, especially at the south-east facade wall and in all inner carrying walls exist numerous slantwise and vertical cracks. At sections where cracks are bigger than 10 mm on vertical wall, which are not spotted at the originally recording, but upon mortar removing, need to be injected and place bar grid Q131 as reinforcement with anchorage Rø10/40 in both directions and shotcrating with cement mortar. For millimetre cracks form 4-10 mm do injecting with premixed injecting mass on base of cement emulsion. All cracks needs to be pre cleaned, from face of the wall cracks needs to be secured with cement mortar on each 40cm and place injection pipes. Injection with overpressure with max 0.50 bar. For smaller millimetre cracks of 3-4mm need to be rehabilitating with casual mortar and smoothing on already prepared surface.

3.3 At foundations:

Under entire south, east and north part south-eastern wing of building, according to details from designing documentation, under existing foundations of building wall under-concreting is being done of existing shallow founded building foundation. Under-concreting is being done in tunnel linear, possiton „Kp'', at alternately segments made of reinforced concrete according to details from static calculation. Excavation for reinforcement of foundations do in linear tunnelling from 1.00m are min distance of 2.00 m alternately, like it is marked in documentation with serial numbers. Segments position „Kp'', which are with „L„ cross-section 80/50+30/12cm and reinforced with horizontal bar 10Rø10 and vertical bars Uk Rø 10/20. Sidewalk is being done parallel as reinforced concrete slab with thickness of d=12cm with grid bars Q335 and founded on foundations made of concrete on pure distance of 3.00m l. Crushing strength of concrete works is „MB20'' and bars RA400/500 i GA240/360, reinforcing grid MAG500/560.

3.4 At the floors and ceiling constructions:

All aged wooden floors in rooms need to be replaced with new boards. Visible cracks in mortar of ceiling need to be removed and do mortar work again. Those entire cracks are not indicating that base wooden floor and ceiling construction is damaged.

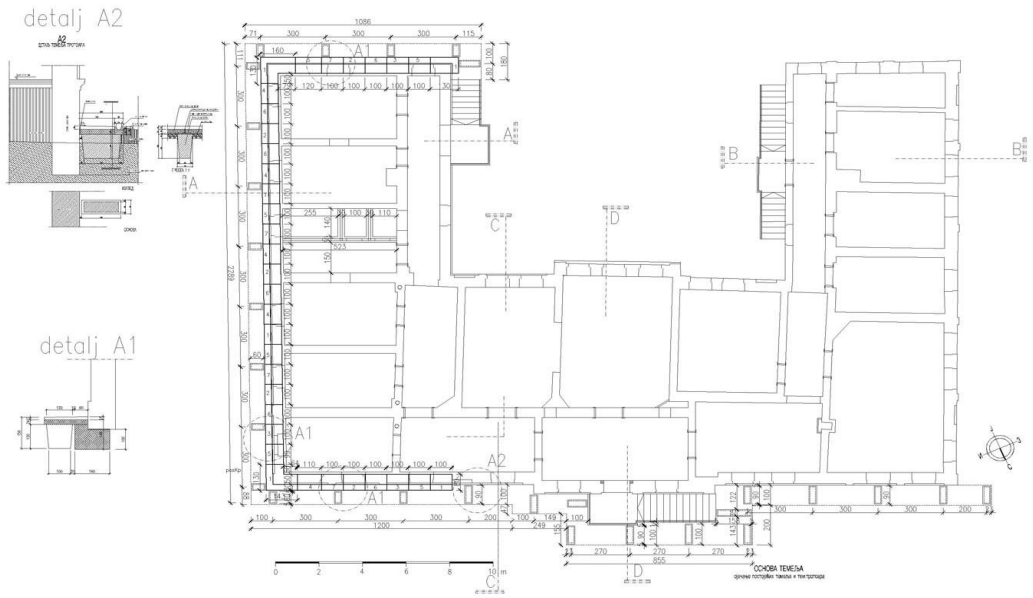


Fig. 4. Rehabilitation of the foundation dormitory

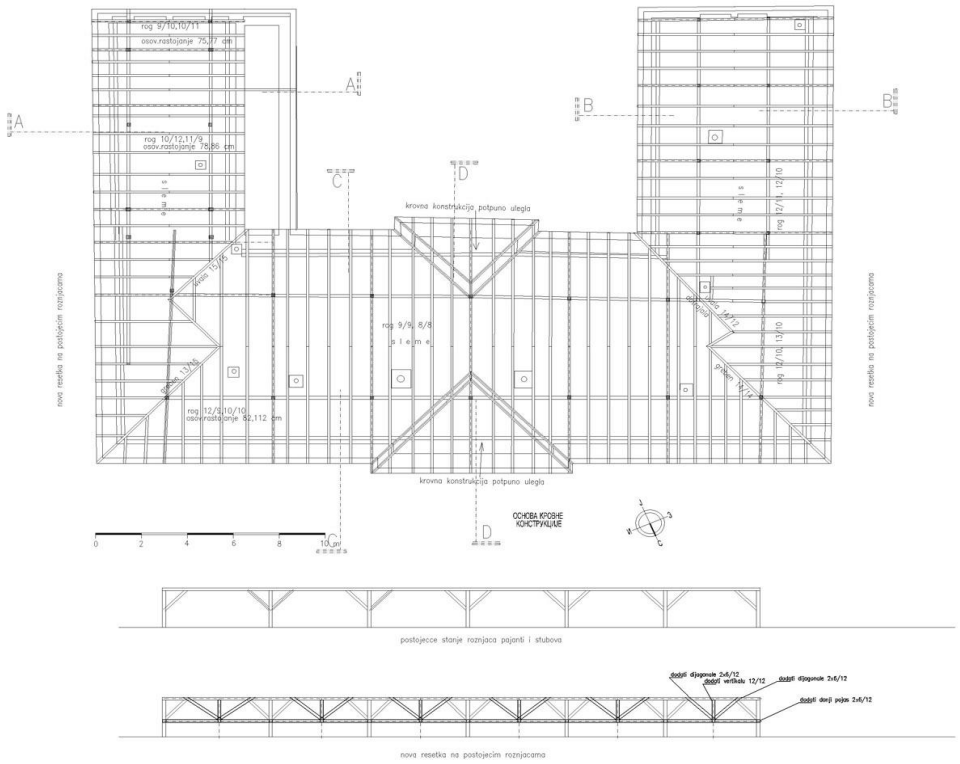


Fig. 5. Rehabilitation of the roof construction creating the grids

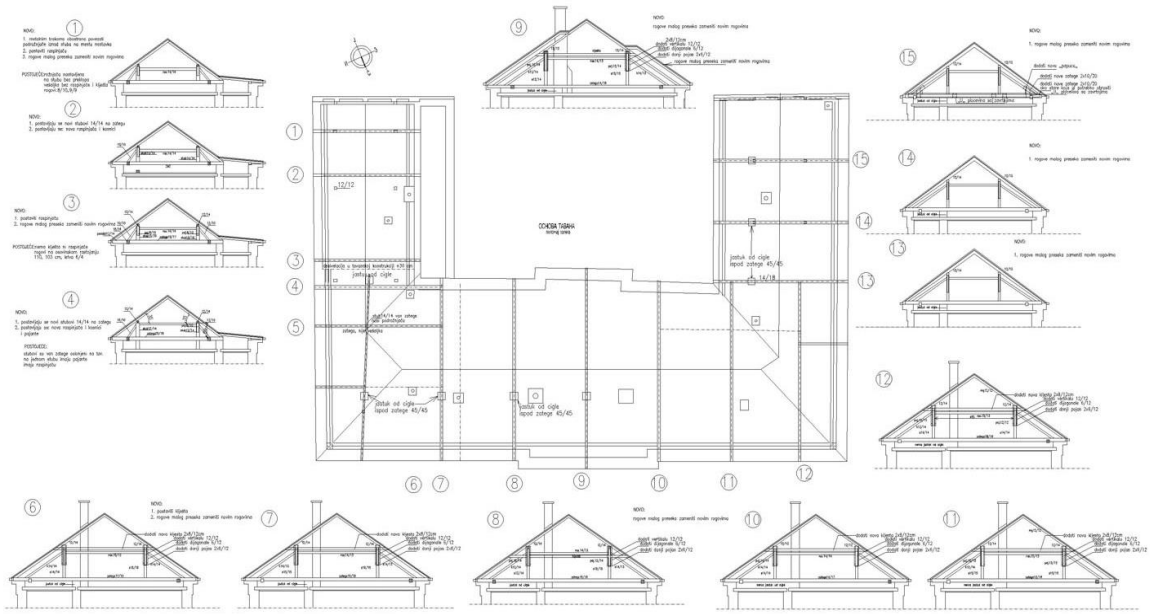


Fig. 6. Rehabilitation of the roof construction – roof hangers

a)  b)  c) 

d)  e) 

Fig.7. a, b, c, d, e Rehabilitation and reconstruction photos of the roof construction

a)  b)  c) 

Fig.8. a, b, c Rehabilitation and reconstruction photos damaged woodworm ties hanger no.15

a)  b)  c) 

Fig.9. a, b, c Rehabilitation and reconstruction photos of the foundation of the building

a)  b)  c) 

d)  e) 

f)  g) 

h) 

Fig.10. a, b, c, d ,e ,f, g , h Rehabilitation and reconstruction photos of the walls of the building

7. Conclusion

Building was damaged a lot from earthquake influence and ages. Structure rehabilitated at fall /winter 2013 and during 2014. With full time supervising during construction works

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REHABILITATION, RETROFIT AND MAINTENANCE AT THE BROOKLYN BRIDGE, NEW YORK CITY IN THE 20TH AND 21ST CENTURIES

Bojidar Yanev[1]

Department of Transportation, New York City, Bridge Inspection and Management.

***Abstract**: The Brooklyn Bridge is iconic. It was designed by John Roebling (1806 - 1869) and completed by his son, Washington and his daughter in law Emily Roebling, between 1867 and 1883. Its main span of 1595.5 ft (486.6 m) nearly doubled the record of its time. A number of features, such as the caissons used in the construction of the towers, the hybrid suspension/cable-stay system, and the air-spinning of the suspension cables were innovative in size and method or entirely unique. The Roebling Rope Company continued to produce high strength steel cable wires into the second half of the 20th century. On the onset of the 21st century the Brooklyn Bridge remains a critically important example for the design and construction of new record-breaking spans. Over the many years of service the bridge has received a number of significant structural and service modifications. In every such case Roebling's foresight made it possible to conduct rehabilitation and maintenance with minimal service interruptions. At 133 years of age the bridge carries approximately 200,000 daily passengers and remains a world champion among examples of engineering art and science.*

***Key words**: Brooklyn Bridge, Roebling's redundancy, remaining life, rehabilitation, retrofit, maintenance,* service modifications

1. Introduction

The Brooklyn Bridge (Fig. 1) is iconic. It was designed by John Roebling (1806 - 1869) and completed by his son, Washington and his daughter in law Emily Roebling, between 1867 and 1883. Its main span of 1595.5 ft (486.6 m) nearly doubled the record of its time. A number of features, such as the caissons used in the construction of the towers, the hybrid suspension/cable-stay system, and the air-spinning of the suspension cables were innovative in size and method or entirely unique. The Roebling Rope Company continued to produce high strength steel cable wires into the second half of the 20th century. On the onset of the 21st century the Brooklyn Bridge remains a critically important example for the design and construction of new record-breaking spans.

Over the many years of service the bridge has received a number of significant structural and service modifications. In every such case Roebling's foresight made it possible to conduct rehabilitation and maintenance with minimal service interruptions. At

[1] Bojidar Yanev, D. Sc., P.E, Executive Director, Bridge Inspection and Management. Department of Transportation, New York City, E-mail: byanev@dot.nyc.gov

133 years of age the bridge carries approximately 200,000 daily passengers and remains a world champion among examples of engineering art and science.

Figures 2 – A and B show the general data of the structure and the evolution of its service until the present. The first significant modifications were the elimination of all rail service and the light trusses introduced by David Steinman after World War 2. As the bridge approached its centennial in 1983, the need for rehabilitation and retrofit of critical structural elements became urgent. The scopes and costs of projects conducted by the New York City Department of Transportation, beginning at that time and still in progress today are summarized in Table 1. Several of these projects are briefly described herein.



Fig. 1. Brooklyn Bridge

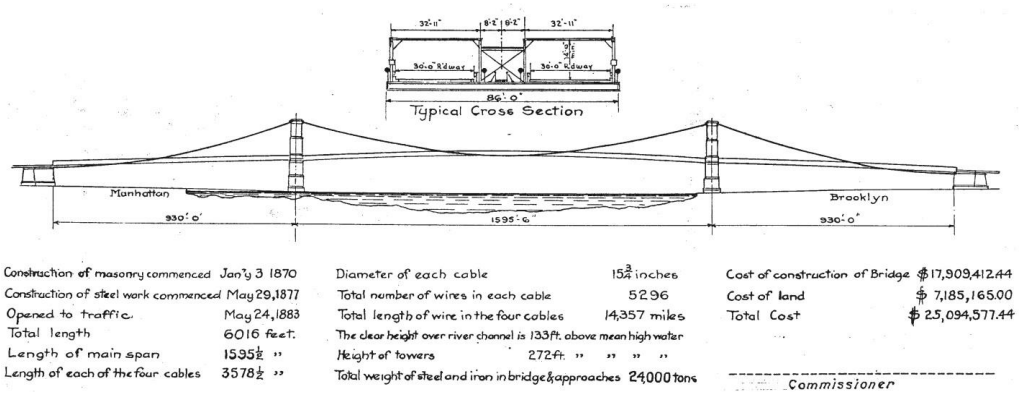
Table 1. Brooklyn Bridge rehabilitation items and estimated costs (NYC DOT, 2014)

Description	(million US$)
Brooklyn tower protection of new sign gantries (1981)	2.72*
Rehabilitate promenade between towers (1983)	0.94*
Rehabilitate cables in anchorage and replace short rod suspenders; rehabilitate balance of promenade and construct bikeway and new pedestrian ramp (1988)	22.68*
Rehabilitate main bridge deck overlay and paint approach structures (1988)	6.21*
Replace suspenders, cable posts, stay cables, hand-rope necklace lights, main cable wrapping; paint suspended spans (1991)	53.57*
Rehabilitate ramp E, concrete piers of ramp C and abutment at ramps C & I, and rehabilitate Sands and Washington Street structures in Brooklyn (1991)	4.73*
Rehabilitate ramps D and H in Manhattan; permanent improvement of promenade at Manhattan approach (1993)	17.92*
Rehabilitate floor systems, stiffening trusses, roadways of suspended spans and Franklin Square trusses (1994)	66.30*
Rehabilitate Manhattan traveler (electrical work) (1997)	1.83*
Rehabilitate ramp D and widening along the FDR Drive (1996)	11.50*
Arch supports for Franklin Square truss structure	9.50*
Resurfacing of the main spans (1998)	6.67*
Replacement of suspended span deck (2000)	36.20*

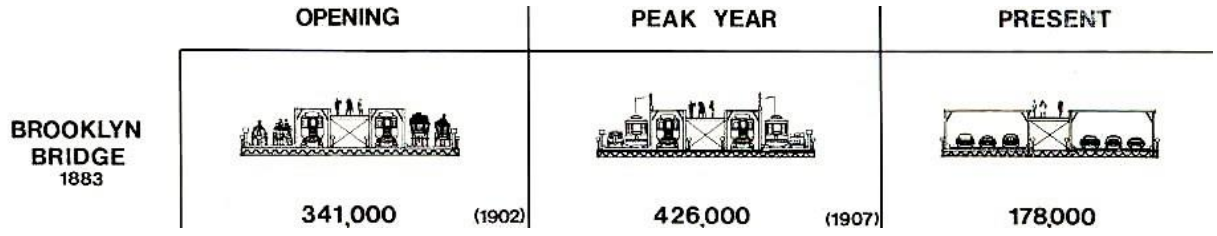
Replacement of travelers	22.34*
Improvement of Manhattan end of promenade (2001)	4.50*
Rehabilitate Brooklyn approach & ramps (B, S, F), rehabilitate Manhattan approaches and remaining ramps (A,B,C,F,G,I,J), paint entire bridge (2010)	508.61*
Seismic retrofit and Arch Block rehabilitation (2019)	300.00 to 325.00**
TOTAL	1,076.22 to 1,101.22

1. Cables, suspenders and diagonal stays

In 1981 one of the diagonal stays on the Brooklyn side of the Bridge broke and in falling down killed a pedestrian on the walkway. A subsequent inspection revealed that all the suspenders and stays in the trademark hybrid suspension system (Fig. 1) were extensively corroded and near breakdown. The emergency contract for their replacement was greatly facilitated by Roebling's foresight. Critics of the original design had objected to the triple redundancy of the bridge stiffening truss, suspension and cable-stay systems. Given the record length of the bridge and the fact that dynamic analysis of suspension structures took another century to develop, such caution was (and remains) highly appropriate. Roebling silenced his detractors with the now famous statement that if any of the three systems would suffer damage, "the bridge may sag but shall not fail". The theory of large deflections developed by Joseph Melan (1853 – 1941) was interpreted differently by bridge designers in the United States. David Steinman who translated Melan's theory into English opted for very deep stiffening trusses and resistance to "infinite" wind speed. Leon Moisseiff reduced them to girders, leading to the collapse of the Tacoma bridge under moderate wind in 1940. In later decades, the cable stayed bridges became independently popular, but hybrids are considered again in super-long new spans as for example at the proposed Messina crossing.



a)



b)

Fig. 2. a) – Brooklyn Bridge construction information, b) – Bridge service (1883 – present)

Roebling's redundancy allowed the contractor to replace suspenders and stays one at a time, providing shielding for traffic protection and without service interruption. The load redistribution between stays and suspenders made it necessary to readjust their tension one more time after all of them were installed.

The main cables were unwrapped, wedged for inspection and rewrapped. The typical Roebling Rope Company wires, with yield strength of roughly 15 t / cm^2, diameter 5 mm, and galvanic zinc coating were found in mostly good condition. Special provisions were made for regular maintenance of the anchorages and the wrapping.

2. Bridge deck

In recent decades the design of the decks on the East River suspension bridges had settled on steel gratings with concrete fill. The traction of the exposed top of the gratings was not satisfactory. Welding steel studs to the grating worsened the performance. A resurfacing was scheduled for 1998, however that work revealed deterioration of the grating. An emergency contract to replace the bridge deck superseded the resurfacing one. The concrete fill in the new deck (Fig. 3) extends above the steel grating and has a thin overlay. Periodic resurfacing is anticipated.



Fig. 3. Typical steel deck grating under construction

3. Dynamic analysis

On May 24, 1883, one week after the bridge opening, a crowd of pedestrians panicked and rushed towards the exits. Several were trampled to death. No structural deficiency was found. During the East Coast electrical black-out in 2003 the Manhattan bound traffic lanes of the bridge were closed to traffic and open to pedestrians. Once again they reported extensive motion. The overall structural stability was never in question, however the public perception is considered as an important performance indicator. The bridge was already scheduled for seismic reanalysis, but the popular concern accelerated the process. Figure 4 illustrates the instruments attached to the bridge for this purpose. The bridge was excited at various locations in the main span with a two-ton actuator. The obtained response frequencies were compared with analytic values obtained from a finite element model (Fig. 5). Typical response modes are shown in Fig. 6. The frequencies of one torsional and one deflection mode are relatively close in magnitude and potentially could influence each other. Passive dampers were designed to correct the dynamic response of the bridge.

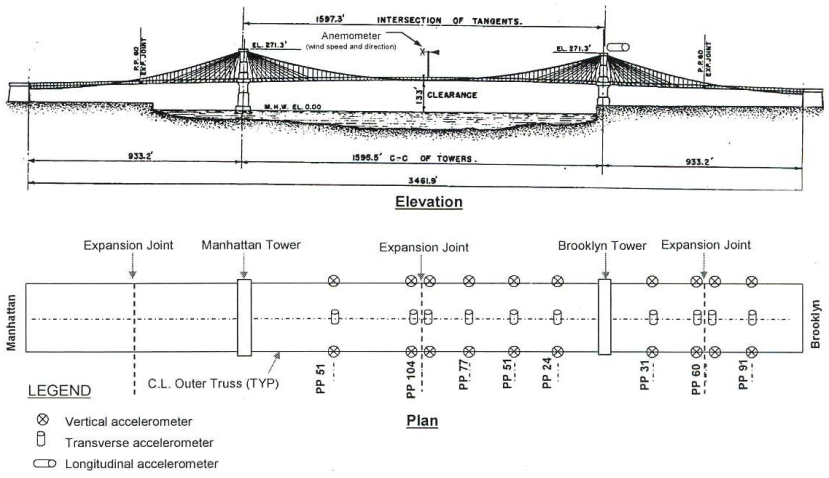


Fig. 4. Instrumentation for the dynamic test of the bridge

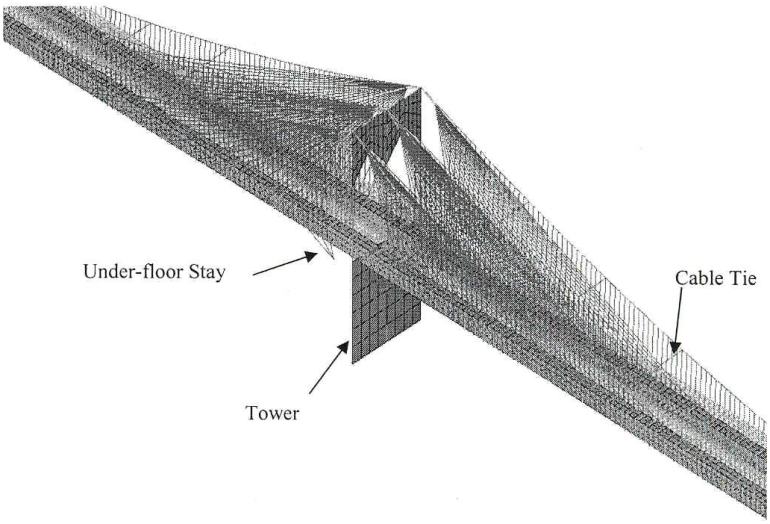


Fig. 5. Finite element model for the dynamic assessment of the bridge

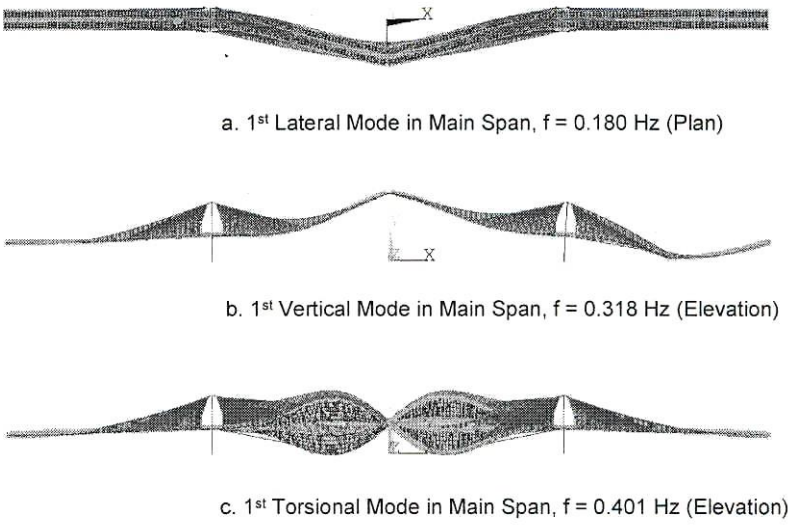


Fig. 6. Typical lowest modes of dynamic response

4. Approaches

The 73 approach spans are decisively overshadowed by the three main spans between the anchorages. Nevertheless, they have absorbed at least 50% of the past expenditures and future estimates in Table 1. John Roebling designed them with his typical attention to detail, even anticipating that some of them should serve as gathering places for the future communities.

The Franklin Square trusses in Manhattan required an unique solution. As parts of the original bridge, the trusses enjoy landmark status. Analysis of the bottom chord eye-bars questioned their capacity. Design specifications (AASHTO) recommend the use of 700 kg /cm^2 (10 ksi) as limit load on iron pre-dating steel production. Tests suggested that the Brooklyn Bridge material might have resistance of up to 1400 kg/cm^2 (20 ksi), however the pinned connections of the eye-bars gave greater cause for concern. The selected design supported the 6 trusses with 6 steel arches, as shown in Fig. 7.

During a current contract two spans of the Brooklyn approach were completely replaced. The Brooklyn – Queens Expressway (BQE) runs under one of the spans. Tall trucks on the BQE frequently strike the bridge fascia girder causing structural damage and extensive traffic delays (Fig. 8).

The replacement structure was designed with an orthotropic deck and girders of reduced depth. For two nights traffic on the BQE was stopped and the spans were installed (one in each direction), as shown in Fig. 9.

The Manhattan side approach of the bridge consists of numerous brick masonry arches with numerous fairly large cracks. The cracks are generally attributed to settlement at some time close to the original construction, however they are still under intense scrutiny. Visual inspection is unsuitable because of the small motions involved. Hence, the arches are perfect targets for monitoring by a high-precision, low-maintenance, real-time web based technology such as the fiber optic sensors.



Fig. 7. Franklin Square arches under the Brooklyn Bridge



Fig. 8. Traffic delays on the BQE under the Brooklyn Bridge

Spans 36-37 of the Manhattan Approach were monitored with a system of fiber optic sensors designed and installed by team from the University of Chicago under professor Farhad Ansari with funding from the Federal Highway Administration in Dec. of 2008. After two years in use, the system was dismantled to allow access for rehabilitation work. The rehabilitation included grouting the cracks. That decision was based on the data provided by the monitoring and indicating that the cracks were not active and moved only slightly in response to seasonal temperature changes.

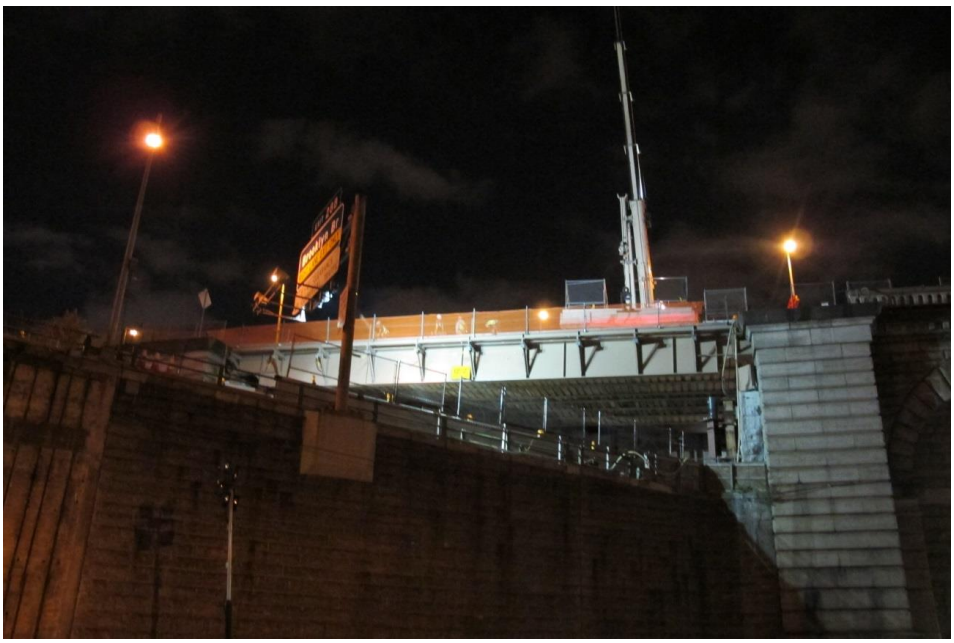


Fig. 9. Installation of Span over BQE with full traffic closure

Based on that experience, a new contract addressed similar cracks in spans 31-34. The following tasks were included:

- Determine the level of urgency of the cracks.
- Develop a plan for monitoring with threshold values of displacements and corresponding plans of action.
- Assess the available equipment, consisting of the computer and fibre optic gauges used in spans 36-37.
- Determine needs for purchasing additional equipment.
- Determine means for remote access to data and storage of information on DOT Servers
- Install system.
- Test operation and instruct DOT personnel on its use.
- Provide troubleshooting support over a test period of at least 6 months.

A recurring difficulty in non-destructive structural health monitoring (SHM) is the determination of threshold values intended to trigger alarm messages. Weidlinger Associates who managed the contract are also designing the pending seismic retrofit of the approach and thus could use the already developed finite element model of the structure in their assessment of movement significance. So far the structure has shown (again) only minor movement correlated with temperature changes. Fibre-optic sensors are generally reliable and do not require compensation under varying temperature, but are extremely sensitive to ambient humidity. However re-using old ones proved impractical. Some tilt-meters were successfully re-used. Another SHM vulnerability is the data transmittal and storage. Experience has shown that this process requires multiple updates and the flexibility to adjust to perpetually upgrading computer platforms. A typical set of readings is shown in Fig. 10.

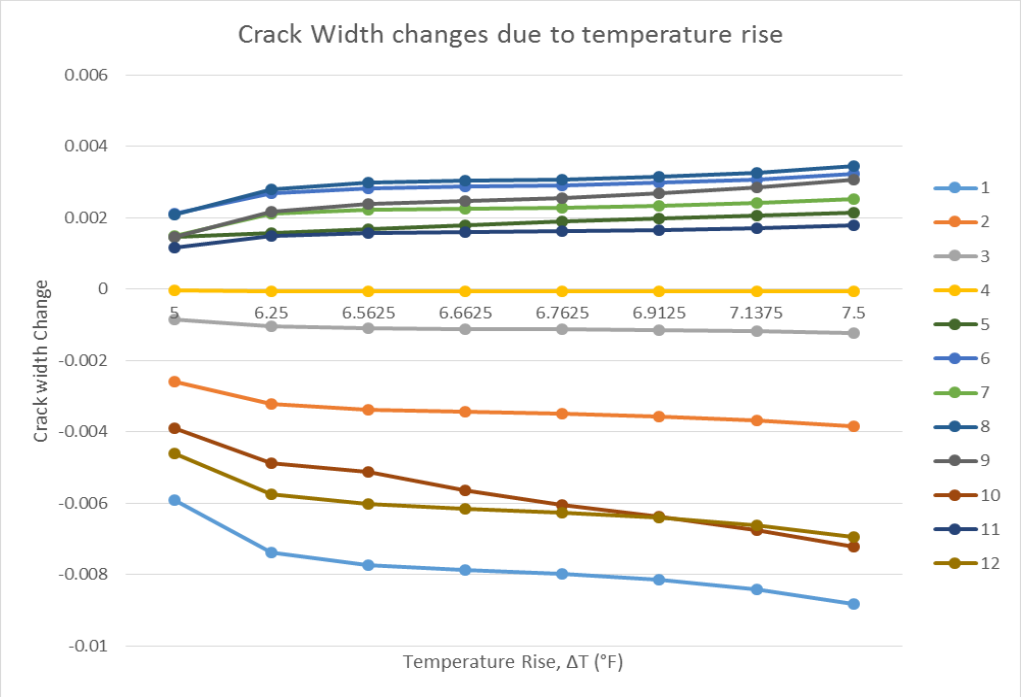


Fig. 10. Fiber-optic sensor readings correlating crack opening and temperature

5. Maintenance

Apart from the maintenance of special emphasis structural details, the Brooklyn Bridge demands considerable traffic maintenance. During a heavy winter New York City

streets use up more than 300,000 tons of salt. The costly rehabilitations of the East River bridges (Fig. 11) demonstrated that eliminating the highly corrosive salt at least from these highest-maintenance structures is cost-effective. After roughly 10 years of negotiations, planning and various tests, including an automatic spray system, traditional *de-icing* salt was replaced by the costlier *anti-icing* potassium acetate. In contrast to salt which can be applied on top of snow and ice, potassium acetate must be applied prior to the precipitation, making the operation much more sensitive. Because of its long-term benefits, the task is considered eligible for capital funding.

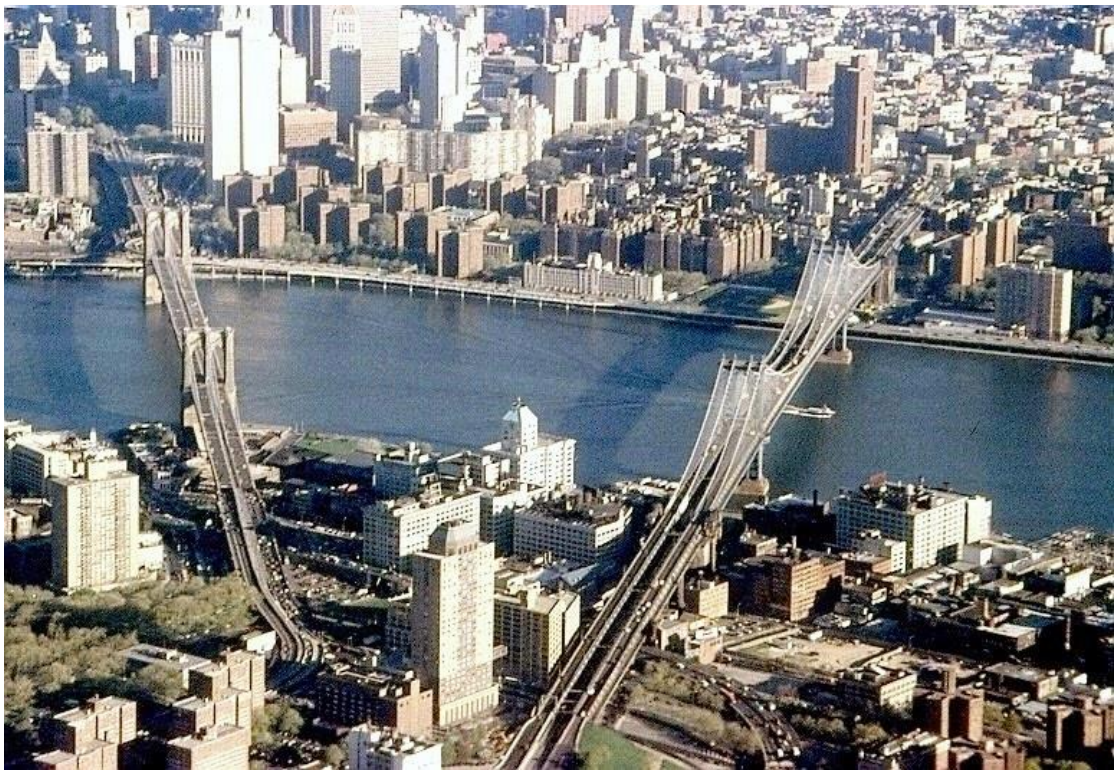


Fig. 11. Brooklyn and Manhattan Bridges, New York

6. Conclusion

Bridge managers are often required to estimate the remaining life-spans of their bridges. In the view of the author, detailed in Yanev (2007), Yanev (2014), and Yanev (2016) the question must be answered on (at least) two levels. The *structural* life is limited not so much by the passage of time (the commonly used dimension), but by the volume of the service. That *service*, however is perpetual. The role of bridges in a functioning society can be compared to that of ideas in the thinking brain. Once the bridge provides a shortcut in the transportation network, the community adjusts to the new topography and the change becomes irreversible. The more meaningful question becomes not whether to replace the bridge but how and when to optimally extend the service. It is already possible to replace short single and even numerous spans with minimal service disruptions, virtually overnight. In contrast, the needs for replacements must be minimized at iconic large structures. Structural enhancements and modifications must be planned decades in advance. As intelligence, bridge service requires continuing maintenance. Society must be prepared to bear its cost.

Disclaimer

This article does not represent the views and positions of any organization or agency.

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HISTORIC REINFORCED CONCRETE BUILDINGS STRENGTHENED BY TIES UNDER SEISMIC SEQUENCES: A COMPUTATIONAL APPROACH

Ang. LIOLIOS [1] , Ant. MOROPOULOU [2] and Ast. LIOLIOS [3]

Democritus University of Thrace, Xanthi, and National Technical University of Athens, Greece.

***Abstract**: A numerical approach is presented for the seismic response of existing historic industrial reinforced concrete (RC) structures, which are elements of the recent Cultural Heritage, have been damaged due to extreme actions and are to be seismically upgraded by using cable elements (tension-ties). A double discretization, in space by the Finite Element Method and in time by a direct incremental approach, is used. The unilateral behaviour of the cable-elements, which can undertake tension stresses only, is strictly taken into account and results to inequality constitutive conditions. Finally, using damage indices, the optimal strengthening version of cable-systems is chosen for the case of multi-storey RC frames under seismic sequences of multiple earthquakes.*

***Key words**: Cultural Heritage Industrial Buildings, Reinforced Concrete (RC) Frames, Seismic Upgrading by Cable-Elements, Earthquakes Sequence.*

1. Introduction

As well-known [1-3], non-usual extremal actions (seismic, environmental etc.) can cause significant strength degradation and damages on existing historic industrial reinforced concrete (RC) structures, which are elements of the recent Cultural Heritage. To overcome such strength degradation effects, various repairing and strengthening procedures can be used, which are similar to ones used for the seismic upgrading of existing RC buildings [3-6]. Among them, cable-like members (ties) can be used as an strengthening and repairing procedure [7-8].

The above cable-members can undertake tension, but buckle and become slack and structurally ineffective when subjected to a sufficient compressive force. So, in the mathematical problem formulation, the constitutive relations for cable-members include also inequality conditions. Such inequality conditions govern also the piece-wise linearized constitutive relations describing the non-linear behavior of the usual RC structural elements.

[1] PhD Candidate, MSc, Democritus University of Thrace, Dept. Civil Engineering , Xanthi, Greece, (e-mail: aliolios@civil.duth.gr)
[2] Prof., National Technical University of Athens, School of Chemical Engineering, 9 Iroon Polytechniou Street, Zografou Campus, GR15780 Athens, Greece (e-mail: amoropul@central.ntua.gr)
[3] Prof., Democritus University of Thrace, Dept. Civil Engineering , Xanthi, Greece, (e-mail: liolios@civil.duth.gr)

Taking into account the above considerations, the full problem of the earthquake response of RC structures strengthened by cable-elements bracings has as governing conditions both, equalities as well as inequalities. Thus the problem becomes a high nonlinear one. For the strict mathematical treatment of the problem, the concept of variational and/or hemivariational inequalities can be used and has been successfully applied [1, 9-10]. As concerns the numerical treatment, non-convex optimization algorithms are generally required [1,10-12].

In the present study, a numerical approach is presented for the earthquake analysis of existing historic reinforced concrete (RC) building frames under seismic sequences. The considered old RC building frames have been environmentally degraded and after their seismic assessment have to be strengthened by cable elements. The unilateral behaviour of the cable-elements and the non-linear behavior of the RC elements are taken strictly into account and result to inequality constitutive conditions. The finite element method is used for space discretization in combination with a time discretization scheme, and damage indices are computed in order the optimal ties-system to be selected.

2. Method of analysis

2.1. Problem formulation and numerical treatment

First, the historic RC frame structural system is discretized in space by using finite elements. The usual frame elements are used for the reinforced concrete frame. On the other hand, for the cable strengthening system, pin-jointed bar elements are used. The behaviour of both, the cable elements and the non-linear RC elements, includes loosening, elastoplastic or/and elastoplastic-softening-fracturing and unloading - reloading effects. A piecewise linearization of the above constitutive relations is shown in Fig. 1, see also [18,19].

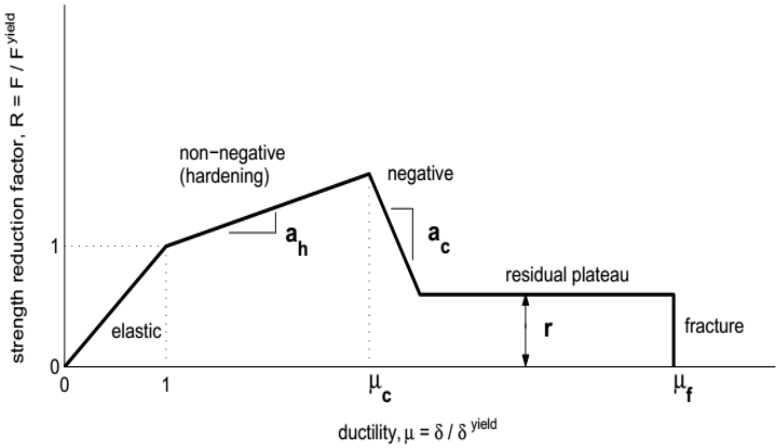


Fig. 1. A piecewise linearized constitutive diagramme (backbone) concerning the constitutive law connecting a generalized force with a generalized displacement [18,19].

All the above characteristics of the constitutive laws can be expressed mathematically by non-convex relations of the general form:

$$s_i(d_i) \in \hat{\partial} S_i(d_i) \qquad (1)$$

Here s_i and d_i are generalized stress and deformation quantities, respectively, $\hat{\partial}$ is the generalized gradient and S_i is the superpotential function, see Panagiotopoulos [9] and Mistakidis & Stavroulakis [10]. In specializing details, for the cables, s_i is the tensile force (in [kN]) and d_i the deformation (elongation) (in [m]), of the i-th cable element.

Next, the dynamic equilibrium for the structural system, considered as unstrengthened, i.e. without cables, is expressed by the usual matrix relations of Structural Dynamics:

$$\mathbf{M\ddot{u}} + \mathbf{C}(\dot{\mathbf{u}}) + \mathbf{K}(\mathbf{u}) = \mathbf{f} \tag{2}$$

Here **u** and **f** are the displacement and the loading forces time dependent vectors, respectively. The damping and stiffness terms, $\mathbf{C}(\dot{\mathbf{u}})$ and $\mathbf{K(u)}$, respectively, concern the general non-linear case. Dots over symbols denote derivatives with respect to time.

When cable-elements are taken into account, equation (2) for the assembled system considered as strengthened, becomes

$$\mathbf{M\ddot{u}} + \mathbf{C}(\dot{\mathbf{u}}) + \mathbf{K}(\mathbf{u}) = \mathbf{f} + \mathbf{Ts} \tag{3}$$

Here **s** is the cable elements stress vector and **T** is a transformation matrix.

The system of the above relations (1)-(3), combined with the initial conditions, provide the problem formulation, where, for given **f** and/or $\ddot{\mathbf{x}}_g$, the vectors **u** and **s** have to be computed. The relevant computational approach is described in [1, 9-13].

By applying a time-integration scheme, in each time-step Δt a relevant non-convex linear complementarity problem of the following matrix form is eventually solved :

$$\mathbf{v} \geq \mathbf{0}, \qquad \mathbf{A\,v} + \mathbf{a} \leq \mathbf{0}, \qquad \mathbf{v}^T \cdot (\mathbf{A\,v} + \mathbf{a}) = 0. \tag{4}$$

Here **v** is the vector of unknown unilateral quantities at the time –moment t, $\mathbf{v}^T$ is the transpose of **v**, **a** is a known vector dependent on excitation and results from previous time moments (t- Δt), and **A** is a transformation matrix.

An alternative approach for treating numerically the problem is the incremental one. Now, relations (3), taking into account also second-order geometric effects (P-Delta effects), are written in incremental form:

$$\boldsymbol{M\,\Delta\ddot{u} + C\,\Delta\dot{u} + (K+G)\,\Delta u = -M\,\Delta\ddot{u}_g + T\,\Delta s} \tag{5}$$

Here ***G*** is the geometric stiffness matrix, by which P-Delta effects are taken into account.

On such incremental approaches is based the structural analysis software Ruaumoko [14]. This software uses the finite element method and permits an extensive parametric study on the inelastic response of structures.

2.2. Choice of the optimal system of ties by using damage indices

The decision about a possible strengthening for an existing RC structural system, damaged by a seismic or environmental event, can be taken after an assessment realization [5,6]. Here the assessment is based on a relevant evaluation of suitable damage indices [16]. After Park/Ang [15], the global damage is obtained as a weighted average of the local damage at the section ends of each structural element or at each cable element. First the local damage index DI_L is computed by the following relation:

$$DI_L = \frac{\mu_m}{\mu_u} + \frac{\beta}{F_y d_u} E_T \quad (6)$$

where: μ_m is the maximum ductility attained during the load history, μ_u the ultimate ductility capacity of the section or element, β a strength degrading parameter, F_y the yield generalized force of the section or element, E_T the dissipated hysteretic energy, and d_u the ultimate generalized deformation. As known [5,6,17,18], ductility concerns the metelastic behaviour, see e.g. Fig. 1., and in terms of a generalized deformation d is defined by the relation:

$$\mu = \frac{d}{d_y} \quad (7)$$

where d_y denotes the yield generalized deformation and it holds $d \geq d_y$.

The Park/Ang global damage index is a weighted average of the local damage indices and the dissipated energy is chosen as the weighting function. The global damage index is given by the following relation:

$$DI_G = \frac{\sum_{i=1}^{n} DI_{Li} E_i}{\sum_{i=1}^{n} E_i} \quad (8)$$

where, DI_G is the global damage index, DI_{Li} the local damage index after Park/Ang and E_i the energy dissipated at location i and n the number of locations at which the local damage is computed.

For the choice of the optimal system of the strengthening ties, various virtual such systems can be proposed respecting functioning and serviceability aspects of the existing building system. Further, various parameters, e.g. section area of ties, economic cost, target displacement constraints concerning the RC system performance can be taken into account. Finally, under above such constraints, the minimum value according to (8) is sought, that is the optimization problem $DI_G \rightarrow \min$. has to be solved

3. Numerical example

3.1. Description of the considered RC structural system.

The historic reinforced concrete frame F0 of Fig. 2. is of concrete class C20/25, has dimensions L = 7 m and h = 3.5 m and was designed according to old Greek building codes. The beams are of rectangular section 30/60 (width/height, in cm) and have a total vertical distributed load 30 KN/m (each beam). The columns have section dimensions, in cm: 40/40.

The frame was initially constructed without cable-bracings. Due to various extremal actions (environmental etc.), corrosion and cracking has been taken place, which has caused a strength and stiffness degradation. The so resulted reduction for the section inertia moments was estimated [17] to be 20% for the internal columns, 40% for the external columns and 60% for the beams, providing the effective stiffness. Three cable-braces systems, shown in Fig. 3, have been proposed and investigated in order the optimal one to be chosen. The first system, denoted as F1, has descending diagonal cable-elements. The second, denoted as F2, has X-bracing diagonal cable-elements. The third, denoted as F3, has inverted V bracing diagonal cable-elements. The cable elements have a cross-sectional area F_c = 18 cm^2 and they are of steel class S220 with yield strain ε_y = 0.11 %, fracture strain ε_f = 2 % and elasticity modulus E_c = 200 GPa. The cable constitutive law,

concerning the unilateral (slackness), hysteretic, fracturing, unloading-reloading etc. behavior, is depicted in Fig. 3.A.

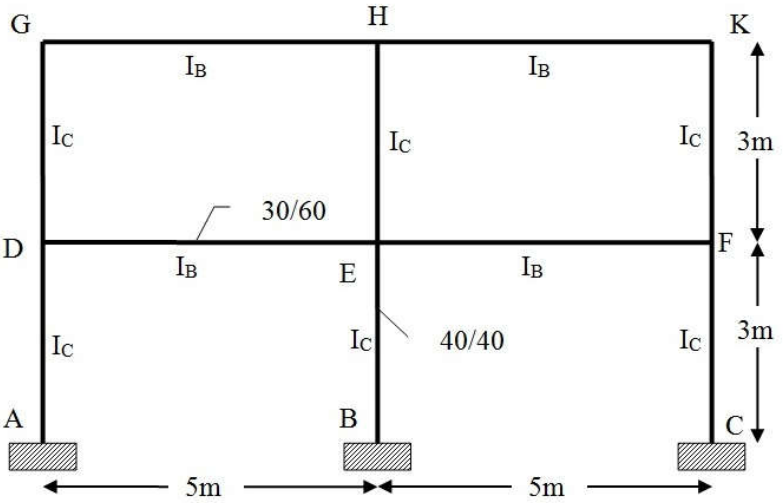


Fig. 2. The initial old industrial RC frame

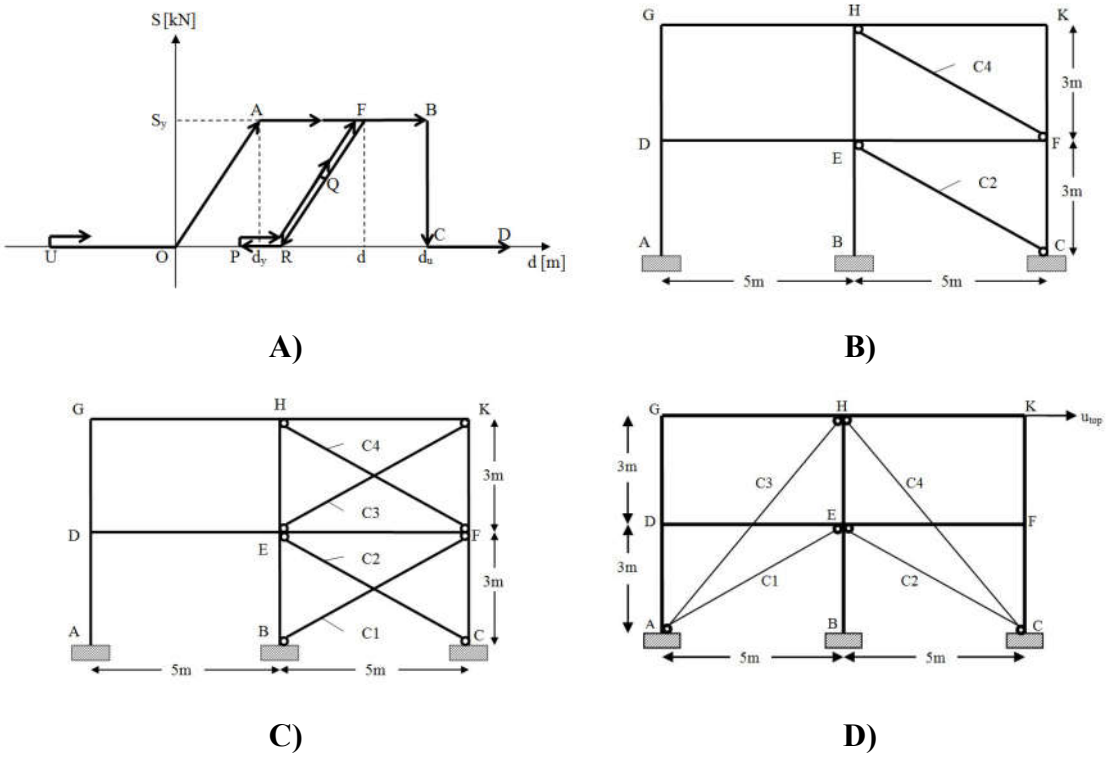


Fig. 3. Numerical example: A) The unilateral behavior of the cable-elements., B) The F1 two-ties-system, C) The F2 four-ties-system X, D) The F3 four-ties-system inverted V.

3.2. Multiple Earthquakes input

The systems F0, F1, F2 and F3 of Fig. 2 and Fig. 3 are considered to be subjected to a multiple ground seismic excitation, presented and discussed in [13]. The complete list of

these earthquakes was downloaded from the strong motion database of the Pacific Earthquake Engineering Research (PEER) Center and appears in Table 1

Table 1. Sequential earthquakes data

No	Seismic sequence	Station	Comp	Date (Time)	Magnitude (M_L)	Recorded PGA(g)	Norm. PGA)
1	Mammoth Lakes	54099 Convict Creek	N-S	1980/05/25 (16:34)	6.1	0.442	0.200
				1980/05/25 (16:49)	6.0	0.178	0.081
				1980/05/25 (19:44)	6.1	0.208	0.094
				1980/05/25 (20:35)	5.7	0.432	0.195
				1980/05/27 (14:51)	6.2	0.316	0.143
2	Chalfant Valley	54428 Zack Brothers Ranch	E-W	1986/07/20 (14:29)	5.9	0.285	0.128
				1986/07/21 (14:42)	6.3	0.447	0.200
3	Coalinga	46T04 CHP	N-S	1983/07/22 (02:39)	6.0	0.605	0.165
				1983/07/25 (22:31)	5.3	0.733	0.200
4	Imperial Valley	5055 Holtville P.O.	HPV 315	1979/10/15 (23:16)	6.6	0.221	0.200
				1979/10/15 (23:19)	5.2	0.211	0.191
5	Whittier Narrows	24401 San Marino	N-S	1987/10/01 (14:42)	5.9	0.204	0.192
				1987/10/04 (10:59)	5.3	0.212	0.200

3.3. Representative results

Representative results of the numerical investigation are presented in next Table 2. In column (1), Event E_1 corresponds to Coalinga seismic event of 0.165 normalized PGA of Table 1 and Event E_2 to 0.200 normalized PGA. The sequence of events E_1 and E_2 is denoted as Event (E_1+ E_2).

Table 2. Representative response quantities for the frames F0, F1, F2 and F3

FRAMES	EVENTS	DI_G	DI_L	u_{top} [cm]
(0)	(1)	(2)	(3)	(4)
F0	Event E_1	0.134	0.179	2.227
	Event E_2	0.301	0.474	3.398
	Event (E_1+ E_2)	0.334	0.481	3.410
F1	Event E_1	0.133	0.185	1.715
	Event E_2	0.256	0.354	3.149
	Event (E_1+ E_2)	0.317	0.385	3.813
F2	Event E_1	0.068	0.007	1.126
	Event E_2	0.097	0.136	1.447
	Event (E_1+ E_2)	0.108	0.154	1.471
F3	Event E_1	0.054	0.009	1.069
	Event E_2	0.082	0.128	1.313
	Event (E_1+ E_2)	0.085	0.137	1.314

In column (2) the Global Damage Indices and in column (3) the Local Damage Index DI_L for the bending moment at the left fixed support of the frames are given. Finally, in the column (4), the maximum horizontal top displacement u_{top} (absolute value) is given.

As the table values show, multiple earthquakes generally increase, in an accumulative way, the response quantities. Based on the values of the horizontal top displacement $u_{top} = u_2^{(A)}$, it can be concluded that the optimal global strengthening version is that one F3 of Fig. 3.D.

4. Concluding remarks

Historic reinforced concrete structures, which are environmentally (e.g. seismically) degraded and strengthened by cable elements, can be numerically treated by the herein presented numerical approach under seismic sequences. As the results of a numerical example have shown, the optimal strengthening version of cable-bracings can be decided by computing suitable damage indices.

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ASSESSMENT, COMPUTATIONAL ANALYSIS, REHABILITATION AND TRADITIONAL STRENGTHENING TECHNIQUES OF TIMBER STRUCTURES IN BULGARIAN CULTURAL HERITAGE STRUCTURES

Doncho Partov[1], Bohumil Straka[2] and Milen Petkov[3]

University of Structural Engineering and Architecture, VSU "L. Karavelov"
University of Technology, Brno

Abstract: *Timber is one of the most used materials in the roofs and floors of monumental constructions in Bulgaria. Complex timber structures, such as those belonging to the roofs of large monuments, are often not easy to understand in a expedite way. Load bearing timber structures are exposed during their life to some degradation factors which lead, in the absence of appropriate maintenance interventions, to the loss of their structural integrity and serviceability. The objective of this paper is to present some experience in this field, regarding the case studies of timber roof structures of the church St. Dimitar in Kustendil. Based on computational analysis and detailed visual inspection results, scope and general methods of works construction ensuring adequate rigidity and load capacity of the structure were determined.*

Key words*: : timber structure; degrading factors; strengthening; wood; traditional materials;*

1. Introduction

In Bulgaria, wood constructions have a vast occurrence, and an old tradition in the civil, industrial and bridge domains[5,7,17](Fig.1a,b,c).



Fig.1a,b,c Wood in roof construction in the civil: a), industrial: b) and bridge domains: c)

Most of the buildings built till the beginning of the XX century in Bulgaria is made of masonry, mainly stone (exterior and some interior walls), and timber elements (floors, roofs, ceilings, interior and some exterior walls). According [5, 6], if properly connected,

[1] Doncho Partov, PhD/Proff., USEA,"L.Karavelov, 175 Suhodolska Str., partov@vsu.bg
[2] Bohumil Straka, PhD/Assoc. Prof. University of Technology, Brno, straka@bohumil.eu
[3] Milen Petkov, Assist.Prof., USEA,"L.Karavelov, 175 Suhodolska Str., petkov@vsu.bg

these elements promote a good global behaviour: the masonry walls support the floor beams and roof trusses which, on the other hand, act as horizontal braces, inducing a more uniform distribution of stiffness and loading throughout the structure. Thus, if properly designed and in good conditions, these systems constitute efficient structures. This type of construction is disseminated all over the country and represents most of our built heritage, justifying the increasing interest on its preservation as memory of culture and identity.(Fig.1,a,b,c). Unfortunately, *most of it is degraded and abandoned,* demanding urgent intervention[5]. In general, direct intervention on the elements, avoiding substitutions, not only results on heritage preservation, but also on the minimization of the necessary actions and their impact. In this field, and particularly for old timber structures, NCREP's option[10] (Nucleus for the Conservation and Rehabilitation of Building and Built Heritage), respecting the International charts and ICOMOS[10], has been mostly oriented to techniques using traditional materials, like wood and steel. These techniques, consisting in the addition of timber elements and steel plates, have been applied in the rehabilitation of old buildings with very good results[18,19]. One examples with old timber roof construction will be analysed in this paper, namely: Church Sv. Dimitar in Kustendil, beginning of end of 1866 year[11]. According [14] the success of wood, as a first class construction material, was proven since the time of the first villages; its applications were varied and intense due to its wide spreading, workability, high strength, and low specific weight. Among the meaningful accomplishments in our country, the churches and monasteries represent a real value for the cultural heritage and conserving them is an important step in our evolution. The preservation of original timber parts makes it possible for them to fulfil design restrictions, reducing the structure alterations to a minimum in a rapid and efficient manner. Considering the fact that the strengthening is applied to buildings with a remarkable cultural value, their aesthetical characteristics must be preserved and emphasized. This can be easily done by using made of traditional materials. Traditional materials like metal, wood or concrete have been used in strengthening systems worldwide and don/t disregarded the aesthetical aspect. Nowadays, the modern age brings up in front the easily tailored, thin, high-strength and light-weight traditional materials, whose advantages especially in this domain are impressive. Steel and wood elements do not only bring an increase in the strength of the members they work with, but also reduce their size and self-weight and increase their ductility and fatigue performance. The necessity of using such materials is therefore reflected in the need of more subtle yet higher quality strengthening works[14].

2. Wood deteriorating factors

According[14] the main goal for the civil engineer is to improve the load capacity of specific elements. Before strengthening structural wood elements, one must firstly understand the reasons for which these elements are deteriorating. There are a number of factors determining the durability of structural wood and they will be shortly presented hereinafter. Timber is a natural building *material* which ages and deteriorates in time, even without the influence of external factors. Its properties depend on the specific wood species, the geographical location where the wood has grown and furthermore on the local growing conditions of every single part of a tree. All the natural imperfections and irregularities are points of weakness in sustaining loads or resisting to other deteriorating factors[14,13]. *Moisture*(Fig. 2.1a,b,c) is the most important factor of influence for all the physical-mechanical properties of wood and it creates favourable growing conditions for agents responsible for wood degradations. Bellow the fiber saturation point, the wood will shrink *when losing moisture and swallow when absorbing moisture* [14]. When exposing wood to *temperatures* higher than 150°C, *its strength will be affected.*

a)  b)  c)  d) 

Fig. 2.1a, b, c, d Moisture in purlins in axis B and V

From the *biological agents* point of view, wood is highly susceptible to the attack of *fungi and insects* or, in some cases, *by some marine borers[14,13](Fig.2.2a, b)* .

a)  b) 

Fig. 2.2a, b Massive timber roof elements with different stages of wood destruction

When analysing this aspect, it is important to realize that, if fungi attack is linked to the moisture content of the wood, *insects can attack in any conditions*[14]. *In optimum service conditions wood can last without noticeable deteriorations.* Special protective measures and chemical treatments are used when the working conditions are not suitable for the timber elements. Protection against fire, fungi, or insects includes chemical treatments which must consider the nature and severity of the risk, the wood type, the eventual previous treatments, and the possible secondary effects of the chemical products[14].

3. Mechanical Failure of the Timber Structural System of the Roof

According [16] the stability of the existing roof timber structures of the church is commonly studied with the general methodology of the Structural Mechanics, the Theory of Timber Construction, the Theory of Materials applied to the wood, the Technology of the Timber Constructions (see for instance the European Codes). The most common causes of failure of the our timber structural systems are inadequacy of configuration (geometry of the structure, sizing of the members, kind of connection of the members, bracing etc.) in relation to the actions, both static and dynamic loading; besides slenderness, instability, defects of the wood laid in place, severe biotic damages, accidental factors. No doubt, that the decay of the wood caused by beetles and fungi is a major problem both for members and structures too. In fact mechanical failures can also be caused by biotic factors that reduce the strength of the material. The failures can hit the structure at any hierarchic level, i.e. that of the members, the units, the whole structural system and the connections. The widespread habit of replacement of the damaged parts of the ancient structures or their total demolition and rebuilding is, unfortunately, extended up to the present days though only by a restricted number of culturally unacquainted operators who rely on a supposed tradition[12]. This habit has the effectual alternative, required by the contemporary cultural instances, of the repair and strengthening *with minimum disturbance of the ancient complex.* This new vision demands for an updated scientific and technical approach[16]. If repair and strengthening must be planned in order to recover the lost efficacy of the system and, at the same time, avoid modifications or at least minimize them, in any case without significantly altering the general concept of the same system, the mechanical failures as well as the causes of their presence must be known and interpreted; a general evaluation of

the efficiency and of the safety of the system will then be possible[12]. Planning the strengthening will subsequently follow in a natural way as the activity, meant to take the right measures and put in place only those remedies judged adequate to counteract the recorded effects of each failure, avoiding the assumption of the generic remedies featured and recommended in the handbooks and in the *dépliants* of companies without a specific reference to the real nature of the damage, and cancel or at least neutralize the causes that are responsible of the problem. A quite specific failure mode is to be considered the longitudinal break of the extremity of a member where a pin or nail is inserted in order to apply the tension. The wood divides along the fibres, (*in other words it splits*), and the holding device slides along the borders of the split thus allowing the tension to release. (Fig. 3.1a,b)

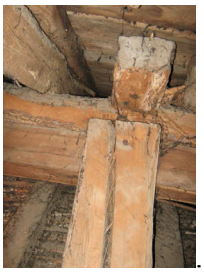
a)  b) 

Fig. 3.1a, b Wood divides along the fibres

The cutting of the lie in three-hinge frame leading to the catastrophe consequences for the whole behavior of the wood construction(Fig.3.2a, b). This fact lead to the displacement in the connection between column and horizontal beam in place of the missing lie in three-hinge framework.

a)  b) 

Fig. 3.2a,b Reversal in the connection between column and horizontal beam in place of the missing lie in three-hinge framework

The most considered *stresses* in design of wood elements are *the bending moment, tensile, compressive and shear forces*. Nevertheless, there are other strength properties that are less important but that can also be used, *like the torsion, creep or fatigue resistance[14],cracs in the vertical and horizontal elements(Fig.3.3a,b,c)*.

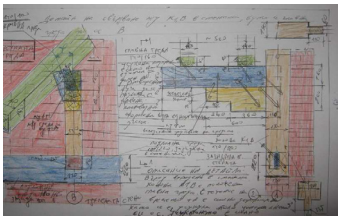
a).  b)  c)  d) 

Fig.3.3a,b,c,d Torsion of purlins: a,d) Horizontal displacement in the top of columns: b), vertical displacement of purlin in axis B-caused the creep: c), and cracks in the column and purlins:c)

4. Strengthening Methods Implying Traditional Materials

4.1 The Structural Intervention and Case studies for strengthening works of beams and columns using traditional materials and methods

According [5] the need for the intervention on timber structures is usually related to the existence of damages or alterations of use with load increase. Between the most common damages, one can refer the natural ones *(knots, splits, etc.)* and those resulting from biotic attacks (insects and fungi) and from incorrect constructive details or structural interventions. These causes not always originate the collapse of the structural elements or structures, but are often associated to their deficient behaviour, with high levels of vibrations and deformations. Consequently, in order to ensure the safety and, at the same time, the proper performance of the structures, it is necessary to intervene in the damaged structural elements through rehabilitation actions. The decision about the type of intervention should be taken only after a rigorous and careful survey of the structure[15]. According to the results obtained in the survey and to the circumstances of each situation, the intervention on a particular element or structure can take two different ways: *Rehabilitation* or *Substitution*. *Rehabilitation* can be seen as the natural solution that allows the maintenance of the element or the structure. This option may involve a strengthening action, particularly when the original structures are improperly designed or when changes of use (with higher loads) are expected, demanding a higher strength. In a limit situation, the intervention can consist in the *Substitution* of the element or structure, a solution that should be carefully analysed taking into account the percentage and intensity of the damage[5] .

4.2 The choice of rehabilitation techniques

The rehabilitation of timber structures can be done using different techniques, with pros and cons concerning effectiveness, compatibility, intrusiveness, etc. when choosing the techniques and materials to use, there are, among others, two criteria linked to heritage protection that should be respected: **Compatibility** and **Reversibility[5]**. **Compatibility** is linked to the physical and chemical interaction between the existing structure and the intervention solution. In particular, the elements, materials and (or) techniques implemented shouldn't react with those of the existing structure or introduce higher stiffness in localized structural areas. This criterion avoids the introduction of new damage in the structure through the intervention. A good example of that are the glued or very rigid connections in timber elements that may induce concentration of stresses in the interface area, i.e. the occurrence of new damage. **Reversibility** is linked to the will that the interventions be substitutable so that they can give place to more efficient and (or) protective interventions in the future. Generally speaking, the less intrusive solutions are often the more reversible ones[5].

4.3 Techniques with traditional materials

There are many different ways of using traditional rehabilitation techniques in old timber structures, namely: - the fixation of timber pieces or thin steel plates, with varied configurations, to the sides of the element ; - the introduction of thin steel plates in the interior of the element; - the installation of steel belts around the element; - the installation of new structural elements (timber or steel) parallel to the existents, among others[5]. To increase knowledge on the efficiency of these techniques in order to give useful information to designers and constructors about the suitability of each technique to solve specific situations, in Prague [1,2] and NCREP[10] is developing a laboratorial testing campaign. As a matter of fact, the information related to research on rehabilitation techniques on old timber structures using traditional materials is quite limited. In the case

of traditional carpentry joints, despite of being widely used, the number of studies on their mechanical performance and on possible strengthening techniques is scarce. With few exceptions, research on timber joints has been oriented towards new engineering configurations. Simultaneously, only few studies were developed in elements subjected mainly to bending; some authors performed bending tests in beams reinforced with steel elements, but reaching contradictory results. The majority of the studies was done in elements with high axial or shear forces. Strengthening techniques on floors to improve the diaphragm behaviour have also been analysed, proving experimentally its efficiency, but advising that further refinement is still needed for the technology to be applied in the construction practice. Concerning the connections between timber structures (roof, walls and floors) and masonry walls, although it is usually appointed as a key element to the overall behaviour of a building[5], in particular under seismic events, no significant efforts have been spent on their study.

5. Interventionations with Timber and Steel Elements

The use of timber elements in the rehabilitation of old timber structures is a very common solution. However, in these interventions it's important to have timber elements of the same wood species and with similar characteristics: density, strength and stiffness, to those of the original structure. In [5] is refers the convenience of using old timber elements, with the drying process completed, and the importance of having compatible moisture contents between new and old elements to avoid physical incompatibilities. When it's not possible to obtain similar wood, timber elements retrieved from the demolition of old buildings can be used or, as alternative, the new elements, already dry, can be previously placed in the constructions where they will be installed to acquire a moisture content in equilibrium with the construction environment. On the other hand, solutions with **steel elements** are commonly used in interventions on old timber structures, particularly on timber floors, leading to an increase of strength and stiffness. Even though, when using these elements, two questions should be analysed: the compatibility with the timber elements (the behaviour of wood and steel is considerably different) and the fire resistance of the metallic elements. In fact, timber structures support temperatures for which steel structures would have already failed. Therefore, to avoid the steel elements to become the weakest point of the strengthened structure it's important to improvement their fire resistance, which can be done through physical barriers or fire retardant products. Simultaneously, steel elements should be protected against corrosion[5]. Strengthening wood structures involves various methods and techniques depending on the final purpose for the intervention, the elements and materials involved, and the importance of the work. Explicit objectives must be set like the intention of keeping the original material and structural concept, the conservation by maintaining the aspect of the elements and structural solution, the modification, restoration or improvement of the bearing capacity, rigidity and other characteristics of the elements and structure [14]. No matter what method of strengthening is chosen, the works must be compatible with the existing structure, so that the coherent assemble to be easily performed. The repairs can be made on the whole length of the element or on certain degraded parts. Due to environmental factors and biological agents, surface degradations like holes and cracks can appear. Therefore, the repair techniques must imply the injection of wood with resins that fill up these openings and so restoring the wood mechanical characteristics. Timber structures, more than those made of other materials, show a very complicated deformational behavior, *mainly because of the property of the visco-elasticity that wood belongs*, in an accentuated way, if compared to other materials, due to the nature of the tissues and the longitudinal position of the fibers. Therefore often it is difficult to assess the cause, the kind and the entity of the stresses

which are responsible for the deformations detected[14,4,9,8]. In the case of eccentric *compressive* loads, when the elements become subjected to both *compression and bending*, the supplementary efforts that appear are extremely dangerous, compromising the integrity of the entire element. Different strengthening methods have been developed to partially reduce the deformations and enhance the rigidity of the member but, for all of them, *the considered elements must be discharged*.

5.1 Element subjected to bending

For elements subjected to *bending*, the considered degradations are either *cracks* situated especially in the middle span area or excessive deformations caused by the change of loads or by long lasting loads. *In these cases the local interventions are meant to stop crack propagation or to enclose it.* One solution includes the utilization of metallic elements that induce compression perpendicular to the crack and stop its propagation[14]. Two holes are drilled at both ends of the crack and two metallic plates are disposed on parallel sides of the element, bonded with bolts, as shown in Fig. 5.1.



Fig. 5.1 a, b, c – Local strengthening of beams: longitudinal cracks[3]: *1* – drilled holes, *2* – clamp, *3* – crack, *4* – plate, *5* – bolts.

5.2 Total strengthening of beams and columns

Total strengthening of beams can be made with or without increasing its transversal dimensions. To change the cross-section, new elements of wood, metal or concrete are added above, below or lateral to the existing members[14]. *E.g.*, placing new wooden elements under the existing beams does not influence the secondary elements or the floor; they are linked with metallic anchorages, (Fig. 5.2 *a*). The same type of anchorages is used for the laterally added elements (Fig. 5.2 *b*).

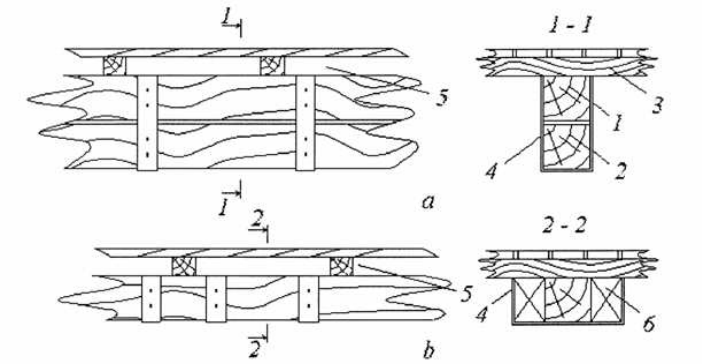


Fig. 5.2 – Beam strengthening using wood and steel elements[14]: *1* – existing beam, *2* – new beam, *3* – secondary beam, *4* – metallic anchorage, *5* – air, *6* – lateral beams.

When keeping the initial beam dimensions, the strengthening involves the insertion of metallic profiles, which have a lower height than the actual beam(Fig.5.3a,b,c). The metallic elements must be proofed with epoxy resins. A first layer of resin is poured after the longitudinal pockets for the metallic elements are made. Then, the metallic elements

are inserted into the pocket (for the metallic profiles case, bolts can be used) and filled up with resin[14].

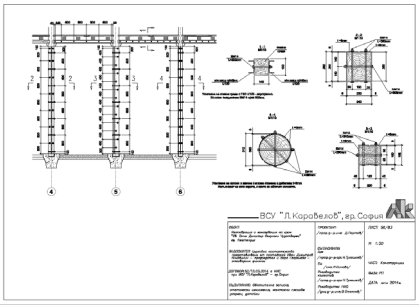
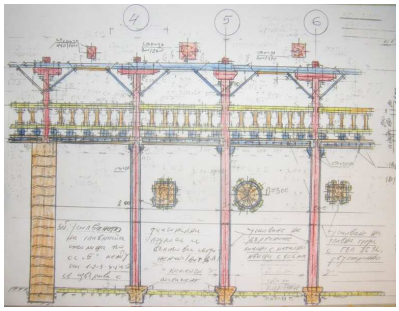
a)  b)  c) 

Fig. 5.3a,b,c – Beam strengthening using steel profiles

When the damage of the beam consists in the rotting of its ends, usually caused by water absorption through the joints or from meteorological water, the degraded material can be removed and replaced with a new one or it can be strengthened using epoxy resins. This second procedure involves only a partial removal of the material at the ends [14].

5.3 Support rehabilitation

The rehabilitation of the timber beams supports was performed through the fixation with steel triangle and steel bolts. Additional connection between roof rafters and horizontal floor beams *using steel triangle* guarantee the global behavior of the building and their correct connection to the stone masonry wall(Fig. 5.4 a,b,c,d). The extremities of the beams was treated against biotic attacks.

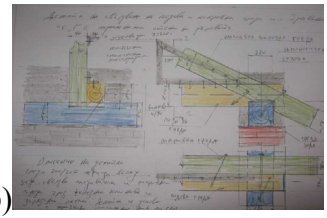
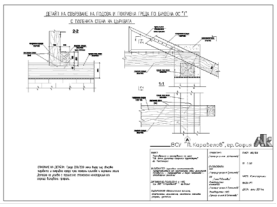
a)  b)  c)  d) 

Fig.5.4 a, b, c, d. Connection between floor and roof beam using steel triangle

Anchoring of purlins to the outside wall is recommended to be done using the steel lashes and steel bolts(Fig.5.5a,b,c)

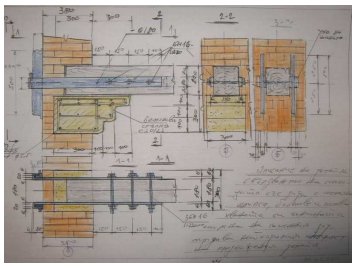
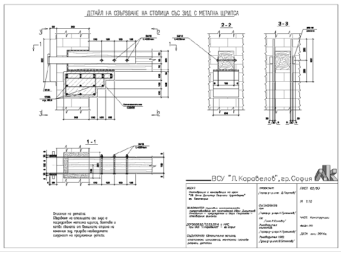
a)  **b)**  **c)** 

Fig. 5.5a,b,c. Anchoring of purlin to the outside wall by steel lashes

Strengthening of the damaged structural element(console-pillow and beam-purlin) with steel are performed by steel lashes and steel bolts also(Fig.5.6, a,b,c).

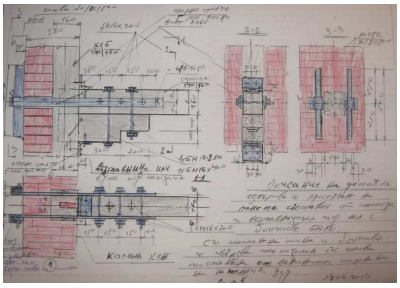
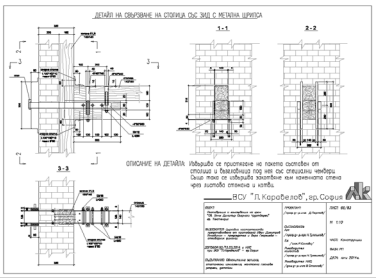
a)  b)  c) 

Fig. 5.6 a,b,c. Strengthening of the damaged structural element(console-pillow and beam-purlin) with steel lashes and steel bolts

5.4 Correction of Deformation

After the rehabilitation of the supports and removal of the heavy load from the roof surface, the existing deflection in the purlins can reduce throughout a system of swept(Fig.5.7a,b,c).

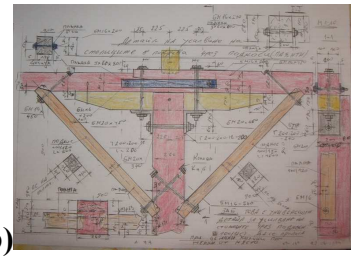
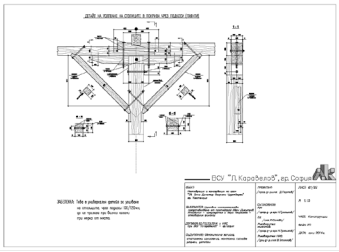
a)  b)  c) 

Fig.5.7a,b,c. Support of the purlins throughout swept

In certain situation it is necessary to substitute partially the damaged elements using prosthesis, with the fixed connection between the new and existing part of the wood elements from M16 threaded rods and screws(Fig.5.8a,b,c).

a)  b)  c) 

Fig. 5.8a,b,c. Construction of wooden prosthesis at the top of the column

6. Numerical Analysis of the Timber Roof of the Church

The main purpose of this part of the article is to show the potentials of a three dimensional computer modelling and simulation of a building structure. We would like to show how the science of engineering in particular, and advanced computer modelling including finite element methods(FEM), can be used to increase the understanding of a structure. We intend to show more than simple strength calculations, which is the most common range of application of the finite element method. We will also demonstrate how to apply this method to a historical building structure. This includes a comprehensive study of the structure in mind, which is done not only to be able to reveal the geometry, but even more to learn to understand the structure and its behaviour. This knowledge is necessary to be able to judge the truth of the results. When the static behaviour of the structure is found we

will illustrate this in a way that is simple to understand even for the less experienced viewer. A historical wooden framework is very likely to be highly complex and machine of time. That is why it is very important to be able to study the results of a calculation when dealing with the framework as an entirely. This includes plots of deformations and reaction forces on the complete structure, as well as special examination of smaller sections of the structure. With the computer model needed for the above analysis it is easy to go further and simulate damage to the structure or exposure to special load cases. This can be done either to include realistic or probable damage in the dimensioning when restoring the building, or to verify observed damage. This will not be demonstrated explicitly in this work, but the possibility will be obvious. As an additional purpose we will also discuss different methods of analysing building structures, especially old historical wooden structures. Originating in the different tools, computer calculations and hand calculations respectively, used in Bulgaria we will try to investigate how the norms and regulations are used. We are interested in whether the rules must be completely obeyed or whether they may in some cases take advantage of the calculation method in question. Within the structural analysis of the historic timber structure, a model is built(fig. 6.1.a,b,c).

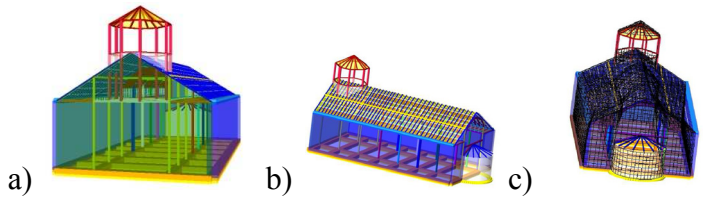


Fig. 6.1a,b,c Church St. Dimitar – (a) Main Truss, (b) Longitudinal Truss, (d) 3D View

Of course at all time, the structural model is a compromise between a scheme close to reality, but too complex to calculate and a scheme, easy to calculate, but far away from reality. The better the model is in line with reality, the more reliable the diagnosis will be. Therefore, a step-by-step procedure within the modelling is used. Initially, with the information available from a visual inspection, a first structural model is made, often not accounting for detailed information on material degradation, missing structural elements, actual deformed shape of the structure. The outcome results of the structural model are compared with the deficiencies identified on site. This initial analysis is worth full since it better aligns additional research efforts. According[5,6] the updated model therefore should ideally account for: overall geometry of the timber roof, cross-sections of the structural elements, nodal details, displacements, missing elements, structural interventions, alterations and weakening; actual material properties, taking into account the rate of decay (mechanical and physical-chemical-biological), instead of the material characteristics specified in the original design or provided by codes; the correct nature of connections and boundary conditions, including differential settlements of the supports; - the uncertainty associated with the validity and accuracy of the models. In general, following remarks can be made: the structural analysis software used (Supperstat, Tower) is mainly developed for the design of new timber structures, according to the limit states design principles, using partial safety factors; there is no software available that accounts for the time dependent (creep) behaviour of timber. The general frame analysis software mainly used within practice does not account for the non-isotropic material characteristics of the timber. Within the analysis different types of nodes are encountered. The outcome of the analysis results strongly depend on the nodal stiffness assumed and their actual restrained(fig. 6.2).

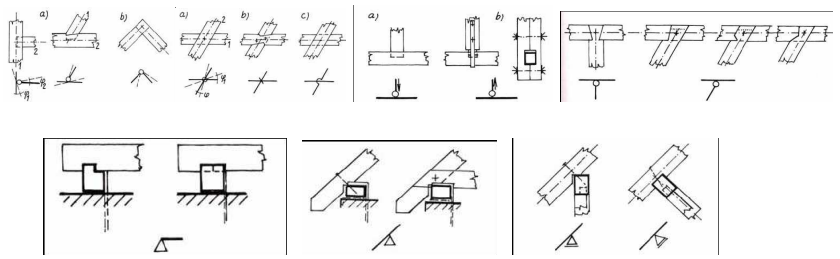


Fig.6.2 Different types of nodes modelled as hinge joints within the structural analysis

7. Conclusion

In the practice, a wide combination of the failure presented in the above mentioned text here can to be found. It is demonstrated that the failures of the timber structures are very peculiar, certainly depending on the kind of action, and different from those of the constructions of other materials, besides characterized by a larger number of types. *Technicians must be acquainted with them and be able to recognize and interpret them on the spot.* They must be able to express an immediate judgement about the level of safety of the construction in the observed condition, *take the immediate measures to avoid collapse*, delaying to a further accurate survey the full evaluation of the general situation. The full understanding of the failures of an existing structural system can greatly help to interpret its behaviour, inconsistencies, *shortening of the level of serviceability*. Similarly, the full understanding of an old structural system, reducing the number of unknown factors, allows a direct and appropriate design of the strengthening measures and devices, the cutting down of the extent and quantity of the intervention with evident advantage for the costs but more for the conservation of the authenticity of the ancient surviving specimens. The risk, otherwise, is to make useless or, worst, harmful interventions. *To prevent this regrettable situation, the strengthening measures must be designed only by technicians who are familiar with the peculiar way of failing of the timber structures and capable to enter into their conception*[16]. In general, the preservation of the structural elements results in benefits, not only in terms of built heritage preservation, but also in minimization of the interventions and their impact. Even though, when this strategy is followed, the implementation of traditional rehabilitation techniques has been commonly passed over by techniques which use modern materials, frequently expensive and with doubtful efficiency. This situation is particularly common in old timber structures, namely roofs and floors, which exist all over the World, in some cases with many centuries. Therefore, an effort should be done to change this situation i.e., to show the community that it is possible to preserve timber structures and, at the same time, to use traditional materials and techniques, leading to more sustained interventions[1,9,10,11,12].

Acknowledgement

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TWO HISTORICAL COVERED TIMBER BRIDGES IN GELNICA

Baláž Ivan[1], Koleková Yvona[2]

Slovak University of Technology in Bratislava, Slovak Republic

Abstract.
Probably the oldest set of 30 photographs of the timber covered bridges on the Slovak territory may be found in the book of the Czech author [1]. A large investigative study of the historical covered timber bridges on the Slovak territory was consequently done by two professors of Slovak University of Technology in Bratislava Dutko, P. and Ferjenčík, P. in the 1954 and 1980. Also their results enabled to the authors to identify all bridges and their details on the more than 100 photographs of originally unknown bridges, which are property of The Monuments Board of the Slovak Republic in Bratislava (PÚ SR – Pamiatkový úrad Slovenskej republiky). The aim of the authors is to perform a study and analysis of all historical and modern covered timber bridges on the Slovak territory.

Keywords: *historical bridge, timber covered bridge, structural system, construction, details*

1. Introduction

The authors of [2-8] found that in 1954 there were 9 bridges from originally 29 timber covered bridges (Fig. 1). The most bridges were built over rivers Hnilec – 10, Poprad – 5 and Hornád – 5. The only bridge which survived till today after several reconstructions is the bridge over Hornád river at Kluknava.

The authors of this paper have collected historical data from archives, chronicles, owners, the oldest inhabitants, contemporary engravings, veduta paintings, old photographs and various publications. It was very difficult to gain or to verify some data.

In this paper only two historical covered timber bridges over river Hnilec in Gelnica are described: (ii) Bottom bridge near railway station, (ii) Upper bridge under the hill with castle ruin (Fig. 2).

2. Bottom Bridge over River Hnilec in Gelnica (Fig. 2-7)

This bridge replaced the similar older bridge in 1901. It was built near railway station in Gelnica. It had red roof. During repair the structure original queen-post truss was strengthened by two pairs of steel rods with ø 30 mm. There are different data concerning

[1] Baláž Ivan, Prof. Ing. PhD., Department of Metal and Timber Structures, Faculty of Civil Engineering, Slovak University of Technology, Radlinského 11, 810 05 Bratislava, Slovakia, ivan.balaz@stuba.sk
[2] Koleková Yvona, Assoc. Prof. Ing. PhD., Department of Structural Mechanics, Faculty of Civil Engineering, Slovak University of Technology, Radlinského 11, 810 05 Bratislava, Slovakia, yvona.kolekova@stuba.sk

its length: in 1901 – 25.75 m, in 1925 – 25.10 m, in 1954 – 25.30 m, or 24.60 m in other sources.

After repairing in 1953 the load carrying capacity of the bottom bridge over Hnilec river in Gelnica was limited to 1 ton. In Fig. 6 it is possible to see a Canadian Military Pattern (CMP) truck Ford F15 with weight 3572 kg, produced in 1940-1945. The photographs were made in fifties after World War II.

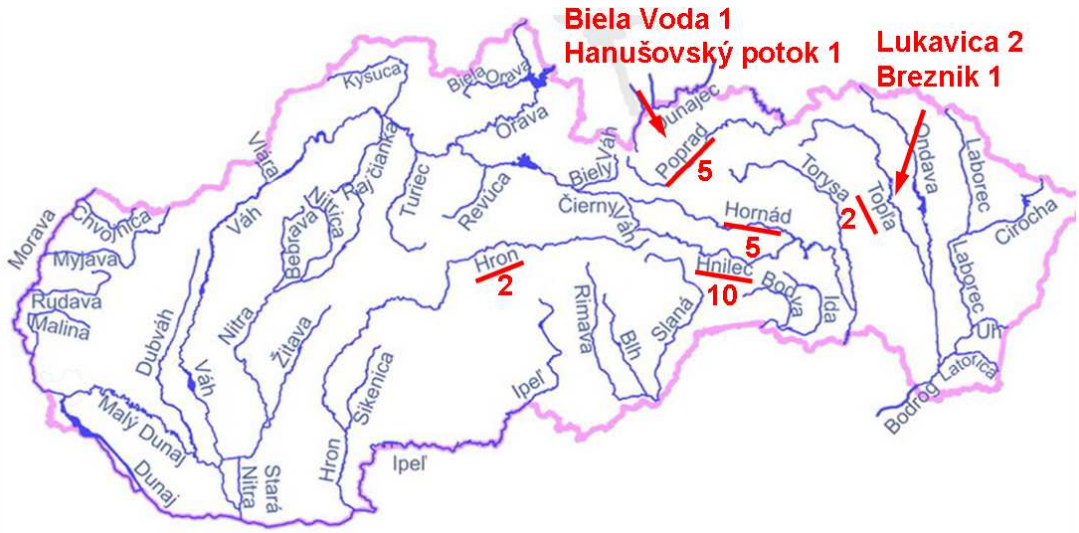


Fig. 1. Rivers in Slovak Republic. Location of 29 historical covered timber bridges

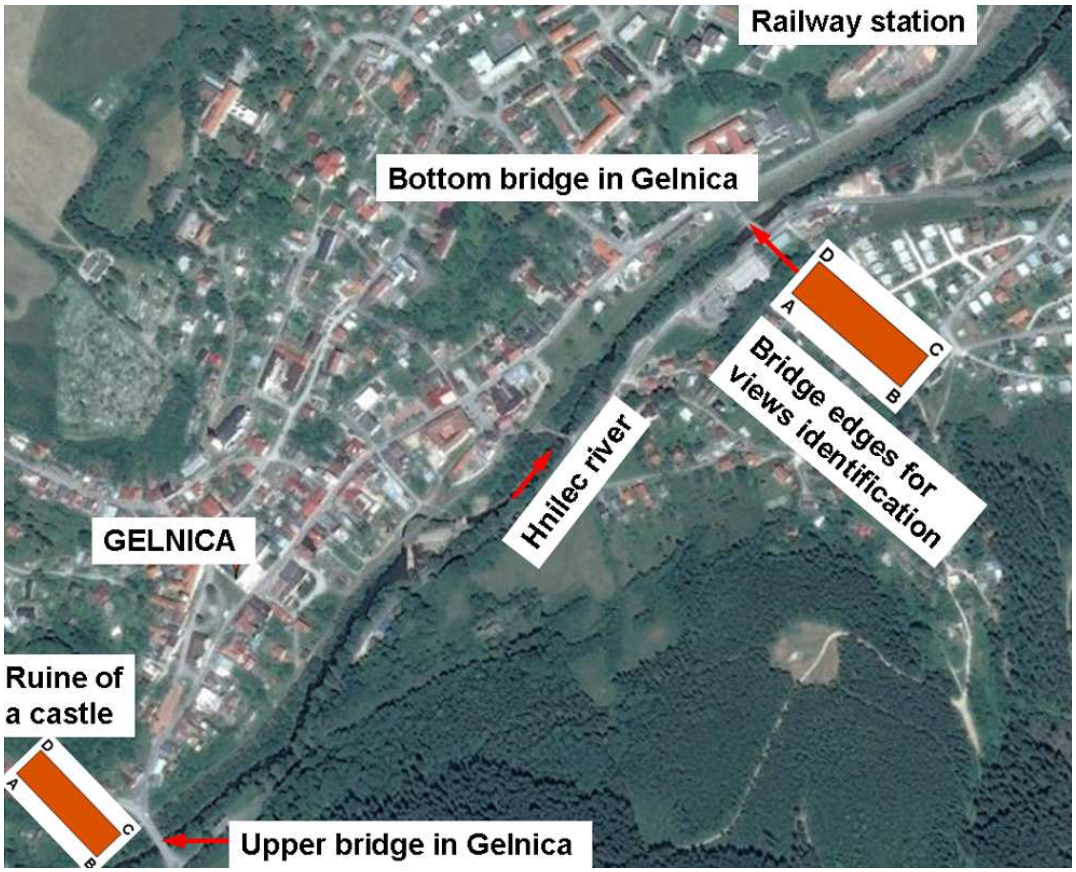


Fig. 2. Upper and Bottom covered bridges located in the past over river Hnilec in Gelnica

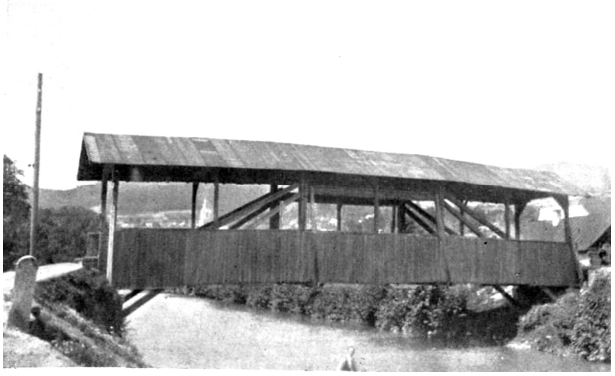


Fig. 3 Bottom bridge over Hnilec river in Gelnica. Side C-D. Built in 1901, repaired in 1953. Photo: summer 1925 [1]

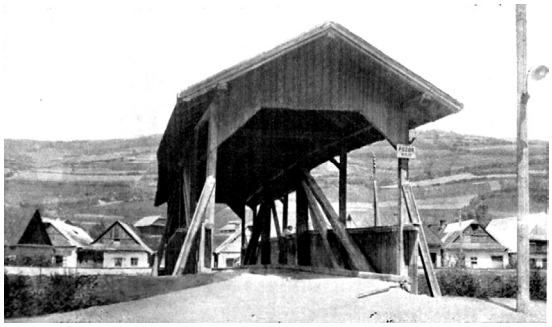


Fig. 4 Bottom bridge over Hnilec river in Gelnica. View B-C. Dismantled in 1960. Photo: summer 1925 [1]



Fig. 5 View B-A-D



Fig. 6 View A-D-C



Fig. 7 View Side C-D

2.1 Global Analysis of the Main Girder of the Bottom Bridge in Gelnica

The two main girders are trapezoidal queen post truss girders with panels lengths 8.65 m, 7.8m and 8.65 m. The main girders are strengthened by strut No. 2 (Fig. 8). The middle panel is without diagonals. The struts No. 1 and No. 2 are located in the end panels (Fig. 9). The strut No. 1 is supported by beam at its end. The strut No. 2 intersects the beam and is supported by masonry support (Fig. 9). The width of the bridge is 3.9 m. Deck of the bridge is supported by 5 longitudinal beams, which are supported by transverse beams. Spacing of the transverse beams is 1.5 m and 1.75 m. There are rigid end wind portals at the both bridge ends. Ridge of the roof is horizontal only in the middle panel. The height of the ridge of the roof at the bridge ends is 0.25 m lower comparing with the height of the ridge in the middle panel of the bridge.

The complete results of globla analysis are given [9]. They were obtained with the help of computer program IQ 100 [10]. Here are presented only distributions of the axial forces (Fig. 10) and bending moments (Fig. 11). The results of global analysis show that the Bottom bridge in Gelnica near the railway station was in 1901 perfectly designed by carpenter Kriwacsy. The bridge design was based on his knowledge and experience.

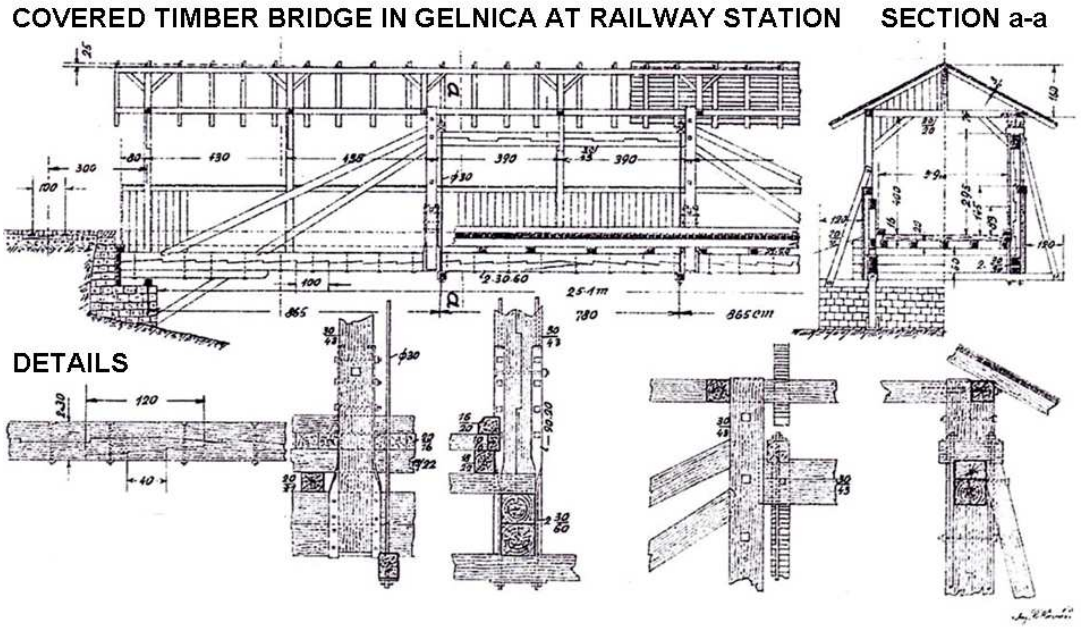


Fig. 8 Covered timber Bottom bridge over Hnilec river in Gelnica [1]

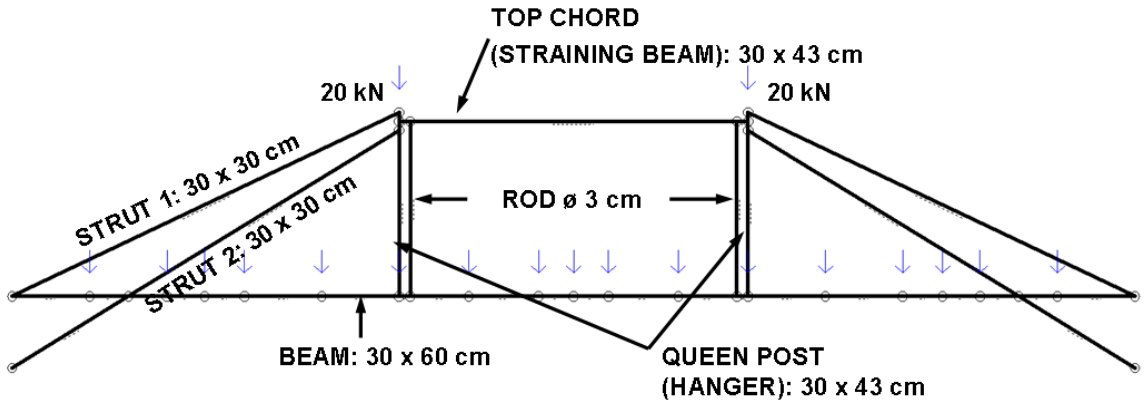


Fig. 9 Statical scheme, member dimensions and values of the actions

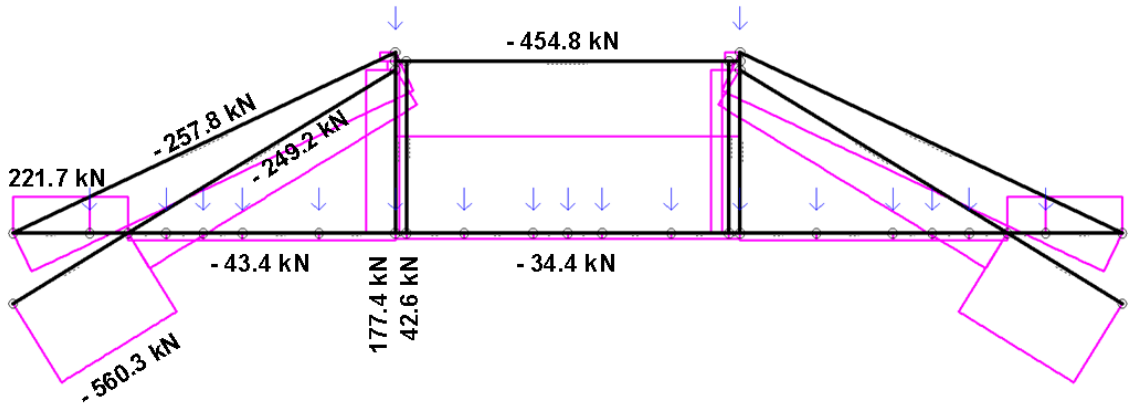


Fig. 10 Axial forces. Negative in compression, positive in tension

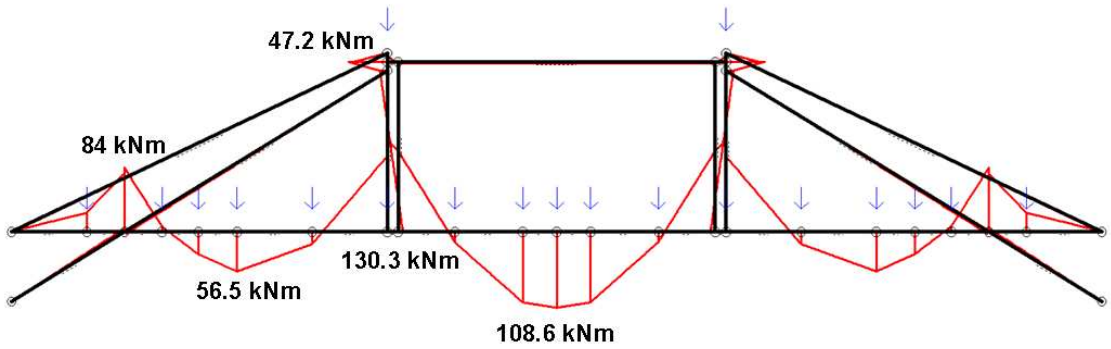


Fig. 11 Bending moments

3. Upper Bridge over River Hnilec in Gelnica (Fig. 2, 12-17)

The bridge was built in 1831, probably repaired in 1881, later strenghtened according to Fig. 11, dismantled in 1957. Length was 35,79 m, width was 4,8 m and height 5,1 m. It was located at the end of the city. In 1954 it was the greatest of covered timber bridges.

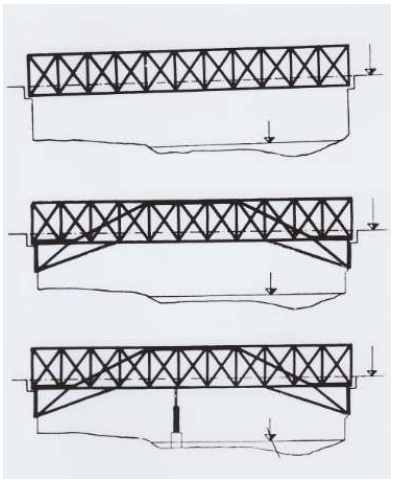


Fig. 12 View A-B.
a) Originally Howe truss,
b) strengthening by strut frame & queen-post truss,
c) added support



Fig. 13 Upper bridge in Gelnica. View A-B-C. In [7], and [8] is mistakenly called as Bottom bridge



Fig. 14 Upper bridge over Hnilec river in Gelnica. Side A-B. Built in 1831, repaired in 1881 and 1934. Photo: summer 1925 [1]

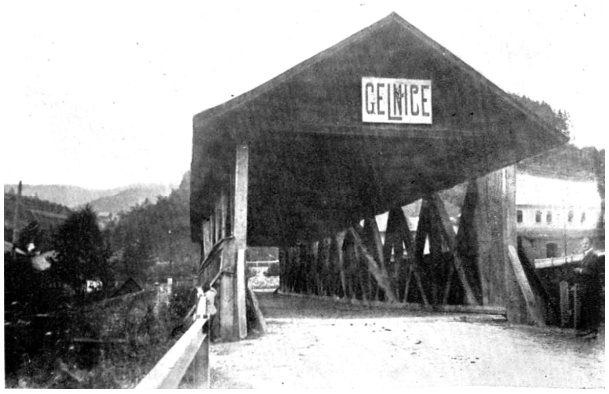


Fig. 15 Upper bridge over Hnilec river in Gelnica. View B-C. Dismantled in 1957. Photo: summer 1925 [1]

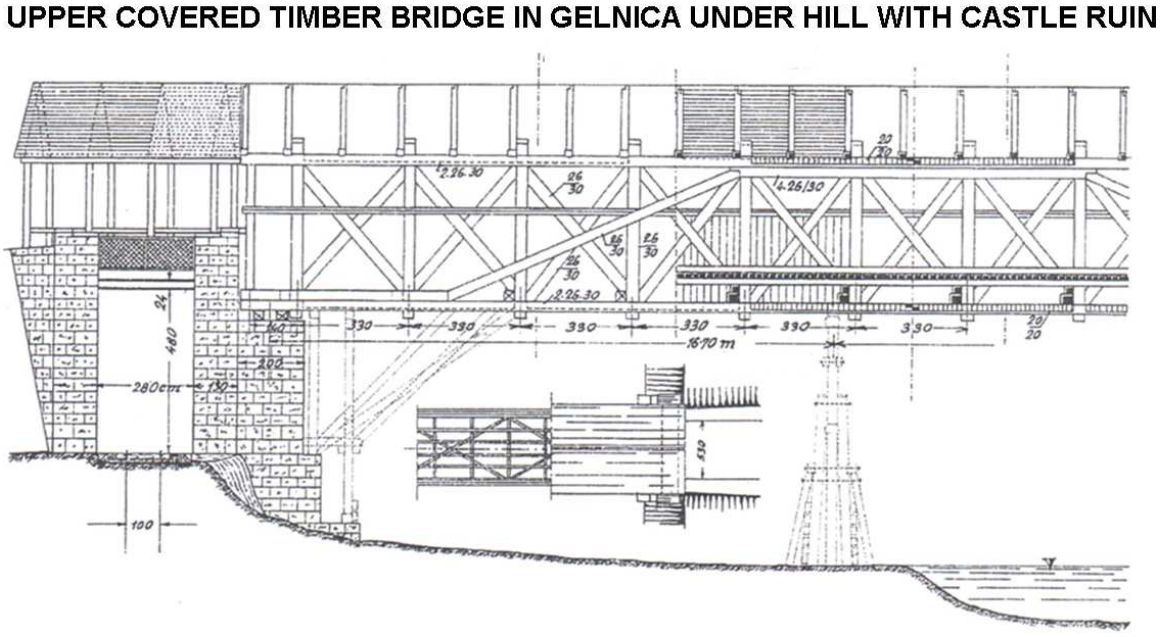


Fig. 16 Covered timber Upper bridge over Hnilec river in Gelnica [1]

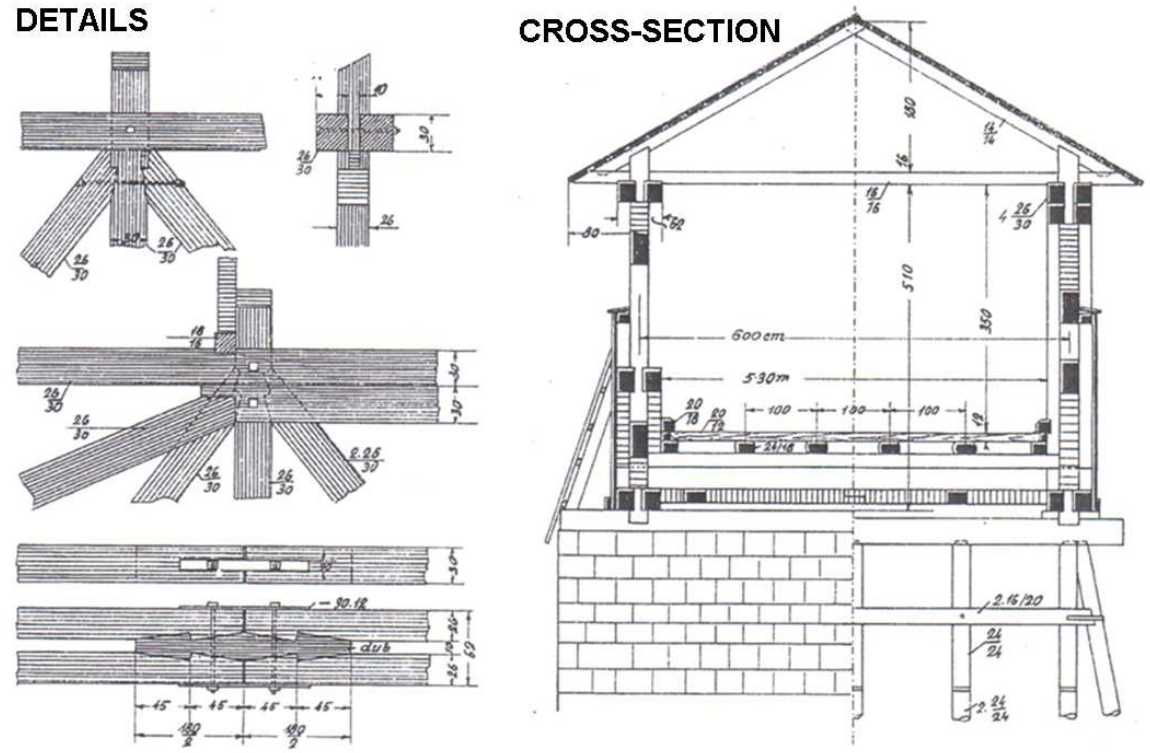


Fig. 17 Cross-section and details of Upper bridge over Hnilec river in Gelnica [1]

4. Conclusion

The authors of the paper have collected historical data about: erection, opening, strengthening, reconstruction, destroying of bridges, geometry, details and other characteristics of bridges and their designers from archives, chronicles, owners, the oldest inhabitants, contemporary engravings, veduta paintings, old photographs and various publications. It was very difficult to gain or to verify some data. Probably the oldest set of 30 photographs of the timber covered bridges on the Slovak territory may be found in the book of the Czech author [1]. A large investigative study of the historical covered timber bridges on the Slovak territory was consequently done by 2 professors of Slovak University of Technology in Bratislava, Dutko and Ferjencik in 1954 and 1980. They published their results in the fifties [3, 4, 5], sixties [6], seventies [7] and eighties [8]. Also their results enabled the authors to identify all bridges and their details on the more than 100 photographs of originally unknown bridges, which are property of The Monuments Board of the Slovak Republic in Bratislava (PU SR – Pamiatkovy urad Slovenskej republiky). The aim of the authors is to perform a study of all historical and modern covered timber bridges on the Slovak territory. The photographs of historical and modern bridges made of various structural materials built on the Czech and Slovak territory may be found in [9-19].

In this paper only two historical covered timber bridges over river Hnilec in Gelnica are described: (ii) Bottom bridge near railway station (Fig. 2-11, (ii) Upper bridge under the hill with castle ruin (Fig. 2, 12-17).

Fig. 9-11 show part of the results of preliminary analysis of the main girder of the Bottom bridge. The results were obtained by computer program IQ 100 [10]. The distributions of the axial forces (Fig. 10), bending moments (Fig. 11) confirmed that historical covered timber Bottom bridge in Gelnica over Hnilec river located at the railway station was perfectly designed. The effective bridge design by carpenter Kriwacsy in 1901 was based on his knowledge and experience. The results of detailed analysis of all structural elements of the Bottom bridge in Gelnica and global analysis of Upper bridge in Gelnica will be published in another paper.

Acknowledgement

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RESTORATION OF SELECTED HERITAGE IRON AND STEEL BRIDGES IN POLAND

Mariusz Maślak[1], Marek Pańtak[2]

Cracow University of Technology

Abstract:
In the paper some restoration techniques used to repair the selected historic bridges made of iron or steel and completed in Poland in the 19th and also in the first half of the 20th centuries have been presented and discussed. The considered structures are: the cast iron suspension bridge erected in 1827 over the Mała Panew River in Ozimek city near Opole, the oldest iron suspension bridge on the European continent with a span length of 31.6 m and the steel welded bridge built in 1929 over the Słudwia River in Maurzyce city near Łowicz, with a span length of 27.0 m, the world's first fully welded road steel bridge.

Key words: *historic bridges, suspension iron bridge, first welded bridge*

1. Introduction

Historia est magistra vitae (History is life's teacher). History is a story about the past that is significant and true. History helps us understand who we are, helps us understand changes and how the society we live in came to be. History is what we inherit, what we make, and what we are fated to become a part of it. We live in a time of rapid changes, a time of progress but we must remember where we come from.

The profession of engineering has a long, rich, and important history. The history of engineering, provides essential information about what was once the state of the art and hence what should be recognized as being fundamental to the latest state of the art. We should take care to preserve the historical heritage for future generations.

Two bridges characterised below are a great testimony of the development of technical thought. These restored structures can be a model to follow and inspiration for both young and senior engineers.

2. The cast iron suspension bridge in Ozimek, Poland

The bridge over the Mała Panew River in Ozimek is the oldest iron suspension bridge on the European continent. It was constructed between 1825 and 1827 and opened for use on September 12th, 1827. At that time the bridge was a pioneering work of Karl Schottelius, royal smelting master, and a worldwide sensation.

[1] PhD, DSc., Eng., prof. CUT, Cracow University of Technology, Faculty of Civil Engineering, Warszawska 24, 31-155 Cracow, Poland, e-mail: mmaslak@pk.edu.pl
[2] PhD, Eng., Cracow University of Technology, Faculty of Civil Engineering, Warszawska 24, 31-155 Cracow, Poland, e-mail: mpantak@pk.edu.pl

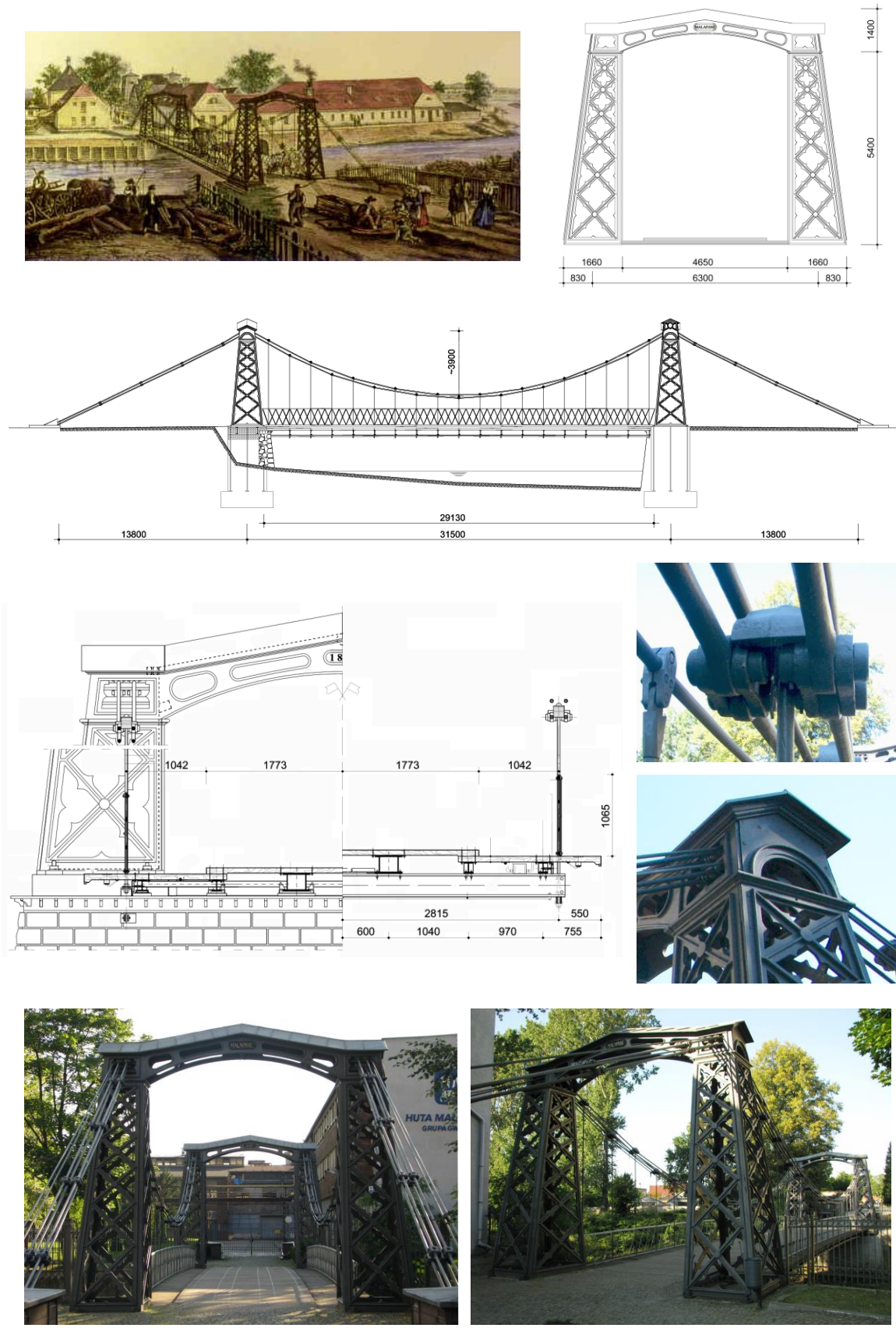


Fig. 1. The iron suspension bridge over the Mała Panew River in Ozimek [4]

The bridge superstructure is formed as a cast iron and cast steel suspended structure with a cast steel and wood deck. The bridge deck is suspended by iron chains, hingedly connected to two cast iron pylons, consisting of cast openwork parts, topped with neo-

gothic style portals. The deck is shaped in a vertical arch of radius 430,00 m. The pylons are 5.3 m high. The axial distance between pylons, measured longitudinally to bridge axis, is 31.50 m, the span of the bridge deck is 29.13 m. The usable width of the bridge deck is 5.60 m while the horizontal clear distance between the pillars of the pylon, measured transversally to bridge axis is, 4.65 m. The distance from the pylons axis to the edge of the anchorages housing is 13.80 m, the distance from the pylons axis to the chains anchoring points is 20.20 m. The total length of the bridge is about 75.00 m.

The main tension bearing members are formed with straight bars Ø45 mm, 3,20 m length made of cast steel. The hingedly connected bars forming the bearing chain. Each chain consist of two levels of bars (four bars arranged in pairs one above the other). The bars are connected to each other by means of pins and other plates (clapms). The chain are arranged in the axial spacing of 5.63 m. Adjustement of the force in chains takes place through turnbuckles, located in each anchorage niches.

The bridge deck is suspended on chains by means of hangers made of cast steel bars Ø35 mm hingedly connected with chains by hat-shaped cast steel elements. The hangers length varies from 2.50 m to 6.00 m. Oryginally the bridge deck was designed as a grillage made of cast steel lateral beams, wooden longitudinal beams and wooden surface made of two layers of palnks (bottom layer with planks 210x115 mm, upper layer with planks 180x30 mm). The wooden surface was placed on 6 longitudinal beams 210x115 mm lying on 17 lateral beams (300 mm I-section) suspended to main chains. Under the lateral beams the flat bars 15x80 mm (two parallel flat bars at each end of letaral beams) were placed The flat bars were conected with letaral beams and anchored in abutments. The lateral beams were braced by means of lateral bracings made of cast steel bars Ø20 mm.



Fig. 2. Grillage of the bridge deck after restoration and modernization work

The bridge railings are designed in modular form placed between hangers and are made of flat bars 8x30 mm for upper chord and 10x35 mm for bottom chord and with X-crossing round cast steel bars Ø20 mm conected with flat bars by menas of bolts.



Fig. 3. Selected constructional details: railing, hanger and lateral beam connection, hanger and main chain connection

The bridge pylons are made of cast iron ornamental trusses (4 trusses for each pylon) forming the truncated pyramids with a rectangular base 1660x2370 mm. The pylon heads are connected by roofed transverse beam with relief of date of completion of construction "1827" and the name of the steelworks "MALAPANE". Weight of a single pylon is about 14.8 Mg.

After detailed technical review carried out in March 2006 and further inspection in Mach – July 2008, after 181 years of bridge exploitation, damages of the bridge elements was classified as directly threatening the safety of users of the object, as well as the structure itself. Main damages identified during technical review and inspections are as follows: strong corrosion on the contact elements of each pylons (due to lack of anti corrosion protection as well as the lack of proper maintenance), transverse cracks in parts of pylons caused (probably reason for this is an accident, which took place at the end of the World Wa II, in 1945 when Soviet tank tried to cross the bridge), advanced corrosion elements of the chains, significant reduction of tension in chains (the upper belt of the chain abutted to the lower belt, while they should be distanced from each other), bending deformations of the bars of the chains, advanced corrosion of the hangers in connections to the crossbeams, advanced corrosion of the crossbeams, lack of the bearings on the abutments under the longitudinal beams of the deck, inadequate protection of the chains anchoring niche against the inflow of water.

In July 2009 a thorough renovation of the bridge was started. The bridge was disassembled, renovated, insignificantly modernized reassembled and strengthened.



Fig. 4. View of the bridge and structural elements before and after renovation and modernization works [4]

After dismantling and detailed inventory control due to the presence of defects the bridge elements were further examined during ultrasound and radiological testing.

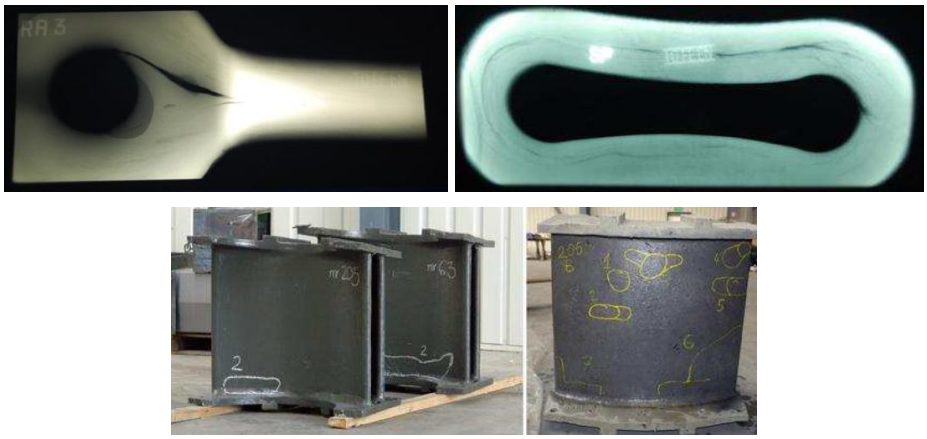


Fig. 5. Radiograms of bridge elements and places of defects of the chains saddles [5]

On the basis of the inspection the need of performance of the following works was found: remove old paint and surface corrosion of the metal element of the bridge by abrasive blast cleaning, remove cracks in parts of the pylon, replenish loss of material in pylons, control and, remove cracks in the chain saddles, lubrication of the chain saddles to reduce friction between the chains and saddles, remove elements that prove the previous interference in construction, replace roof elements over the transverse beams of both pylons, replace all bolt connectors, apply corrosion protection on all elements of the pylons, replace damaged elements of the chains into new identical in shape and material, remove deformations of the bars in chains, reduce friction at the chains joints by the application of lubricant, apply corrosion protection of chains anchor blocks and turnbuckles allowing the regulation of the chains tension, adjust the tension of the chains, protect the chains anchorage against water penetration, ensure proper drainage of the area around the chains anchorages, adjustment of the tension in lateral bracings of the bridge deck, apply an elastomeric bearings under the longitudinal beams of the bridge deck, apply corrosion protection of metal elements of the deck grillage, adjust the grade line of the bridge span.

During the renovation process, after additional static and strength analyses, an insufficient bearing capacity of the main chains was found. Due to significant cracks in some chains elements the bearing chains were strengthened by additional steel ropes (two ropes for each chain). Introduced ropes minimally change the original appearance of the chains, imperceptible to the untrained eye. Additionally to protect the bridge against vibrations the bridge deck was modernized. The wooden longitudinal beams in the bridge deck were replaced by continous steel beams (see Fig. 1, 2: two central box beams 200x350 mm and four wide flange H beams HEB120).



Fig. 6. General view of the additional ropes strengthening the bearing chains

After renovation, finished in September 2010, bridge was opened for use. The structure was reclassified on footbridge with possibility of passing, in rare cases, of a vehicle with a total weight up to 10 tons. Today the bridge is a major tourist attraction of the city.

2. The bridge over Sludwia River in Maurzyce, Poland

The bridge over Słudwia in Maurzyce, near Łowicz is officially confirmed world's first fully welded bridge. The bridge was erected during 1928/1929. The load tests of the bridge was carried out 9 August 1929. Soon after erecting, in the interwar period, the bridge was an object known all over the world as the first steel, totally welded road bridge. The designer of the bridge Professor Stefan Bryła, a well-known Polish scholar and constructor, preceded its designing by many years of studies on the strength of welded joints, their result being the first scientifically worked out rules of such joints in building constructions. Originally the bridge was placed during the road from Warsaw to Poznań. Today the structure is placed next to the road national road 92 (only 25 m up the river) and is declared as immovable historic monument ('class 0' monument, most prized historical monuments of international significance).

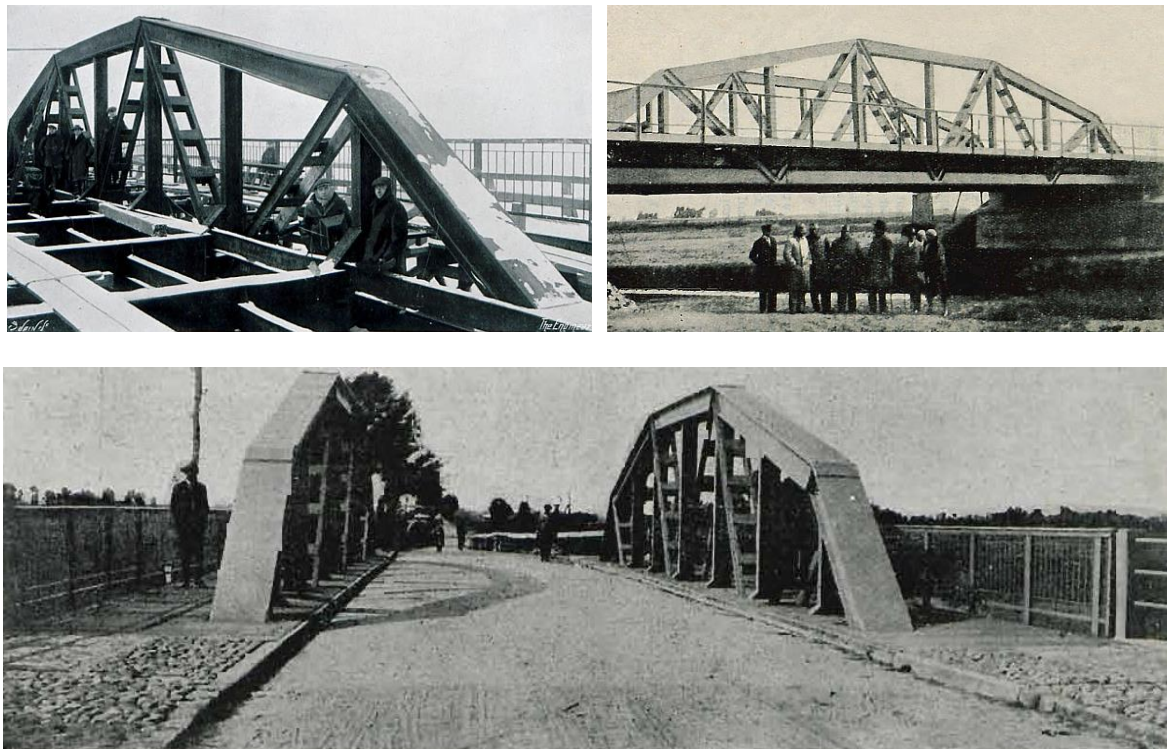


Fig. 7. General view of bridge in Maurzyce during construction and after opening [2, 3]

The bridge was built with ingot steel of strength 360-410 MPa [3]. The structure consists of two main truss beams, with a straight lower flange and a parabolic upper flange. Theoretical span of the truss girders is 27.00 m, theoretical height of the girders in the middle of the span is 4.30 m, the distance between joints in lower flange is 3.375 m. The width of the bridge between the main beams axes equals 6.76 m and in the clear distance between the girders it is 6.20 mm. The main beams are joined by cross bars and horizontal bracings situated in the plane of lower flanges, they have no bracings in the upper flange. Cross bars are joined with the main truss posts by stiff joints and stringers are fixed to the cross bars by means of trapezoidal plates. On both sides of the girders (outside the girders) two sidewalks were designed, each 1.50 m wide.

The total mass of welded construction was 59 tonnes, while the mass of the riveted structure was supposed to be 70 tonnes, thus the construction mass was reduced by 17%.

Until the late 1970s the bridge was placed during national road no. 2, the Polish section of the European route E8. However in 1977 due to the increasing traffic and too small width the bridge was closed to traffic and moved 25 m up the river and a new composite bridge was built in its place.

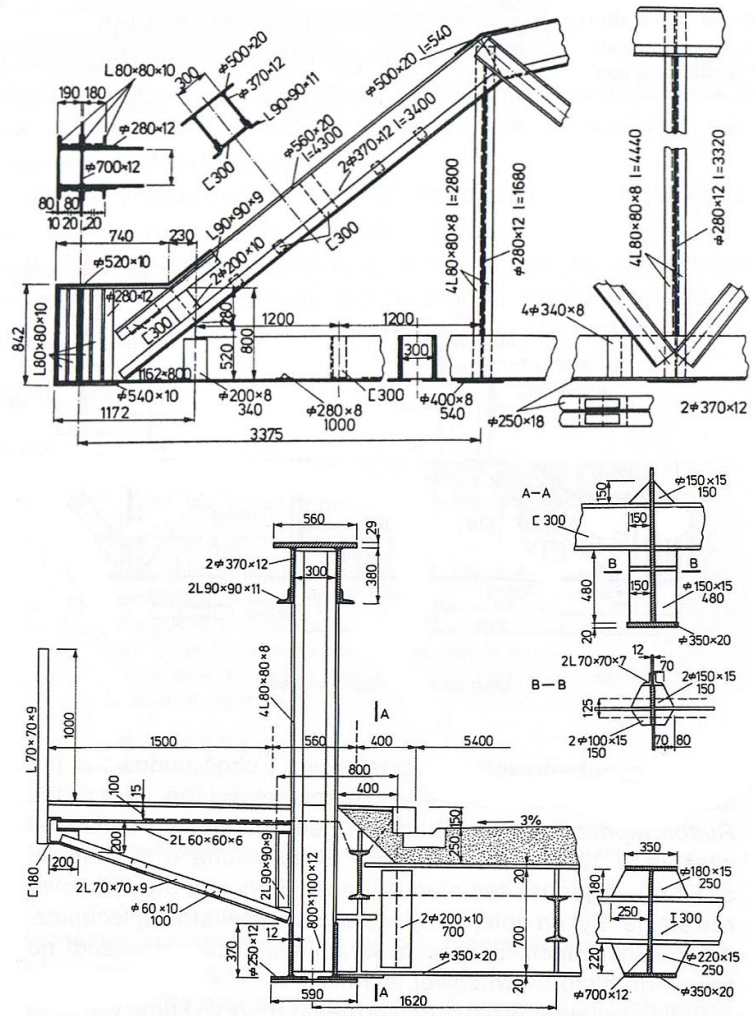


Fig. 8. Longitudinal and cross section of the bridge in Maurzyce [1]

In 2009 the bridge was refurbished. Construction was cleaned of rust and repainted, and the road surface was replaced with a granite sett. In 2011 a memorial plaque to Professor Bryła was unveiled in front of the bridge.



Fig. 9. General view of the bridge during restoration work

In 1995, the American Welding Society honored the achievements of Stefan Bryła by "Historic Welded Structure Award" for welded bridge on Słudwia. In 2010 the Lodz branch of General Directorate for National Roads and Motorways for the renovation of the bridge received the award "Well-kept monument" granted by Polish Minister of Culture and National Heritage and General Conservator of Poland.



Fig. 10. General view of the bridge after restoration

4. Conclusion

Heritage is the history, unique knowledge, values and traditions. It is a potential which should be used for future development. Heritage provide the basis for an understanding in the different subjects: culture, education, science, policy etc. Heritage tells us the story of progress, story of nations and societies as well as the story of individual people. The preserved cultural goods allow us build our social identity. Protection, preservation and maintenance of heritage goods for future generations is a big challenge and a duty. This is our duty and gift for future generations and for ourselves.

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DAMAGE TO *POMBALINO* BUILDINGS INDUCED BY GROUND DISPLACEMENTS AND EARTHQUAKES

Hugo Renda[1], Rita Bento[2], Rui Gomes[3]

[1,2,3] CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal

Abstract:

In Lisbon historical centre there is a totally peculiar constructive feature, the Pombalino buildings, developed after the devastating 1755 earthquake and the induced tsunami and fire, which almost totally destroyed Lisbon. These buildings have high heritage value and represent about 25% of Lisbon existing building stock. They are characterized by external rubble stones masonry walls and by the internal timber-framed masonry (the so-called "frontal walls") which would play a significant role in the seismic resistance of the building. Despite the cultural and economic potential of Pombalino buildings, they are vulnerable to different natural hazards (e.g. earthquakes) and subject to different types of losses. For example, they are exposed to of ground movements due to the progressive increase in the exploitation of the subsoil, together with a consolidation of Lisbon downtown alluvial soil. This paper will assess the damage caused by soil settlements and the effect of this damage in the earthquake resistance of Pombalino buildings. The building in study is analysed inserted in the block. The nonlinear numerical analyses will be performed with the 3MURI/TREMURI program.

Key words: *Pombalino buildings; Heritage residential buildings; Structural damage; Soil settlements; Capacity curves.*

1. Introduction

Lisbon downtown is an historic urban center composed of old heritage residential buildings (well known *Pombalino* buildings) which has an intangible asset value due to historical, cultural and touristic reasons. This heritage must be preserved and transferred to future generations in good safety conditions and preserving the authenticity of the buildings.

However, despite this cultural and economic potential, *Pombalino* buildings are vulnerable. Post-earthquake surveys reported cases of these old heritage buildings with weaker seismic performance than expected. This effect may have been caused by pre-

[1] Hugo Renda, MSc, CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal, e-mail: hugo.renda@tecnico.ulisboa.pt
[2] Rita Bento, PhD, Assoc. Prof., CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal, E-mail: rita.bento@tecnico.ulisboa.pt
[3] Rui Gomes, PhD, Assist. Prof., CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal, E-mail: rui.carrilho.gomes@tecnico.ulisboa.pt

existing damages due to ground movements, low quality rehabilitation works, and/or previous earthquakes. In the future, it is expected that these losses will grow due to not only natural disasters and human actions, but also to environmental and climate change.

The 1755 earthquake (Mw 8.7), felt all over Europe, completely destroyed the Lisbon downtown. Lisbon downtown is known to be the joint point of two underground streams. The soil profile includes a surficial layer of debris from the 1755 earthquake, laying over a few tens of meters of alluvial sediments transported from those streams. After the 1755 earthquake, a complex but standardized reconstruction scheme (the *Pombalino* system) was imposed in downtown. The *Pombalino* system included the use of modern seismic reinforcement techniques and new planning concepts, such as the *Pombalino* cage, the orthogonal blocks, the similarity between buildings with regular openings, buildings with the same number of floors and aligned [1]. The main characteristics of *Pombalino* Construction is presented in section 2.

Nowadays, most of the buildings located in Lisbon downtown are still the *Pombalino* buildings. In last decades, the area was involved in a large number of construction works, including building rehabilitation, construction of basements, new infrastructures and subway lines. In section 3.1 it is referred some of the main causes of differential movements in *Pombalino* buildings and the settlement measurement evaluated in Lisbon downtown.

There are only few studies which report damage of *Pombalino* buildings due to settlements. Correia *et al*. [2] described the damage in a building located in Lisbon downtown, and measured the building's movements [3]. However, these reports are classified and are not accessible. Maranha das Neves [4] and Moreira and Flor [5] analysed the effect of tunnel construction on the buildings in Lisbon downtown. However, probably for legal reasons, the differential settlements prior and after tunnel construction are not indicated.

Pombalino buildings were considerably studied by several authors (e.g. [1,6,7,8,9]), focusing mainly on their seismic performance. To accurately evaluate these buildings' seismic performance, the initial state of the building must be characterized and reproduced in the analysis. Thus, it is very important to simulate the existing damage on masonry structures that may be due to a combination of different actions. On *Pombalino* buildings, the damage induced by ground movements prior to earthquake loading were never taken into account, according to the authors knowledge.

The building studied in this work corresponds to an original *Pombalino* building constructed just after the historic earthquake of 1755 [6]. In this study, the global response of this building was assessed by using the TREMURI program; the commercial release to generate the model (3Muri release 5.0.1) and then the scientific version [10, 11].

The *Pombalino* building in study is analysed inserted in the block. It is studied in detail and for one level of magnitude and configuration of differential settlement imposed at the base. Then, for the building damaged due to impact of ground movements, the capacity curves are evaluated. The results obtained show that ground movements prior to earthquake loading play a relevant role on the seismic performance of old heritage buildings.

2. The *Pombalino* Constrution

The *Pombalino* buildings of downtown Lisbon have a recognized patrimonial value both nationally and internationally. They were introduced after the 1755 catastrophic earthquake as a structural solution that would provide the required seismic resistance. Based on the know-how of that time and on the empirical knowledge gathered from the buildings that survived the earthquake a new construction type was proposed; this being generally referred to as *Pombalino* construction nowadays. The buildings were designed

with a three-dimensional (3D) wood truss that provides resistance to horizontal forces in any direction. The wood truss, called *Gaiola* (Fig. 1) is the Portuguese word for cage, as the *Gaiola* consists on a 3D wood truss that looks like a cage. The *Gaiola* is constituted by a set of plane trusses, called *frontal* walls, connected at the corners by vertical bars that belong to orthogonal *frontal* walls (Fig. 1a). Each *frontal* wall is constituted by a set of triangles, a geometry similar to the steel trusses of nowadays. Since the triangle is a geometric figure that cannot deform without variation of the length of the sides, in fact it is the only one, each *frontal* wall only needs to mobilize the axial force of its bars to resist to forces in any direction in its own plan. Therefore, the connection between orthogonal *frontal* walls by means of common vertical wood bars yields a 3D truss capable of resisting forces applied in any direction. Thus, they would support not only the vertical loads but also horizontal seismic loading and would have a beneficial effect on the out-of-plane failure of the façade walls since they were connected to them through the floor. In general, the space between the wood bars of the *frontal* walls is filled with weak masonry (Fig. 1b), and the surfaces are covered with a finishing material, therefore the *Gaiola* in general is not visible.



a) b)

Fig. 1 *Gaiola* a) after removal of cover and masonry b) with masonry filling

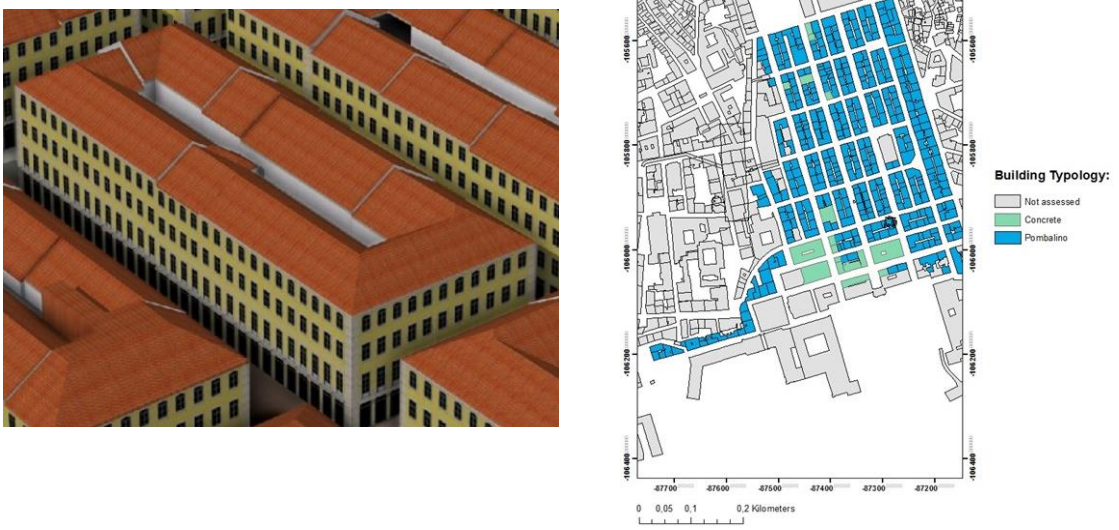
This construction type can be summarized as follows (for more detailed see Meireles [6] and Lopes et al. [1]): Buildings were built in quarters, each block comprising an average of 10 buildings (Fig. 2a). The foundations consist of a system of wooden piles over the alluvium layers. The piles are similar and repetitive, on average 15 cm in diameter and 1.5 m in length. These form two parallel rows in the direction of the main walls, which were linked at the top by horizontal cross-members attached by thick iron nails. The construction between the ground and first floors consisted of solid walls and piers linked by a system of arches. In more elaborate cases, thick-groined vaults spanned between the arches, which protected the upper floors from the spread of any fire that might start at ground floor level. From the first floor up this building system has the aforementioned timber Gaiola structure (Fig. 1). As abovementioned, *Gaiola* is composed of traditional timber floors and *frontal* walls, one of the key characteristics of these buildings. The front and back façades as well as gable walls of the upper floors are made of rubble masonry. The gable walls are common to both adjacent buildings.

In downtown Lisbon about 95% of existing construction belong to *Pombalino* structural typology (Fig. 2b). However, it is worth to note that significant changes have been occurring the time they were built until the present day, changing their seismic behaviour [12].

3. Settlements

3.1. Settlement measurements

Lisbon downtown is located in the northern bank of the estuary of River Tagus (Fig. 3a). As abovementioned, this area was severely damaged during the 1755 earthquake and was reconstructed in the following years. As the built area is over the junction point of two underground streams, the thick layer of alluvium soil and the groundwater close to surface turns Lisbon downtown in a region which requires frequent and careful monitoring. Two subway lines cross each other in this region, at Baixa-Chiado station (Fig. 3a), and the recent expansion of one of the lines was marked by a flooding event in a tunnel under construction close to Terreiro do Paço (Fig. 3a) station in 1999, inducing a rapid drawdown that induced settlements in the range of a few hundreds of meters, affecting a large number of *Pombalino* buildings. Moreover, in last decades the area was involved in a large number of construction works, including building rehabilitation, construction of basements, new infrastructures and subway lines. Also, underground waste piping and/or underground downspout piping can crack or break and generate local settlements. All these effects combined produced a complex configuration of differential movements in *Pombalino* buildings. These movements induced damage to *Pombalino* buildings, ranging from negligible to severe.



a) b)

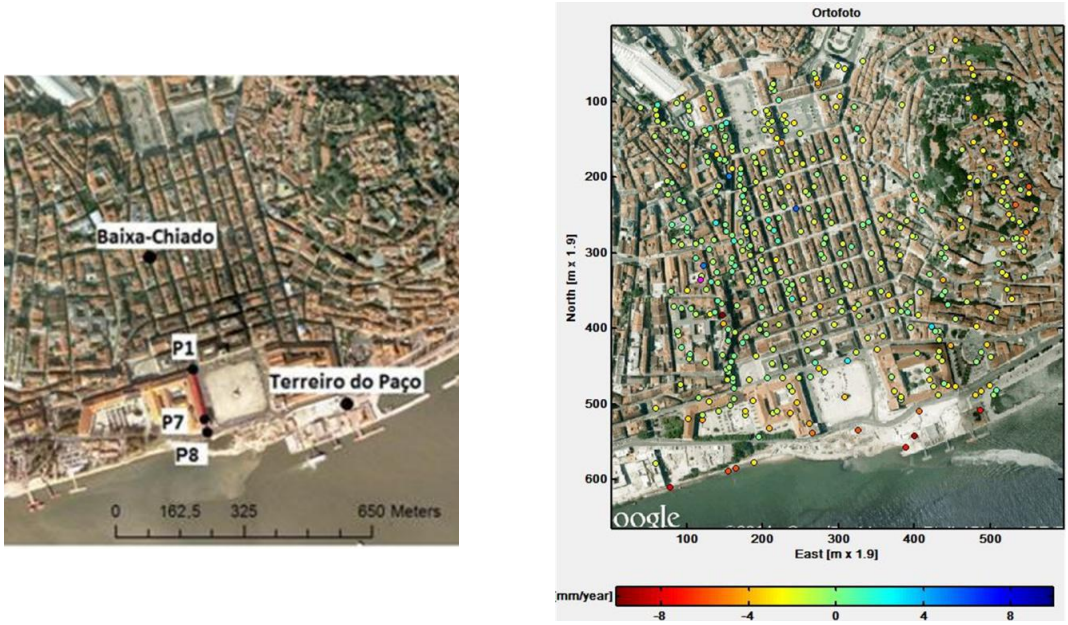
Fig. 2 a) *Pombalino* quarter (modelling with the use of parametric rules [12]; b) Structural typology of downtown Lisbon's buildings [12]

Recently, Roque et al. [13] used PS-InSAR strategies [14] to monitor subsidence to Lisbon downtown that was validated against levelling data. Seasonal effects are identified in Fig. 4, where it is suggested that they might be related to hydrogeological parameters and changes in groundwater level, with good agreement with levelling data.

A good agreement between the displacement velocities determined by PS-InSAR and levelling surveys was verified for both P7 and P8. Although the results only could be validated for two points, an average difference of 1.0 mm/year was observed. It must be taken into account that the points where PS-InSAR technique calculated the displacements are not in the same location of the levelling points, which may contribute to the observed discrepancy.PS-InSAR detected displacement velocities from -9.7 mm/year to 5.9 mm/year (Fig. 3b). At the western wing of Praça do Comércio, an increase in the subsidence velocity is observed towards the river.

3.2. Imposed differential settlements

In this paper, the level of induced damage to the structure is assessed through the angular distortion, generally used in current practice, defined as the differential settlement between two points divided by the distance between them. Two cases are studied: none angular distortion was imposed with no damage induced prior to earthquake loading; moderate damage is expected for angular distortion equal to 1/200 [15].



a) b)

Fig. 3 Lisbon downtown: a) location of subway stations and levelling points; b) Displacement velocity in the study area [13].

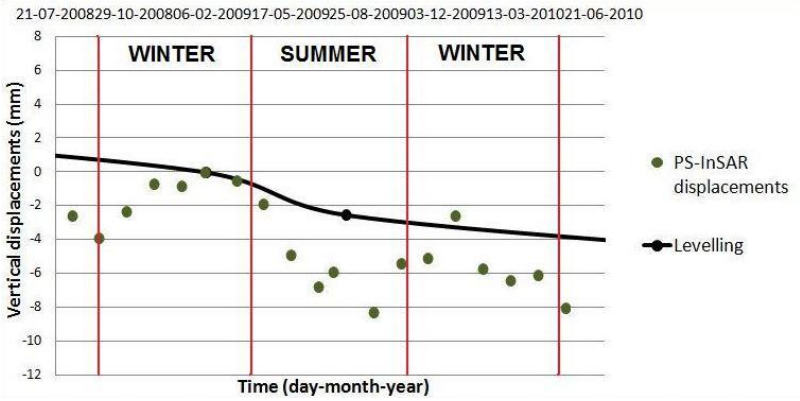


Fig. 4 Vertical displacement values for P7 (Fig. 3a) [13].

One generic configuration of differential settlement was adopted in the analyses. Fig. 5 shows the displacement configuration where the maximum vertical movement is uniformly imposed to a gabble wall (side wall).

4. Case study

The studied masonry building is inserted in a block and has four floors without structural reinforcement. The ground floor is 4.5 m high, while the upper floors are 3.5 m high, thus the building is 15 m high. The building has rectangular shape (Fig. 6) in plan view ($11 \times 17.3\ m^2$).

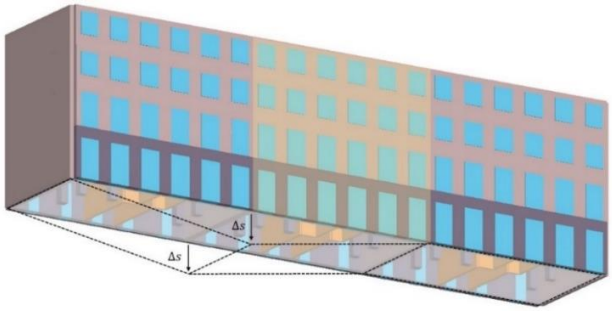
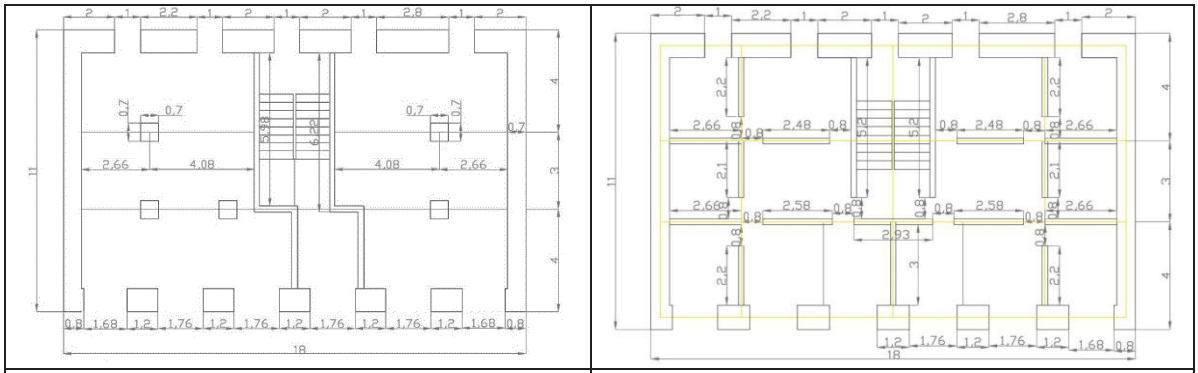


Fig. 5 Displacement configuration analysed for the building in the block

The façade of building has six openings on each floor, $1.68\ m$ or $1.76\ m$ wide. The ground floor entrances are $3.5\ m$ high, while the first floor balconies are $3\ m$ high. The windows of the second and third floor are $2\ m$ high.

The openings of the building backwards are $1\ m$ wide. The ground floor entries are $3\ m$ high, while upper floors the windows are $1.5\ m$ high.

The structural elements material type and size are given in Table 1. The façade and backwards thicknesses decrease along the height of the building.



a) b)

Fig. 6 Plan view: a) ground floor and b) upper floors [6] (dimensions in m).

Table 1 Structural elements: material type and size [6].

Element	Material type	Area/thickness
Piers (ground floor)	Stone masonry	$0.70 \times 0.70\ m^2$
Façades (façade and backwards):		
Ground floor	Stone masonry	$0.90\ m$
First floor	Rubble masonry	$0.85\ m$
Second floor	Rubble masonry	$0.80\ m$
Third floor	Rubble masonry	$0.75\ m$
Gable walls	Rubble masonry	$0.70\ m$
Staircase and internal walls (ground floor)	Brick Masonry	$0.24\ m$
Frontal walls	Wood/Rubble masonry	$0.15\ m$

The mechanical properties of masonry walls are presented in **Table 2.** The stone and brick masonry properties are average values given by the Italian regulation [16].

Several experimental studies were carried out by other authors (see [6]) to characterize the wood used in Lisbon's downtown, known as *Pinho Bravo Português*. Table 3 summarizes the mechanical properties of that wood. The loads used are described

in Table 4, defined according Eurocode 1 [17]. In the study, the live loads were considered and applied simultaneously with the displacement of the ground, because the settlements are long-term actions.

Table 2 Mechanical properties of masonry types [6].

Masonry type	Average Young modulus $[E\ (GPa)]$	Average shear modulus $[G\ (GPa)]$	Average compressive strength $[f_c\ (MPa)]$	Average shear strength $[f_t\ (MPa)]$	Weight $[\gamma\ (kN.m^{-3})]$	Ultimate shear drift $[D_{sh}\ (\%)]$	Ultimate bending drift $[D_{fl}\ (\%)]$
Rubble masonry	1.23	0.41	2.50	0.043	20	0.40	0.60
Stone masonry	2.80[a]	0.86[a]	7.00	0.105	22	0.40	0.60
Brick masonry	1.50[a]	0.50[a]	3.20	0.076	18	0.40	0.60

[a] In the simulations these values were reduced by a factor a 2 to consider the stiffness decrease due to cracking.

Table 3 Mechanical properties of wood used.

	Average Young modulus $[E\ (GPa)]$	Average shear modulus $[G\ (GPa)]$	Average compressive strength $[f_c\ (MPa)]$	Average Young modulus perpendicular to the fibres $[E_{90}\ (GPa)]$	Average compressive strength perpendicular to the fibres $[f_{c,90}\ (MPa)]$	Weight $[\gamma\ (kg.m^{-3})]$
Wood	12.00	0.75	18.00	0.40	6.90	580

Table 4 Load types (Eurocode 1 [17]).

Element	Location	Value[a]
-	Floors	$2.0\ kN/m^2$ (*ll*)
-	Stair floor	$4.0\ kN/m^2$ (*ll*)
Stairs	Stair floor	$0.7\ kN/m^2$ (*dl*)
Internal walls	Floors	$0.1\ kN/m^2$ (*dl*)
Wooden floors	Floors	$0.7\ kN/m^2$ (*dl*)
Ceilings	Floors	$0.6\ kN/m^2$ (*dl*)
Frontal walls	*Frontal* walls	$3.0\ kN/m$ (*dl*)
Vaults	Masonry walls of the ground floor	$3.5\ kN/m$ (*dl*)
Gable walls roof	Masonry walls of the fourth floor	$17.3\ kN/m$ (*dl*)
Roof	Masonry walls of the fourth floor	$4.4\ kN/m$ (*dl*)

[a]Load type: if live load (*ll*) or dead load (*dl*), respectively.

As referred, the *Pombalino* Building was modelled in TREMURI program, where the Equivalent Frame method is employed for the analysis of standard masonry wall structures with openings. The wall is discretized in a set of masonry panels, which are deformable and where the non-linear response (damage) and deformation is concentrated, connected by rigid nodes. The deformable panels (macroelements), which undergo damage, are classified into two main types: the piers (the principal bearing elements carrying vertical and horizontal loads) and the spandrels (secondary horizontal elements providing coupling between the piers). The *frontal* walls macroelements implemented by Meireles et al. [6] are used in this work. TREMURI software is specifically oriented to the seismic analysis of

masonry structures and explicitly models flexible horizontal diaphragms, very common in old masonry buildings.

The global model of the building is shown in Fig. 7a, while Fig. 7b shows details of the ground floor.

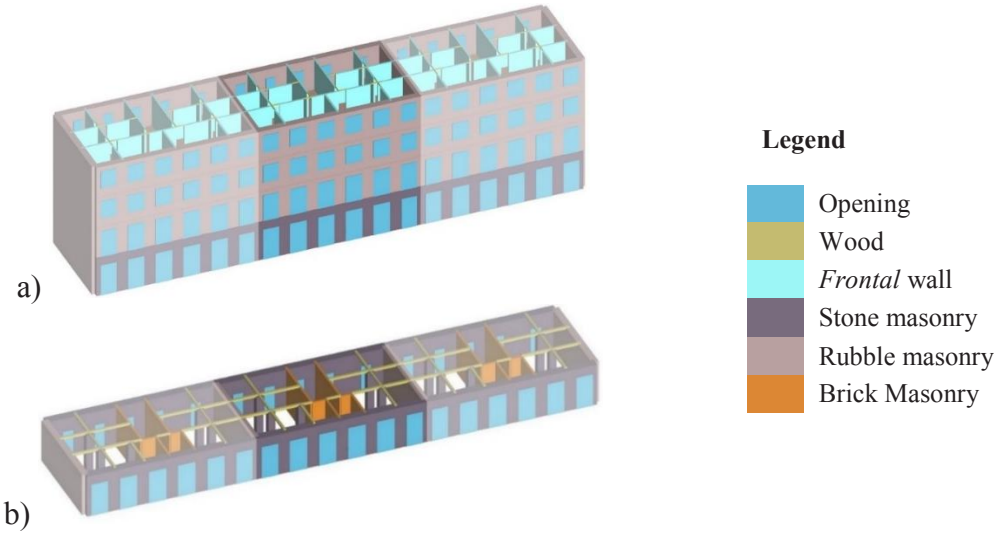


Fig. 7 Building model: (a) building; (b) ground floor.

5. Results and discussion

5.1 Numerical simulation of damage to the building due to ground movements

Fig. 8 shows the damaged in the façade and the backwards of the building when subjected to angular distortion, $\boldsymbol{\beta}$, equal to $\mathbf{1/200}$. It can be seen that the spandrels are the most damaged due to the vertical displacements. For $\boldsymbol{\beta = 1/200}$, which corresponds to a relative vertical movement equal to $\mathbf{8.65\ cm}$, almost all spandrels from the façade and backwards collapse by bending.

5.2 Influence of damage induced by ground movement on the capacity of the building

In this section, the capacity curves with and without prior ground movement are compared. The capacity curves are obtained through a pushover analysis in the two main directions (along the façades and the side walls) with uniform (pattern of forces applied to each node of the building and proportional to its mass) and pseudo-triangular (pattern of forces proportional to the product between the mass of the node and its height with respect to the base) horizontal loads distributed in height and the control node located on the top floor near the centre of gravity.

Fig. 9 shows the results of the capacity curves of the building inserted in the block (total base shear $\boldsymbol{Fb}$ *vs.* relative top displacement) under the action of displacement configuration considered herein ($\boldsymbol{\beta = 1/200}$) and without being subjected to imposed displacements on the base ($\boldsymbol{\beta = 0}$). It is depicted the curves for the both main directions (YY along the side walls and XX in the direction of the façades) and for both distribution of lateral loads: uniform and pseudo-triangular). The pushover curves provide essential information about the behaviour of the building in terms of stiffness, overall strength and ultimate displacement capacity. The curves for $\boldsymbol{\beta = 0}$ are the reference curves, because none relative movement was induced at the building's base. The capacity curves for $\boldsymbol{\beta = 1/200}$ show similar evolution to the curves obtained for $\boldsymbol{\beta = 0}$, but always with lower values of maximum $\boldsymbol{Fb}$ (decrease of strength between 3% and 20%).

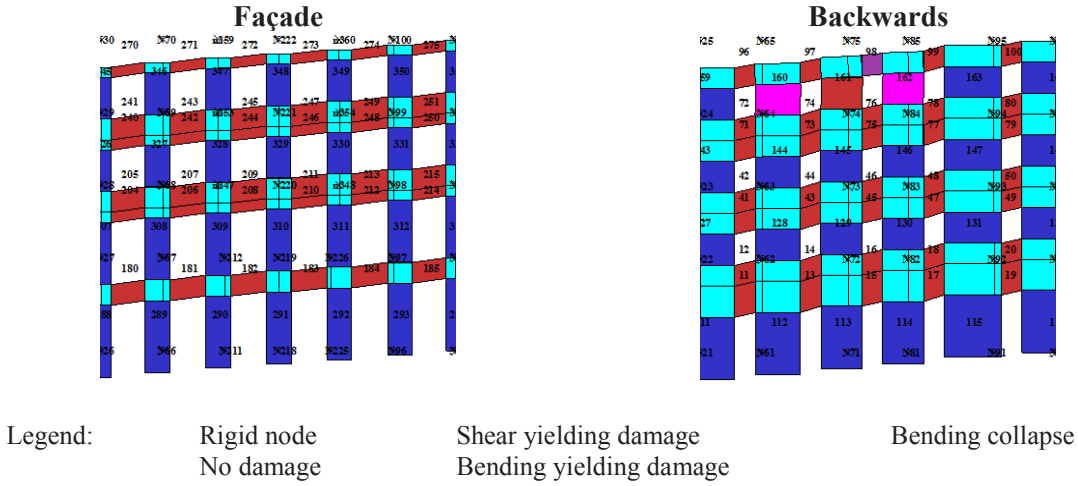


Fig. 8 Damage pattern in the façade and backwards of the building subject to displacement at the base - $\beta = 1/200$ (scale factor equal to 10).

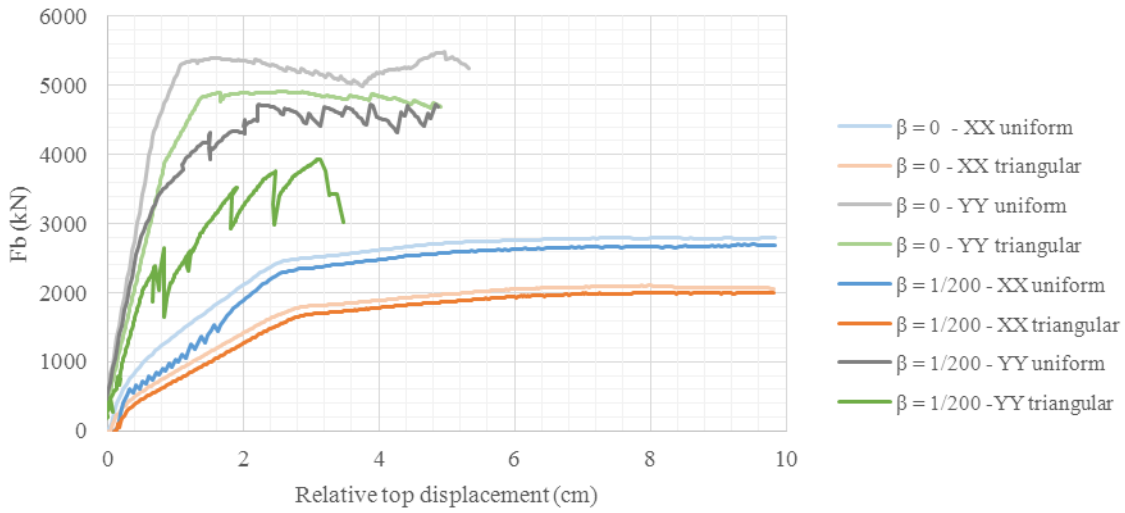


Fig. 9 Capacity curves of the building subject and not subject to imposed displacements on the base (YY –load applied along the side walls; XX load applied in the direction of the façades). Moreover, in the X direction the effect of the imposed displacement on the base lead to a decrease of the initial stiffness while in the Y direction this imposed displacement reduce the ultimate top displacement.

It is evident that X direction has lower strength in all cases studied. These differences are related to the presence of external blind walls (no openings) in the Y direction, where the external walls in the X direction are characterized with the higher number of openings. The initial part of the capacity curve, which corresponds to the elastic phase, has greater stiffness in Y direction than in X direction. The type of load distribution influences de capacity curve. The uniform load distribution lead to larger values of Fb, with larger deformation for Y-direction.

6. Conclusions

A *Pombalino* masonry building, inserted in a block and built after the 1755 earthquake subjected to imposed base displacement was analysed. The capacity curves of the structure without and with damage due to base movements were assessed; for this, horizontal loads, reproducing the inertial forces that are generated when an earthquake occurs, were applied at the level of the floors.

When the movement imposed to the base produces an angular distortion equal to 1/200, the capacity curves clearly show a reduction of the ultimate shear force and deformation capacity of the building, proving that it is very important to consider the effect of the initial deformation of a building to assess their actual seismic performance.

This paper presents the first stage of an ambitious work under development to assess the seismic vulnerability of old heritage buildings to ground induced displacements.

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REMEDIAL WORKS AND REPAIRS OF A HISTORICAL MASONRY BRIDGE

Vladimir Kristek [1], Iva Broukalova[2]

Czech Technical University, Prague, Czech Republic

Abstract: *In addition to describing repair of the Charles Bridge, the paper presents the general lessons learned: multi-decade response of a masonry structure, assessment of damages, failures and deterioration processes related to materials, environment, climate, structural arrangement and detailing, assessment of the masonry bridge with respect to heritage, historic and structural aspects, discussion on appropriate strategies for refurbishment, restoration, conservation and preservation corresponding to location and significance of the historical bridge and ways to increase durability and long service life of historical bridges ensuring that they will be protected against harmful effects for many years to come*.

Key words: *repair, refurbishment, restoration, conservation, Charles Bridge*

1. Introduction

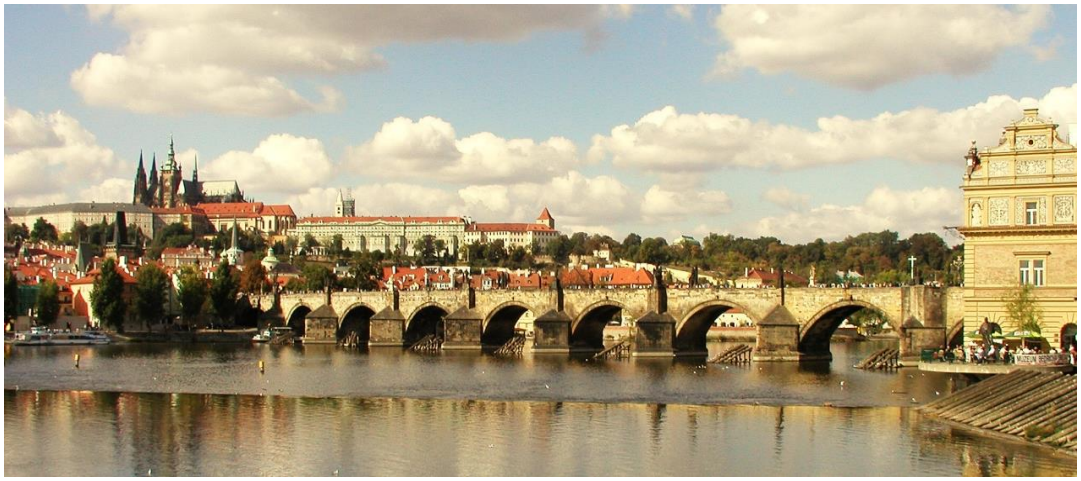


Fig. 1. Present appearance of the Charles Bridge. View from the right Vltava riverbank

[1] Professor, Dipl.Ing., Ph.D., DrSc., Dr. h. c., FEng., Department of Concrete Structures and Bridges, Czech Technical University in Prague, Faculty of Civil Engineering, Thákurova 7, Prague 6, Czech Republic, E-mail: kristek@fsv.cvut.cz

[2] Ass.Professor, Dipl.Ing. Ph.D., Department of Concrete Structures and Bridges, Czech Technical University in Prague, Faculty of Civil Engineering, Thákurova 7, Prague 6, Czech Republic, E-mail: iva.broukalova@fsv.cvut.cz

Originally Stone Bridge, now the Charles Bridge in Prague (CHB) was founded in 1357 and hand built by primitive means of the fourteenth century in less than 50 years. The total length of the bridge is about 500 m, its average width is 15 m at its 16 bridge spans contain as much as 100 000 tons of stony materials, including 60 000 pieces of accurately worked sandstone blocks (Fig. 1). Over 600 years of its existence, the bridge survived a number of serious accidents caused mainly by floods of the river Vltava (Fig. 2) as well as construction changes due to urban development of the city. For five centuries the bridge was the only fixed crossing over the river in Prague and in the adjacent 100 km of the river.
Currently, the CHB is the world-renowned cultural and technical "celebrity" and the yearlong sightseeing goal for millions of visitors to the Czech capital.



Fig. 2. The bridge had been seriously damaged by numerous floods.

Like any building, the CHB requires a systematic professional care, maintenance and repairs corresponding to structure aging, to operation and external conditions, especially to climatic influence (Fig. 4). The aim of the last major repair of CHB in 1965 – 76 provided by the large-scale bitumen insulation was to prevent the stonework from eroding by leaking rainwater (Fig. 4).



Fig. 3. Bitumen insulation from 1970 fails to perform the expected function after a very short time



Fig. 4. The proof of rainfall water leakage through the bridge masonry in the wintertime

But already in 1983, it was confirmed by probes that the insulating layer fails to perform the expected function (Fig.3) and a new, substantially sophisticated compensation is required immediately. The investor's project had suggested significantly improving the overall technical condition of the bridge by replacing all structural layers over the vaults without taking into account their historical value (Fig. 5).

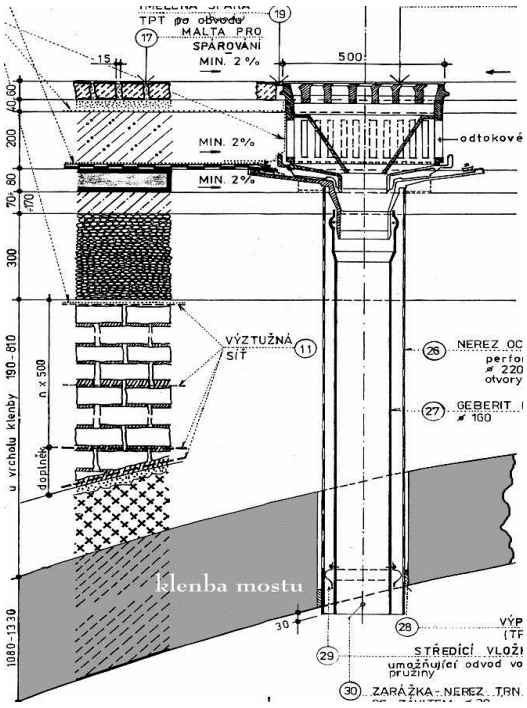


Fig. 5. The rejected project of „radical" bridge repair – the replacement of the construction layers over the vault

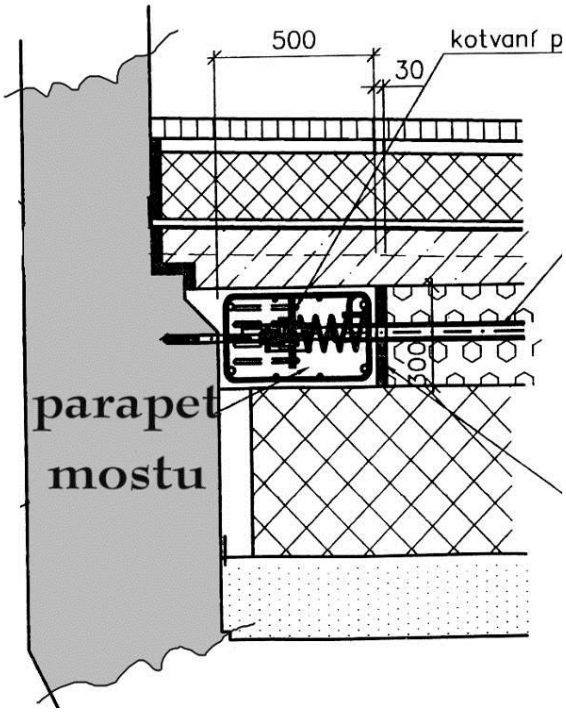


Fig. 6. The rejected project of „radical" bridge repair – used technology of prestressing

The proposal of such "radical" solution, however, evoked categorical disapproval of the Czech Association of Civil Engineers (CSSI), especially owing to numerous specific defects and to the lack of complexity of the solutions. What was, among others, criticized was the insufficient prevention against foundation undermining, the faulty geotechnical survey, the inadequate drainage system, the problematic up-to-date design modifications alien to the Gothic bridge (Fig. 6). The serious rift in the technical evaluation of the quality of the CHB repairs have resulted in the project dispute carried out by independent experts coming from the spheres of construction practices and universities.

At the same time, the National Heritage Institute (NHI) also independently assessed the project of "radical" interventions of the CHB. Its professional opinion flatly refused the project due to its utter unacceptability from conservation point of view. It is not accidental that the opponent team of technicians later found not only common language with the NHI conservationists but also optimal variant of repairs – considerably more suitable and economical.

Critical evaluation of the existing unsatisfactory course of technical preparation of the CHB repairs made the investor take extraordinarily vigorous steps:

- Nullify the already approved project documentation of the "radical" concept of repairs
- Replace the authority of direct investor, design and engineering organization
- Based on the dispute findings order to newly elaborate a comprehensive concept of optimal repair of the CHB carried away in a friendly and economical way and performed in separate stages.

This final concept adopted in 2005 was approved by "Technical Coordination Committee for CHB Repair" as a binding basis for the development of new project documentation. In it, the investors already demand maintaining the public pedestrian traffic during the repair (Fig. 7). The price for the more difficult working conditions was the

extension of the total construction time and the necessity to reduce the workplace into chess-like organized sections located alternately every one-half the of the bridge.

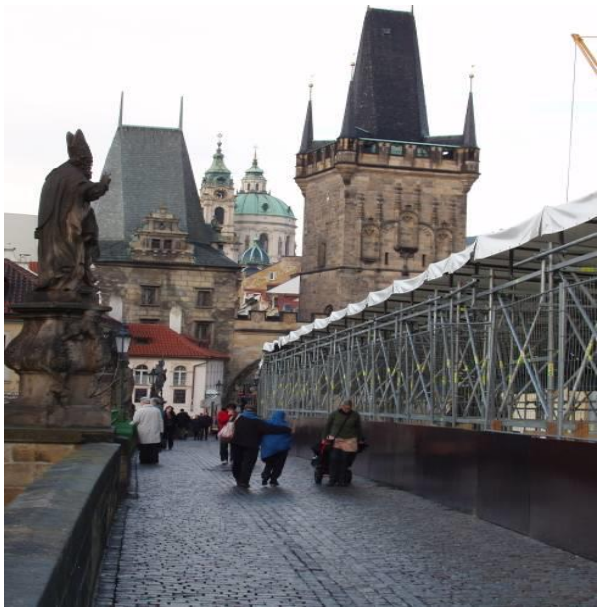


Fig. 7. The concurrence of public traffic with the construction carried out on a longitudinally separated half of the bridge



Fig. 8. Deepening of pillar fundaments No. 8 and 9 with progressive mechanization from water level.

The time schedule of repairs was divided into three major stages:

Stage I: Ensuring the static stability of the bridge during the flood emergency by protecting the shallow-based pillars against the undermining of bedrock foundation joints.

II. Stage: Protecting of the upper bridge structure against the destructive effects of rainwater leakage, climate and emissions. Establishing durable waterproof system all over the bridge.

III. Stage: Repair or replacement of sandstone blocks of the facial walls of the bridge threatened by the loss of load carrying capacity and durability through staling.

After the diving exploration in 2003, the first phase of redevelopment of two shallow-based pillars foundations on the left bank which were damaged during the 2002 floods was

included in the work program as a priority (Fig. 8). The new walls of protection "envelopes" situated around each pillar were made of steel sheet piles, were vibrated into pre-drilled holes and anchored 1m deep into the bedrock of the river (Fig. 9). Under the bridge vaults short flat sheet piles were used and they were fixed by jet grouting.

For future safety, a specialized engineering company carried out the necessary change of the original arrangement of both pillars in an uninterrupted bridge operation in record time (12/2004-6/2005) with a silent consent of conservationists. A contemporary progressive technology was used perhaps also because there is no other "historical" technical alternative (Fig. 8).

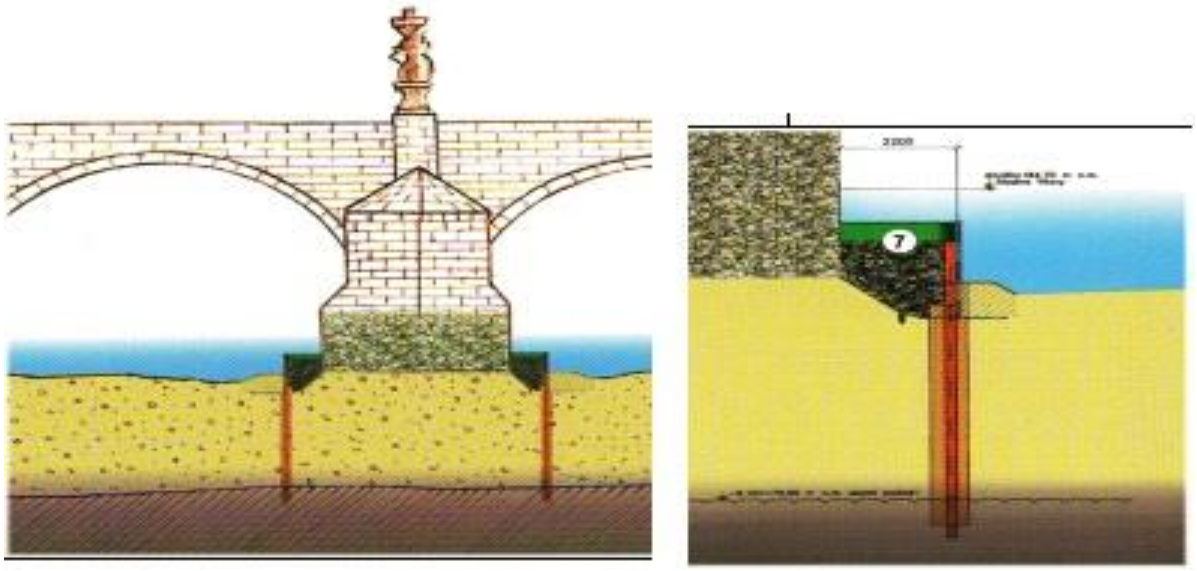


Fig. 9. Protecting the shallow-based pillars by steel sheet piles anchored 1m deep into the bedrock of the river

By the deep foundation of the remaining two pillars in the live stream, the CHB received, for the first time in its existence, the guarantee of the necessary stability and aging resistance of the whole substructure to catastrophic flooding. Final building report of the completed first phase confirmed that the repair was performed in accordance with the project, the contractual deadline and the quality standards were met and there are good prerequisites for future reliable functions of the bridge.

These findings opened a way to the next stage of repairs delayed for years. It fully devoted to the upper structure of the bridge, with the emphasis on waterproofing system renovation (Fig. 10), the overall statics and the extension of the life of the bridge. The project of the second phase was discussed for two years in collaboration with consulting experts of all relevant professions, including the archaeological and heritage protection.

The resulting proposal received, after a very demanding dispute, a building permit and was applied as a base project for a public competition for a construction contractor.
The actual repair of the upper structure then proceeded to maintain public pedestrian traffic in a specific working mode in the period of 2007-2010. Public and professionals, as well as mass media closely followed it. The original project documentation from the time of the original bridge construction and the repairs of most flood disasters was not maintained.

This is why the detailed structural-historical and archaeological research, along with checking the current status of the structure was usually performed only during the construction work.

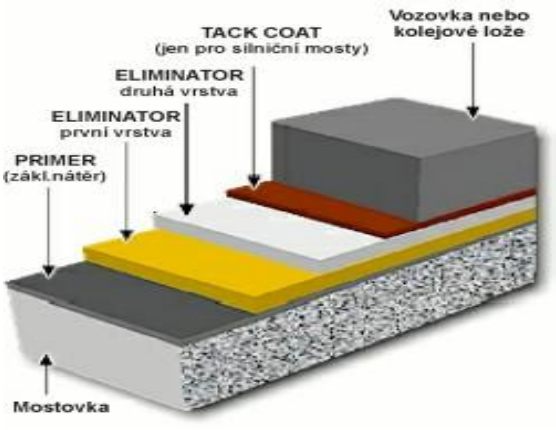


Fig. 10. The system of multi-layer sprayed hydro isolation



Fig. 11. Spraying the hydro isolation „Eliminator"

Top teams of surveying departments verified the properties and behavior of the bridge as a whole as well as the physical and technical characteristics of individual construction materials, which often showed significant disagreement with the assumptions of designers. What came as a surprise was a very low contamination of leachate, high quality inner layers from major repairs 1965-1976 (concrete strength, non-corroded reinforcement, low masonry humidity), strength of filling masonry made of quarry stone and hydraulic mortar, which, unlike the considered stone riprap, substantially alters its static function in a structure. The main attention, however, has gradually focused on sandstone blocks and the joints of the facial walls of the bridge, the different evaluation of which became the apple of discord between the construction-technical and official preservationist communities. This conflict of opinions, inspired by the preferential interpretation of Czech Heritage Law spread by the assertive media campaign, which culminated in the misguided investor's accusations of serious damage to this unique national monument.

Despite the adverse development of relationships and aggravated position of the bridge construction, work continued according to the approved project and the time program. Successful was also the most important stage of this technology - the multi-layer waterproofing spray Eliminator (Fig. 11). The choice of this technology was the result of technical assumptions compared with the available competing methods and verification of practical experience with its effect on the reconstruction of railway bridges under heavy traffic. Well handled was also the problem (though feared initially) of parallel construction and pedestrian traffic on the bridge.

The Czech Technical University experts' analyses proved wrong the original project hypotheses about the linearly elastic behaviour of the bridge due to temperature changes and confirmed the legitimacy and the optimistic prognosis to the future. To clarify the situation and to defend against false accusations an independent panel composed of Technical University authorities and representatives of relevant professional organizations was established. This body was entrusted with an objective assessment of comments and objections to the implementation of the bridge structure. The result of the detailed control analyses - a written finding - gave an unconditional technical discharge to the second phase of the CHB repair on October 30, 2010.

So far, the two stages of CHB repair have fully confirmed the correctness of the technical concept of the investor. It is going to ensure that this unique structure will be performing safely in its present form for the centuries to come.



Fig. 12. The example of advanced phase of staling of sandstone blocks of facial bridge masonry

Compared to the original technical condition of the bridge, the CHB of today bears traces of a long development, starting by the change of its foundations, sculptures, the reconstruction of structures damaged by floods, waterproof insulations, gas and electrical installations, etc. The CHB structure as a technical unit is now stable and able to provide investors, conservationists, designer as well as the general public enough time to seriously prepare for the third, most probably the most challenging phases of the bridge repair - the rehabilitation and gradual replacement deteriorated sandstone blocks of masonry arches and facial brickwork. (Fig. 12).

The technical specification (what needs to be done) has been clear from the very start of the construction. Therefore, what is essential here for the subjects in charge is to be in synch while dealing with the task within a given time. The conservative desire to return in the third stage of repairs to the historically preferred applications of the original medieval building may be, for the contemporary society, an interesting thought, but it is completely utopian and for ensuring the CHB future, totally meaningless. However, there is no doubt that the realistic and acceptable solution does exist and it can be, respectively, it has to be, agreed upon.

None of the existing CHB repairs managed to avoid the problematic phenomenon – the frequently substantial disagreement on the optimal choice of technical solution of the construction, which occurred even among the top-level professional builders. This traditional phenomenon perhaps reached its historical peak during this very reconstruction. The one-sided interpretation of the superiority of subjective propositions of the Heritage Act stood against the objective influence of all joint activities forming the common work, e.g., for instance, the technical, safety, static, transportation, environmental, sanitary, standardized, and the currently limiting economic conditions and criteria.

This discrepancy was resolved in arbitration by the superior Ministry of Culture, which, upon the request the City Hall in May 2011, confirmed: *"We agree with your view that an individual stone slab is not an art-craft or a piece of artwork. Adherence to the traditional craft practices in this case is not to be considered "restoration" in accordance with § 14 section 8, Heritage Act, but instead, a qualified craft repair."*

In the clash of conflicting philosophies of professional bridge repair there is no realistic justification of the faulty thesis proclaimed by the state cultural institutions. It claims that the Charles Bridge should be considered as a work of art and the decision upon the destiny

of each individual sandstone block is to be entrusted to the ruler's restorers and conservationists. CHB has been throughout its turbulent history an explicitly purpose-built public construction. Despite the wish of certain groups of officials, it cannot be anything else either legally or factually. This fact itself, however, does not weaken the spontaneous reverence and love which culture-loving Czechs have always felt for "their" bridge.

What seems to be a social problem is the exclusive definition of the future existence of the Charles Bridge based on a qualified evaluation of the essential technical knowledge of the existing functionality of the bridge over six centuries, on professional experience and expertise drawn from contemporary repairs and finally on forecasting application possibilities of modern and further developing materials and technologies compatible with the character and dignity of this historic structure (Fig. 13).

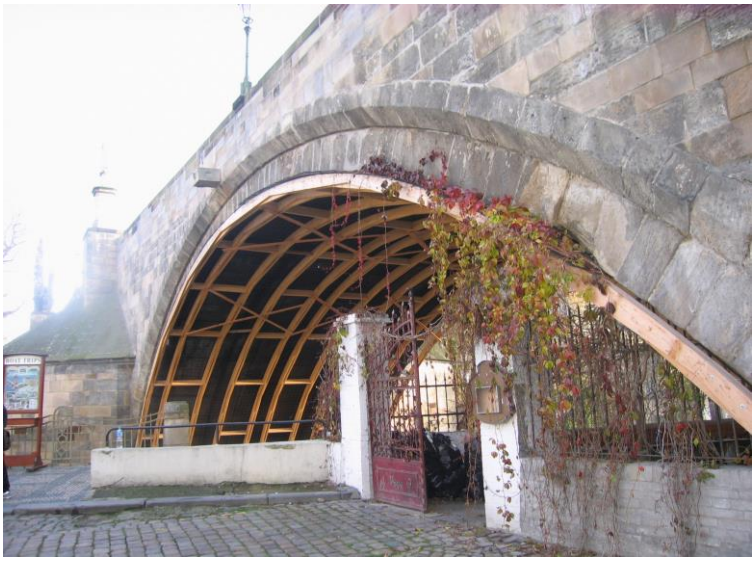


Fig. 13. The vault damaged by staling temporarily supported by wooden construction

It is obvious that the CHB is completely beyond the balance sheets of stability and durability of modern bridges in the Czech Republic with their expected lifespan of 100 years. The current technical condition of the CHB justifies the assumption of its further life for centuries. It is the Prague City Authoritymobil: that carries the responsibility over the CHB as a part of urban living organism. That is why the world public as well as Czech preservationists will undoubtedly appreciate it if the maximum lifespan becomes the investor's priority within all social requirements in preparing the final stages of repair of this unique national monument.

In a multiyear-survey, project, and investment preparation the Charles Bridge repair has been proposed. It will be carried out in three phases over approximately 10 years. Since 2004, in the first stage, the bridge foundations in the river stream have been secured with no special problems. The second stage, however, brought the escalation of the confrontation of two diametrically opposed concepts – the objective bridge engineering technology against its counterpart - fundamental ideas of official representation of conservationists. Nevertheless, the bridge reconstruction successfully fulfilled its professional task. The conceptual differences, however, still remain blocking the continuation of necessary bridge repairs at its third stage, tentatively estimated at 10 years of work. The article justifies the priority motivation of construction experts - to provide realistic functional life of the historic bridge for the centuries to come.

2. Conclusion

Originally forming the only route across the River Vltava, Charles Bridge has played an important role in the growth of the city. Today it plays a major part in the city's tourism industry with the gothic structure being an attraction in its own right. In the 14th Century the construction team used what were then innovative methods and materials, aiming to increase the life of the bridge (Figure 14, 15).



Fig. 14. King Charles IV founding the bridge in 1357



Fig. 15. A probable 15th century pillar-foundation technology.

The second stage of the refurbishment included repairs to the upper bridge section, replacement of the old concrete deck, installation of a new waterproofing system, replacing stones in sills where required, new drainage and repair to the structure's piers. Like their predecessors the engineers on the project were keen to use long-lasting solutions for this work, one of which was the Eliminator waterproofing system, which replaced the existing leaking system.

Essential to the success of the refurbishment was the chosen waterproofing solution's ability to achieve a strong bond to the deck of the bridge. Consequently, minimum bond strength of 1.6MPa to both the new concrete deck and the existing sandstone of the main structure were required.

The Eliminator system provides a tough, durable membrane that will be tolerant of site conditions, while offering an extended service life. Being based on advanced methyl-methacrylate technology enabled the system to be applied in a range of temperatures and climatic conditions, which meant that installation of the waterproofing could be carried out throughout the year.

ACKNOWLEDGEMENTS

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DAMAGE ASSESSMENT OF THE ROCK-CUT CHURCH IN GOREME OPEN AIR MUSEUM, CAPPADOCIA

Şerife Özata[1], E. Görün Arun[2]

[1] *Yıldız Technical University, Faculty of Architecture, Department of Architecture*
[2] *Hasan Kalyoncu University, Faculty of Fine Arts and Architecture*

***Abstract**: Maltese Cross Church is one of the rock-cut churches in Cappadocia, Goreme Open Air Museum. The museum is listed as a World Heritage Site by UNESCO and the rock structures in it have problems on their material and structure, which endanger their existence. The aim of this study is analysing the problems of a rock-cut church; Maltese Cross Church, in the museum and suggesting solutions for damages according to the data obtained with in-situ damage assessment, laboratory and in-situ tests which were done during the winter and summer season in 2014. Rock samples of the church were assessed to have their mechanical, physical, chemical, petrographic and mineralogical characteristics and the deteriorations of the rock material was searched. And, suggestions to overcome the problems are proposed.*

***Key words**: Maltese Cross Church, Rock-Cut Structure, Cappadocia, Goreme Open Air Museum, Physical-Mechanical-Chemical-Petrographic and Mineralogical Characteristics of Rock Material*

1. Introduction

Cappadocia is a place that is located in the Central Anatolia, Turkey. Cabinet Council of Turkey determined the borders of Cappadocia and announced the region as "The Privileged Region for Touristic Development" in 1973. The whole area of Nevsehir and Soganli Valley of Kayseri comprise the region (Fig. 1).

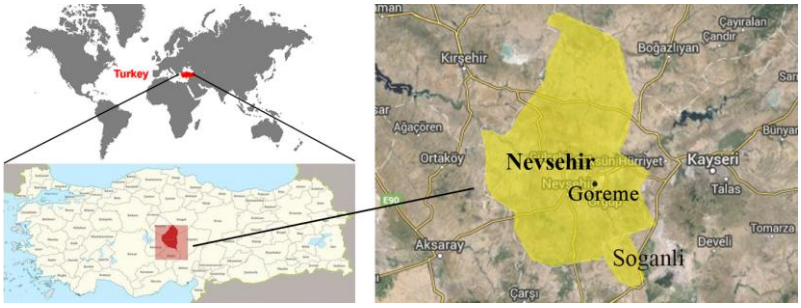


Fig. 1. Approximate borders of Cappadocia Region

Man-made carvings and structures are integrated with nature and history in that region for thousands of years. Three types of structures exist in Cappadocia according to

[1] Şerife Özata, Architect (MSc)/Res.Asst, Yıldız Technical University, Istanbul, ozataserife@gmail.com
[2] E. Görün Arun, Architect (PhD)/Prof. Dr., Hasan Kalyoncu University, Gaziantep, goruna@gmail.com

construction types of buildings' structural systems. These structures are masonry, rock-cut&masonry and rock-cut. The building in the scope of this study is a rock-cut church. Rock-cut structures were categorized according to their usage as religious, military and civil architecture buildings (Fig. 2). The church is in the religious buildings group as a temple and it has tombs, too.

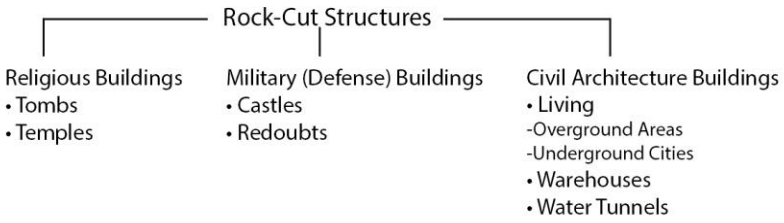


Fig. 2. Types of rock-cut structures according to their usage [11]

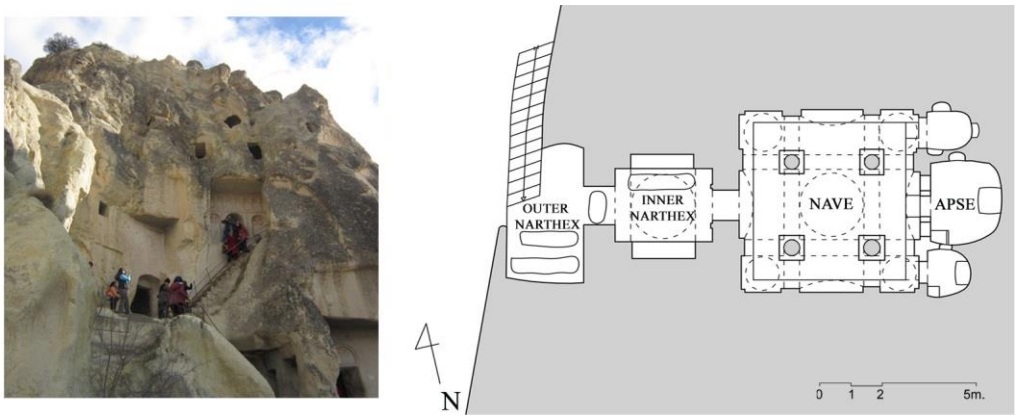
1. Goreme Open Air Museum and Maltase Cross Church

Goreme is a town where a part of the area is in the UNESCO World Heritage List, Göreme National Park and the Rock Sites of Cappadocia. "Korama" is the first known name of the town that is found in a document of 6th century. The name was changed as "Korama Matina", then "Maccan", ultimately the name of the town is changed as "Goreme" with the decision of Council of Ministers in 1975 [6].

Goreme is in the 3rd degree seismic zone and there was no earthquake which caused detrimental effects since 20th century [4].

After Cappadocia is listed as a world heritage, Goreme Open Air Museum and Goreme town became a touristic centre. The museum consists of rock-cut structures, which were built between 4th and 13th centuries to live the Monasticism. Massive rocks form a valley that house refectory, room of monks and nuns, churches, chapels, monasteries and living spaces carved in rock.

Nevşehir Museum Director, Murat Ertugrul Gulyazı, stated the church is called as Maltase Cross Church due to type of mural paintings in it, which have maltase cross shape and are more than twenty.



a) b)

Fig. 3. a) Façade and the entrance of the church b) Plan of Maltase Cross Church

Church is cross-planned in a rectangular (Fig. 3b). There are two graves in the ground of outer narthex and one grave in the ground of inner narthex. Five domes and four columns exist in the nave area. Church has three apses. There are more than twenty mural paintings in the church and all of them are Maltese cross shaped.

This church is one of the worth preserving rock-cut structures. To assess the deteriorations and damages on this structure tests for material characterization as physical, mechanical, chemical, mineralogical and petrographic characteristics of the rock were done. Preserving original material and suggesting compatible materials was possible with such material characterization.

2. Damages and Deterioration on the Maltase Cross Church

Cross-planned Maltese Cross Church consisting of outer and inner narthex, nave and three apses is carved into the rock like other churches in the Goreme Open Air Museum. The surface of the Church rock has biological colonization like lichens and mosses and there is exfoliation on some parts of the surface. Repair damage due to cement and inappropriate materials like railings exist on the stairs of the church (Fig. 3).

Discoloration is seen on the dome of the inner narthex (Fig. 4). There are three cracks and fragmentation on the SW wall of this narthex. There is weathering on the top of the wall, behind the arch (Fig. 5). Scratching type vandalism on the door of northwest (NW) wall of inner narthex and cracks around that door are seen in the BB section (Fig. 6). There are inappropriate materials hiding the original shape of the door.

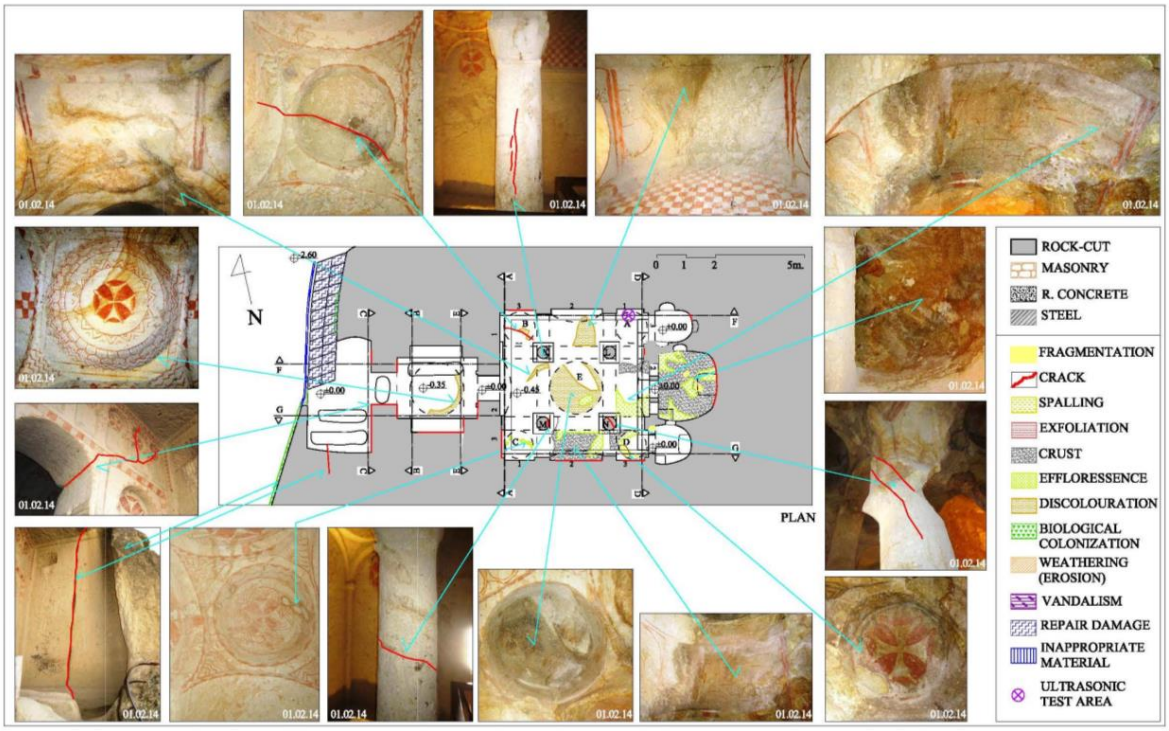


Fig. 4. Damages and deteriorations on the plan

There are damages like scratching due to vandalism on the decorated horseshoe arches that are near the entrance of the church. Cracks are seen on the entrance and on some horseshoe arches on the east wall of the outer narthex. Also, discoloration exists around the entrance door. These damages are shown in the CC section in Fig.5.

On the southwest (SW) wall of the outer narthex, there are discoloration, biological colonization, crust and crack, which continue throughout the wall (Fig. 5). In addition, there is a crack on the SW wall of the entrance, between inner and outer narthex (Fig. 4).

Discoloration and fragmentation exist on the south east (SE) wall of the inner narthex and cracks in different sizes are seen in the EE section in Fig.6.

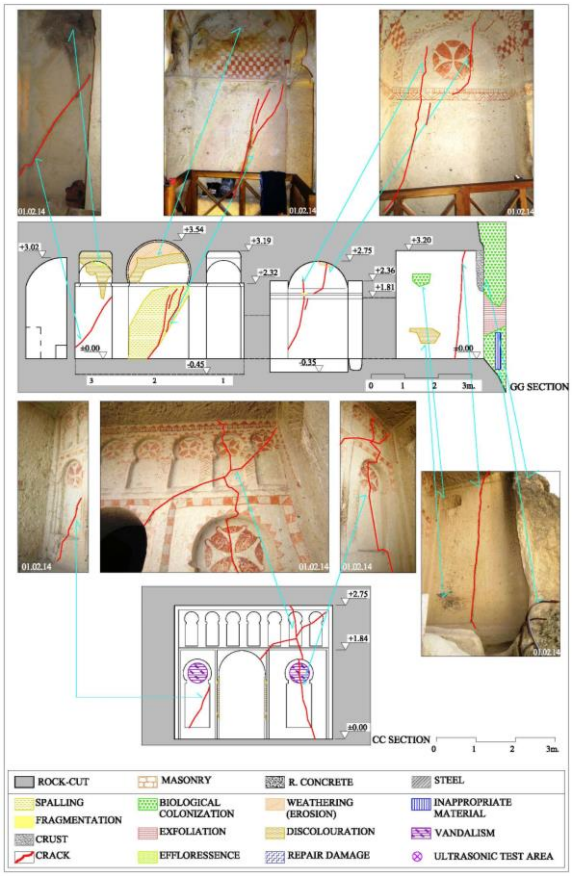


Fig. 5. Damages and deteriorations in the section GG and CC



Fig. 6. Damages and deteriorations in the section FF-BB and EE

There is no damage on the A dome of the nave but crack and discoloration are seen on the B dome. There is discoloration on the vault that is between A-B domes. Cracks exist on the K column and there isn't any damage on the L column. Efflorescence is seen on C dome and D dome has fragmentation, efflorescence and crust. Discolorations exist on the vault between B-C domes and on the arch between K-M columns. There are different sized cracks on the M and N columns. Fragmentation is seen on the N column. Efflorescence and crusts exist on the vault between A-D domes. There are discoloration and efflorescence on the E dome, which is in the middle of the nave (Fig. 4).

There are efflorescence, discoloration and crack on the SW wall of the nave which is numbered with 3 in the GG section view, Fig. 5. Weathering and discoloration are seen on the SW wall that is numbered with 2 in the GG section. Besides, there are spalling and 3 cracks on this wall (Fig. 5).

There is spalling on the northeast (NE) wall that is numbered with 1 and 2 in the FF section in Fig.6. Also, there are weathering and discoloration on the NE wall that is numbered with 2. Cracks and discoloration are seen on the NE wall that is numbered with 3 (Fig.6).

Discoloration is seen on the NE wall of the nave that is numbered with 1 and weathering exists on the NE wall, which is numbered with 2 in the AA section on the Fig. 8. There are discoloration, a crack and exfoliation on the NE wall that is numbered with 3.

The walls between the nave and apses are considered as outer walls of apses. Semi dome of the central apse that is seen in the DD section (Fig. 8) and on the plan has crust, efflorescence and fragmentation, and crack damages. There are efflorescence and discoloration on the outer wall of the central apse. When the picture in Rodley's [12] book

is compared with the current situation, there is no difference in deteriorations on the outer wall of central apse for 30 years (Fig. 7a-7b).



a) b)

Fig. 7. Outer wall of central apse a) in 1985 [12] b) in 2014

There is a crack on the east wall of the north apse (Fig. 4). On the outer wall that is between this apse and central apse, a crack and discoloration can be seen (Fig. 8).

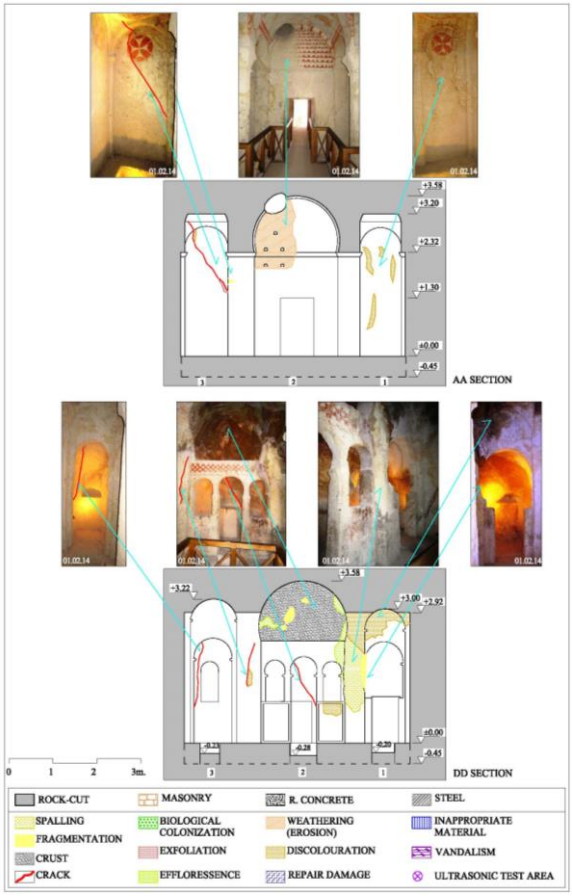


Fig. 8. Damages and deteriorations in the section AA and DD

There is not any damage on the ceiling and SW wall of the south apse (Fig. 4). Fragmentation can be seen on the edge of the entrance. Spalling and discoloration exist on the outer wall between south apse and central apse (Fig. 8).

The church does not have any damage on the floor in general. Wooden walkway and railings are built to protect the ground from weathering and erosion. Visitor circulation is done on the wooden floor. It is thought that this walkway and railings are compatible with the space.

4. Material Characterization of the Maltase Cross Church

Numerous on-site and laboratory tests were made for the assessment of the material characterization of Maltase Cross Church samples. In order to identify samples, each test sample was named as MHK-1, MHK-2 and so on.

4.1 On-Site Tests and Results

On-site measurements on the accessible spaces of the church were made during the February and July of 2014. Moisture and temperature measurements and ultrasonic pulse velocities (UPV) were taken on the rock surface.

Rock surface temperature (T, ^{o}C) and moisture (R, %) were measured with the Protimeter Surveymaster device. Temperature (T, ^{o}C) and relative humidity (RH, g/m^3) in the space were measured with thermometer and moisture meter. Value of the test results given in Table 1 is the mean values. Outdoor mean temperature in February is 0,9 ^{o}C, mean relative moisture is 68,3 g/m^3. In July, the outdoor mean temperature is 20,1 ^{o}C, mean relative moisture is 48,0 g/m^3. Surface temperature is higher than space temperature during the summer and winter in the church. Surface moisture value is lower than the space's relative humidity in winter, while it is high during summer (Table 1). Unlike these values, moisture value of the cracks on the nave walls and ceiling is between %70 and %100 during the summer and winter.

The device used for Ultrasonic Pulse velocities is as identified in ASTM D2845 [2]. According to values of UPV in Table 1, values of summer measurement is approximately four times higher than winter measurement. Based on this data, it is thought that pores of the rock material are full during summer than winter.

Table 1 Mean temperature, moisture, relative humidity and ultrasonic pulse velocity values

Place	Rock Surface				Space				Ultrasonic Pulse Velocity (m/s)	
	Mean Surface Temperature(°C)		Mean Surface Moisture (%)		Mean temperature (°C)		Mean Relative Humidity (%)			
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
MHK	5,60	28	31,8	37,16	5,3	25,8	52	34	214	906,9

4.2. Laboratory Tests and Results

Samples were taken from the top of the church. Samples' physical and mechanical tests were done in the Yıldız Technical University Building Material Laboratory. Chemical, petrographic and mineralogical characterization tests were completed by the Istanbul Technical University Geological Survey Laboratory team.

4.2.1 Physical- Mechanical Characterization and Results

Physical features as apparent and real density, compactness, total and open porosity of samples were found with the methods defined in TS EN 1936 [17]. Obtained results are shown on the Table 2. Saturation (open porosity / total porosity) was found with the values of open and total porosity [13]. Color values specified with Konica Minolta CM, defined with the methods of TS EN 15886 [15] and Munsell Color Chart.

One of the mechanical characteristics of samples, uniaxial compression stresses, were determined with the methods defined in TS EN 1926 [16].

Mean apparent density of the samples is 1,67 g/cm^3 and mean real density is 2,28 g/cm^3. MHK-2 sample has the highest open porosity with the amount of % 12,13 and MHK-3 has the highest total porosity with the %28,11. Also, MHK-3 has the lowest compactness with the percentage of 71,89. Saturation level is important for deciding on freeze-thaw resistance of materials. The saturation ratio under % 80 means durability against freeze-thaw cycles [13]. Accordingly, all samples have freeze-thaw durability. According to mean values, physical characteristics are similar (Table 2).

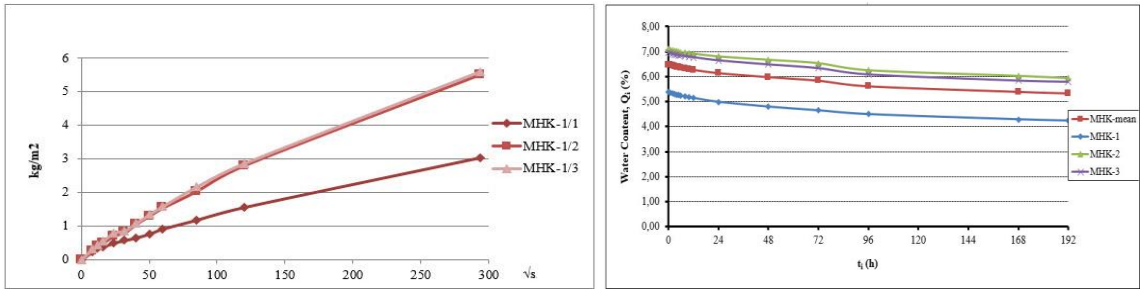
Table 2. Physical and mechanical characteristics of the samples MHK-1-2-3

Sample	Physical Characteristics							Mechanical Characteristic
	Apparent density (β,g/cm^3)	Real density (γ,g/cm^3)	Compactness (k, %)	Total porosity (p, %)	Open porosity (A_h, %)	Saturation (D_d, %)	Color (value)	Compression strength, MPa
MHK-1	1,73	2,28	75,88	24,12	9,92	41,12	orange-yellow	24,62
MHK-2	1,65		72,32	27,68	12,13	43,83	orange-yellow	22,41
MHK-3	1,64		71,89	28,11	11,64	41,40	orange-yellow	19,59
MHK-mean	1,67	2,28	73,36	26,64	11,23	42,16	-	22,21

Uniaxial compression stresses of samples change between 19,59 and 24,62 MPa. Mean strength is 22,21 MPa. According to Yıldırım & Gökaşan's [18] classification of rock compression strength, MHK is in the semi-hard rock group.

Capillary water absorption capacities of samples were found according to methods of TS EN 15801 [14] (Fig. 9a). Samples' water desorption (Fig. 9b) is specified with the method in the ICCROM Laboratory Handbook [8].

Capillary water absorption capacity (Qi, kg/m2√s) of samples were obtained from the graphic curves of the changing amount of water absorption of each sample from unit area (kg/m2). Ascending sort of samples' capillary water absorption capacity is MHK-1 (0,013) < MHK-2 (0,024) = MHK-2 (0,024). Open porosity values support this result.



a) b)

Fig. 9.a) Capillary water absorption of MHK-1-2-3 b) Water desorption of MHK-1-2-3

The changing percentage of water desorption of each sample in unit of time is shown on the Figure 8. The quickest water desorption ratio belongs to MHK-2 and MHK-3 and MHK-1 has slowest desorption. If the sample has low open porosity, its water desorption is low, too.

4.2.2 Chemical-Petrographic and Mineralogical Characterization and Results

Chemical, petrographic and mineralogical characteristics of MHK sample was investigated through thin section, x-ray diffraction (XRD) and x-ray fluorescence (XRF) analyses.

MHK macroscopic analysis: The sample has speckled appearance due to minerals. The sample has fine-medium grain sizes. Its hardness is 6-6,5 Mohs except matrix part. There was no reaction when aqueous solution with HCl dripped onto the sample as a sign of non-being or too little amount of calcite and dolomite [9].

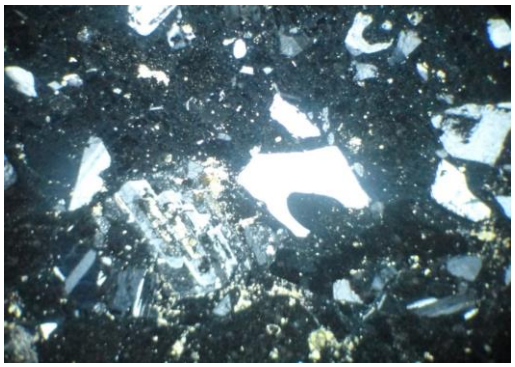


Fig. 10. Photomicrograph of MHK sample (double Nicol, width 4mm) [9].

MHK microscopic analysis: It contains approximately 30 percent of mineral-crystal and rock spall and 70 percent of matrix (binder). Sample has a characteristic of rhyolitic tuff. Aggregates consist of plagioclase, quartz and sanidine (a type of K- feldspar) and biotite. Most of the matrix consist of volcanic glass and pumice fragments. There are secondary conversions in matrix. Conversion of silica, mica, chlorite, zeolite and clay is common in the matrix (Fig. 10), [9].

The major oxide amounts of samples, were supplied with XRF analyses, are shown on Table 3. SiO_2 amount is the highest of major oxides in the sample. According to igneous rock type classification of Helvacı & Ersoy [7] if the rock has an amount of SiO_2 more than % 66 of total major oxide, it is an acidic (felsic) rock. Therefore, the sample is acidic. It is foreseen that albite (a kind of Na-Feldspar), quartz low, illite or amorphous minerals that contain silica constitute the SiO_2 (Table 4). Al_2O_3 has the second highest ratio. It is perceived that albite and amorphous minerals constitute Al_2O_3 ratio and the proportion of other oxides in the samples.

Table 3: Major oxides of the MHK sample [9].

Formula	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Ba	LOI
Concentration (MHK)	74,30	10,43	2,57	0,29	1,99	1,33	3,00	0,26	0,04	0,04	813 PPM	4,73

Mineral ratios of the rock samples of Ortahisar Castle, were obtained with XRD analyses, are seen on the Table 4. Illite and smectite have the feature of swelling due to water or cation exchange and illite may turn to vermiculite or montmorillonite. The illite ratio of the sample 5 percentage and smectite ratio is %10 (Table 4). Swelling is possible for this rock according to mineral ratios. Moreover, existence of quartz low indicates that the rock was formed at various temperatures below 573°−1000°C [1].

Table 4: Mineral ratios of the rock sample MHK [9].

Sample	Opal	Quartz	Albite	İllite	Amorphous Mineral	Smectite	Calcite	Dolomite
MHK	~5	~45-~50	~15-~20	5	~10	~10	2-3	3-5

5. Conclusions

Rock carvings constructed in the Cappadocia was implemented for thousands of years and many of them are still in use. Some of them are listed as World Heritage Site by UNESCO like Maltese Cross Church. Although many problems are observed in these structures, some interventions had even damaged the structure as they are made without a full investigation. Damages and deteriorations on these structures have to be minimalized and the rock-cut structures have to be conveyed to the next generations safely.

It is thought that UPV values is higher during the summer because of moisture retention features of swelling minerals in the sample or due to high moisture effect of visitor circulation. To minimize the type of deterioration like spalling, weathering (erosion) and discoloration on the rock structures, it should be checked if there is the cation absorbent minerals, water and/or high visitor ratio in the structure. If these damages occurred outside of the structure, they should not be intervened to protect oxidation shell, which occurs naturally [10]. Applying water-repellent agent to the rock surface is not beneficial for rock and may causes cracks [5]. In addition, surfaces with harmless lichens may be provided to mitigate spalling and weathering. Although mosses, algae and lichens cause biological deterioration on the rock-cut structures, removing them from the surface is not recommended. These biological formations especially lichens constitute only 1 cm thick in 300 years [19] save structure from spalling, exfoliation, crumbling and weathering.

To prevent the rock from crust and efflorescence, the presence of absorbent minerals in the rock-cut structure has to be investigated. Efflorescence develops if nitrate and sulfate salts are on the structure.

Cracks in the rock-cut structures are very significant damages in terms of rock falls and damages and deteriorations around cracks affect it adversely. The reason of cracks may be ground subsidence, intrinsic properties of the rock or natural disasters. In the church it seems that cracks are due to intrinsic properties and neglecting. The reason should be identified with endoscopic examinations if needed. After the cause of the cracks are identified, the condition of crack whether the movement goes on or stabilized should be monitored. If the cracks are moving, temporarily annex underpinning or partly grouting can be used. It is not recommended to use the materials which can corrode due to moisture like steel because its thermal expansion coefficient is not same with rock [20]. Bolting or pricking cracks with steel plaques is not recommended due to low hardness of rock and non-compatibility between steel and rock [21]. If there is risk of freezing water inside the cracks like in the church, it is suggested that cracks should be filled with a compatible mortar. After and before this process, cracks must be monitored. Fragmentation usually occurs around the cracks. Similar methods to minimize cracks can be used for fragmentation, too. Controlled separation has to be the last option for fragmentations.

To avoid the repair damage, intervention decisions should be taken under the supervision of experts. Materials with salty content should not be used in rock-cut structures. Limiting the number of visitors in places might be useful in reducing damage resulting from moisture.

Rock-cut structure is a structure type continued to function in Anatolia and all over the World. Rock-cut building regulations and standards must be established for transferring its value to the future generations.

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THE HABICHTSBERG AERIAL STEEL TOWER - FROM HERITAGE TO MODERN REQUIREMENTS

Hartmut Pasternak[1]

Brandenburg University of Technology, Cottbus, Germany

***Abstract**: This paper deals with a case study of a former TV tower, built before the Olympic Games in Berlin in 1936. After assessment of conditions (concrete foundations, steel construction) and after the analysis on a FE model, details about refurbishment and how to limit the horizontal deflections are given. The refurbishment of the aerial tower seems to be an economical and environmentally friendly solution. Now it is used by a mobile phone company.*

***Key words**: Template, formats, instructions, length, Times New Roman, 12 pt, Italic, Justified*

1. Introduction

The aerial tower "Habichtsberg" in Stülpe, Germany - south of Berlin - was designed and built as a part of the line between Berlin and Leipzig around 1935 for the Summer Olympic Games in Berlin, 1936. After Word War II till 1990 it was part of the Party and Eastern German Army microwave network.

The lattice tower was constructed mostly from angle sections with bolted connections and with an extension tube on the top of the tower. The original height of the structure reached 88 m. In the seventies the upper part of the tower was dismantled and the main struts of the lattice structure were partially strengthened. In the last years the tower was out of service.

Figure 1 shows the state of the structure with a height of 56 m in December 1995 before refurbishment.

The condition of painting is important and may indicate the extent of corrosion and cracks. Paint shad to be carefully checked around bolt heads. Connections and gusset plates are particularly susceptible to corrosion (Figure 2). These areas are not easily accessible, but frequently they are spots where corrosion begins (Figure 3). The diagonals of the structure are battened sections, critical is the condition of coating between the members and at the connections between the contact surfaces.

The bolt holes are critical areas for cracks and also for corrosion (Figure 4). Special attention had to be paid to the connection between the steel structure and the concrete foundation. The exposed concrete foundation can be examined for the presence of cracks and other signs of deterioration.

[1] Prof. Dr.-Ing. habil. Hartmut Pasternak, BTU, K.-Wachsmann-Allee 2, D-03046 Cottbus
E-mail: Hartmut.Pasternak@b-tu.de



Fig.1. The Habichtsberg tower

2. Preliminary Investigations – Assessment of the Existing Structure

For the first step, it was necessary to examine the existing structure very carefully. This general inspection involves the control of the geometry, the check of the physical condition of the structural members and the determination of the material properties.

The examination began normally with a visual inspection along the whole structure to detect any imperfections - either vertical or horizontal - of all members. The dimensions of the structure and the elements were measured.



Fig.2. Corroded structure

At the "Habichtsberg" tower a special examination team worked. The elements were checked usually in their original place but some elements and gusset plates were dismantled and checked extensively on the ground.

The material were have been identified by material testing.

The laboratory tests showed that the structural material of the tower is not weld able low-strength steel.

The investigations allowed to declare, that the tower was in a good condition. The bolted connections were not sensitive for fatigue, cracks couldn´t be detected. Only some members had to be changed or strengthened because of corrosion. The corrosion protection had to be generally renewed generally. The old platforms and access ladder were removed



Fig.3. Joint without gusset plate



Fig.4. Gusset plate

3. Analysis of the Structure

The aim of the analysis was to decide if the structure is able to fulfill the new requirements or some parts of it to be strengthened. For the Mobil phone company, 10 parabolic aerials had to be placed at the upper part of the tower, and for the future developing place for more aerials should be allocated. The governing requirement is the limitation of the deformations on the top of the tower.

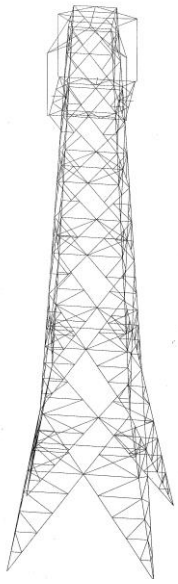


Fig.5. 3D-model of the structure

The structural analysis was performed with the computer program "Sofistik", using the structural geometry and material properties from the preliminary investigations. The

computed deformations of the tower were unacceptable. This led to the need of change of the supporting structure for the aerials. The final version of the supporting structure is working together with the original mast to resist the wind forces and to reduce the deformations on the upper part of the tower.

4. Constructional Details

Because of the non-weld - ability of the material of the old mast, the connection between the old and new structures had to be bolted. The details of the supporting structure for the aerials are shown in Figure 6. The bolt quality is 10.9 (prestressed) and 4.6 (normal) for other connections. It should be mentioned that this solution is very sensitive for the structural uncertainties and requires exact in-situ measurements.

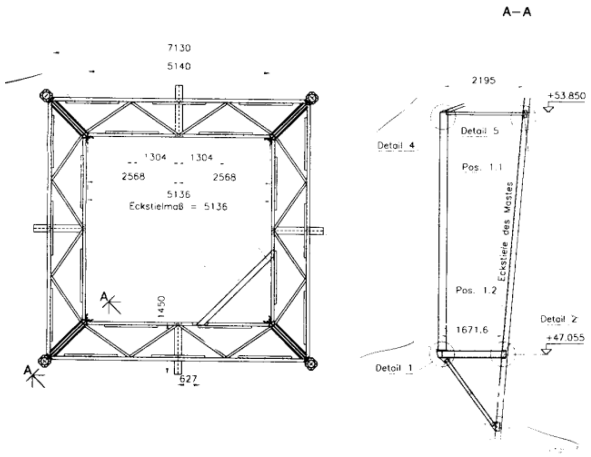


Fig.6. The supporting structure for the aerials

The new access ladder is an advanced construction: light, aesthetic, without safety-ring around the ladder, but safe. It works with a special rolling device with safety-belt, this device can roll up but one catch inhibits the accidental rolling down. (Figure 7-8).



Fig.7. The access ladder



Fig.8. Rolling device

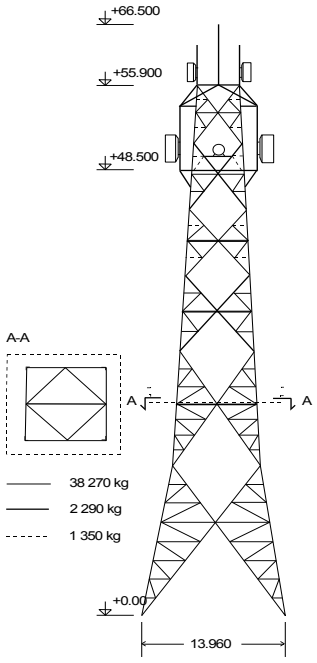


Fig.9. Scheme of the tower after rehabilitation

4. Conclusion

Figure 9 shows the "Habichtsberg" tower in its final form. The original structure is drawn with thin line, dashed lines indicates the structural members to be dismantled. The new elements and the bars to be strengthened are drawn with thick lines. The weight of the new elements are only 6% of the original structure. According to the approximate costs, the refurbishment of this old steel tower can be characterized - in spite of complicated constructional technology - as an economical and environmentally friendly solution.

RECONSTRUCTION OF ČEJVAN – ĆEHAJIN HAMMAM IN MOSTAR

Maja Roso Popovac[1], Suada Hasanagić[2], Sanela Klarić[3],

Univerzitet Džemal Bijedić, Mostar, Bosnia and Herzegovina
GD Arhitekt, Mostar, Bosnia and Herzegovina
International BURCH University, Sarajevo, Bosnia and Herzegovina

Abstract:

After the Old Bridge complex, reconstruction of Čejvan – Ćehajin Hammam in Mostar was the biggest reconstruction project after the war in 1992 -1995. It was an international project funded out of local, French and Turkish assets. As the Hamam was not in function for at least 100 Years, and that some parts of it were irreplaceably gone, it was impossible to reclaim it's original function, so it was reconstructed as an exhibitioner facility. Nevertheless, all original elements such as hipocaustum floor with heating channels were preserved. In this reconstruction we used only materials that were found in situ – stone blocks of same quality, mortars of same components, hand made bricks identical as the ones found in the vault, glass and lead. The condition of Čejvan – Ćehajin Hamam was very poor in the moment when the reconstruction started. Years of neglect, new surrounding structures ignorant towards Hamam and severe war damage left huge wounds on this beautiful monument. As this project started in autumn 2003 and it had to be finished until the opening of the Old Bridge on 23.07.2004, it was a hard task to do.

Key words: *Hammam, Mostar, reconstruction, Cejvan-Cehajin,*

1. Hammam in Bosnia and Herzegovina

Hammam as a building type and custom was brought to Bosnia and Herzegovina by the Ottomans. This was not the first bath-type structure in B&H – during the Roman period, as the country was rich in thermal wells of the highest quality, one of the settlement types was in vicinity of the Baths. From that period we have several big and important locations: Dolmavium in Srebrenica, Aqua S in Ilidža, Fojnica and many others.

The location, form and layout of Bosnian Hammams was similar as many throughout the Ottoman Empire, and although it had close connection to obligatory Islamic rituals of washing, it was also a place for social interaction. It was free for everyone, male, female, young, old, rich and poor. There were two types of Hammams: "tek-hamam" (single) and "čifte-hamam" (double). The "tek-hamam" women were allowed to come in during daylight hours, and men early in the morning or evening. In "čifte-hamam" parts for

[1] Maja Roso Popovac, Associate Professor PhD, Sjeverni logor bb; maja.popovac@unmo.ba
[2] Suada Hasanagić, , MBA architect, Rudanova 2a, suada.hasanagic@gmail.com
[3] Sanela Klarić, Assistant Professor PhD, Francuske revolucije bb, sanela.klaric@ibu.edu.ba

women and accessories for men were completely separate. Some baths in Bosnia and Herzegovina were complex, but in addition to the male and female parts, had a part for non-Muslims.

Hammams were paved with large stone slabs, domed or coved with barrel vaults made of tufa stone or brick, with lead cladding. On the vaults and domes there were small openings, usually hexagonal, octagonal or star-cutted and arranged in rows or circles, covered with massive, rounded, convex glass lid (an elephant's eye).

The main materials for the construction of the Hammam were limestone, travertine, brick and lime mortar mixed with keče (especially processed hair scraped from bovine skin) served as mortar. The walls were 70-155 cm thick, outside always somewhat thicker than in the interior.

Each hamam had at least three rooms: Šadrvan - Fountain (Apodyterium) that served as a waiting room and dressing room and there one could usually get tea or coffee, Kapaluk (Tepidarium) where the body is wash with soap and water, massaged and rubbed, hot room Halvat (Caldarium), in which the body was exposed to steam. In addition to these, each Hammam had three additional rooms: Hazna or water tank, and Ćulhan for heating and toilet. Bigger Hammams also consisted of Mejdan – big squared room for massage, depilation or resting.



Fig. 1. Arial view to Hammam and surrounding area from 1993.

2. Background of Čejvan – Čehajin Hammam Reconstruction

Full view to Čejvan Čehajin hammam was possible after the demolition of residential building from Austro-Hungarian period which was almost completely destroyed in the last war (1992-1995). It was not a rare example that large scale buildings from Austro-Hungarian period were interpolated into the small-scale fabric of Ottoman

settlement throw-out the Bosnia and Herzegovina cities. That was also a proof that the Hammam was already not in function at that moment.

After the devastating war in 1992-1995, Mostar, especially its Old Town, suffered major destruction. Not just that the Old Bridge, the symbol of Mostar was destroyed, but also the majority of the buildings on both banks of the Neretva River.



Fig. 2. Čejvan – Ćehajin Hammam in 2002, South façade



a) b)

Fig. 3. Čejvan – Ćehajin Hammam in 2002: a) main room; b) dome

The ruins of valuable historical buildings were outspreaded all around the city waiting for reconstruction. First years of that process comprehended the repair of smaller buildings, mostly by assets of the users and without the consultations with professionals in the field of reconstructions. Available materials were also inadequate, which in combination with lack of knowledge and need to speed up the reconstructions was devastating for many valuable structures. One of the problems was also the ownership – most of these buildings had more than one owner, and City governance and donors were not in the position to invest in that kind of arrangement. Looking from the professional side – the worst problem was the lack of satisfying basic documentation and projects. The archives were mostly lost in shelling and fires, many architects, historians and engineers

was depopulated to other countries during the war, so the situation for drafting the proper projects and deliver quality reconstruction was poor. The time was important so there was no space for proper investigations and archaeological survey in-situ, most of the projects were just an extension of sometimes inadequate interventions from '60, '70, and '80. Moreover, the jurisdiction, competency, and hierarchy was completely unintelligible. Before the war, Bosnia and Herzegovina, within the Federal Yugoslavia had several levels of monument protection institutions, with clear organization and hierarchy. After the '90's war, and Dayton peace agreement and its Annex 8, the Commission to Preserve National Monuments was formed on the state level. Nevertheless, two entities formed had Institutes for Protection of Cultural, Historical and Natural Heritage of Bosnia and Herzegovina. Instead of establishing good relations and distribute the jurisdictions and engagements, these institutions started the conflict that led to many misunderstandings, bad judgments and quarrels, that led to serious problems in the real situations.

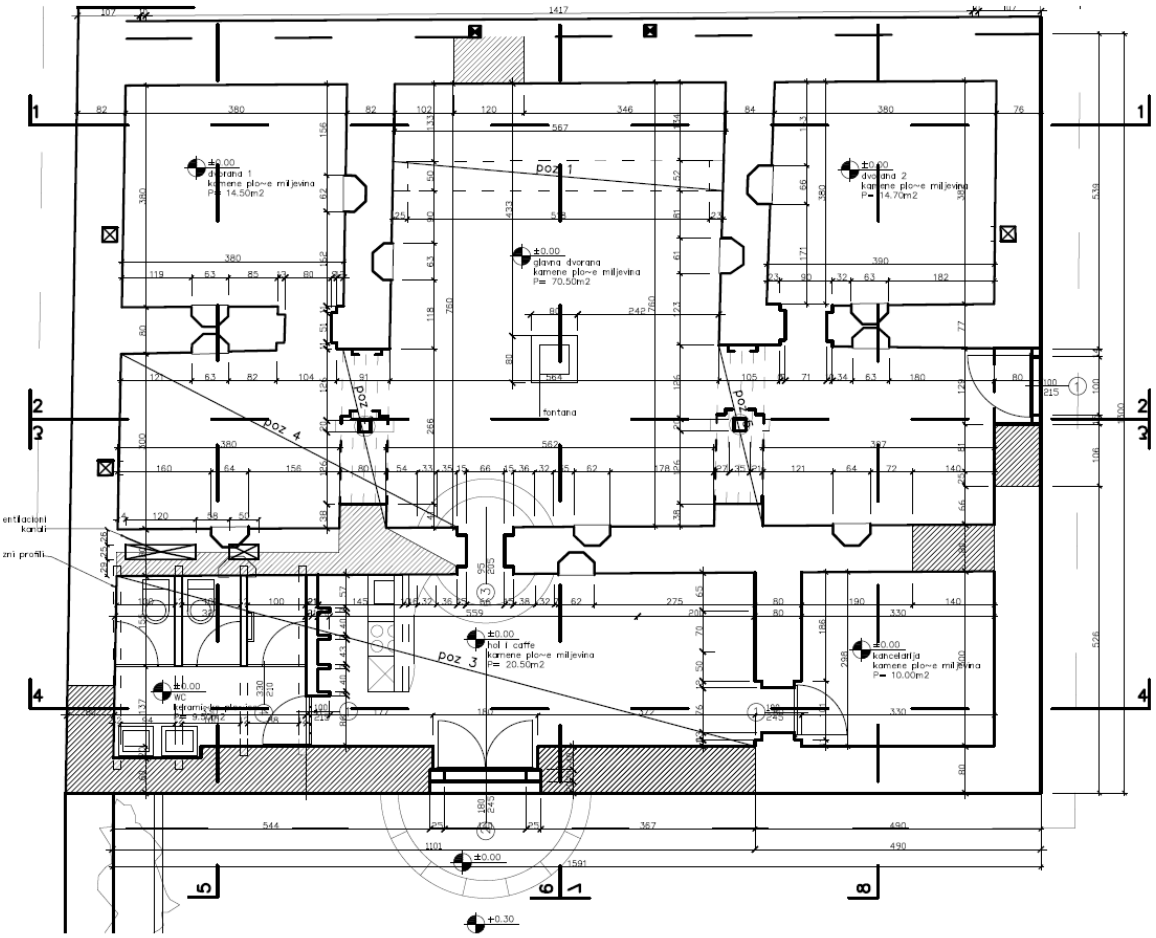


Fig. 4. Čejvan – Ćehajin Hammam - layout

Hammam of Mostar was one of the monuments that suffered a lot because of all these problems. Although the reconstruction in 1954 was unsuitable and inadequate for contemporary standards, it managed to consolidate and preserve the remnants of the structure for following years. Archaeological excavation were absent than, but unfortunately they were also not part of the survey before the last reconstruction. That led to many problems due to different theories between the experts: on one side UNESCO (with Mr. Bernard Fonqurnie as engaged expert) and Institute for Protection of Cultural, Historical and Natural Heritage of Bosnia and Herzegovina, and on the other side the Commission to Preserve National Monuments (with Mrs. Zeynep Ahunbay as engaged

expert). During the reconstruction, the most challenging part was to balance the relations between these parties and to keep the site functioning. At the end, although the Hammam is one of the most valuable and most important monuments in Bosnia and Herzegovina, it is not on the list of national monuments, but on the other hand it is a reconstruction performed under strict UNESCO regulation and patronage.

This was obvious example how politics and personal egos unfortunately can counteract professionalism and benefits for the heritage, which is our common human treasure that we all should nominate as first goal in process of protection.

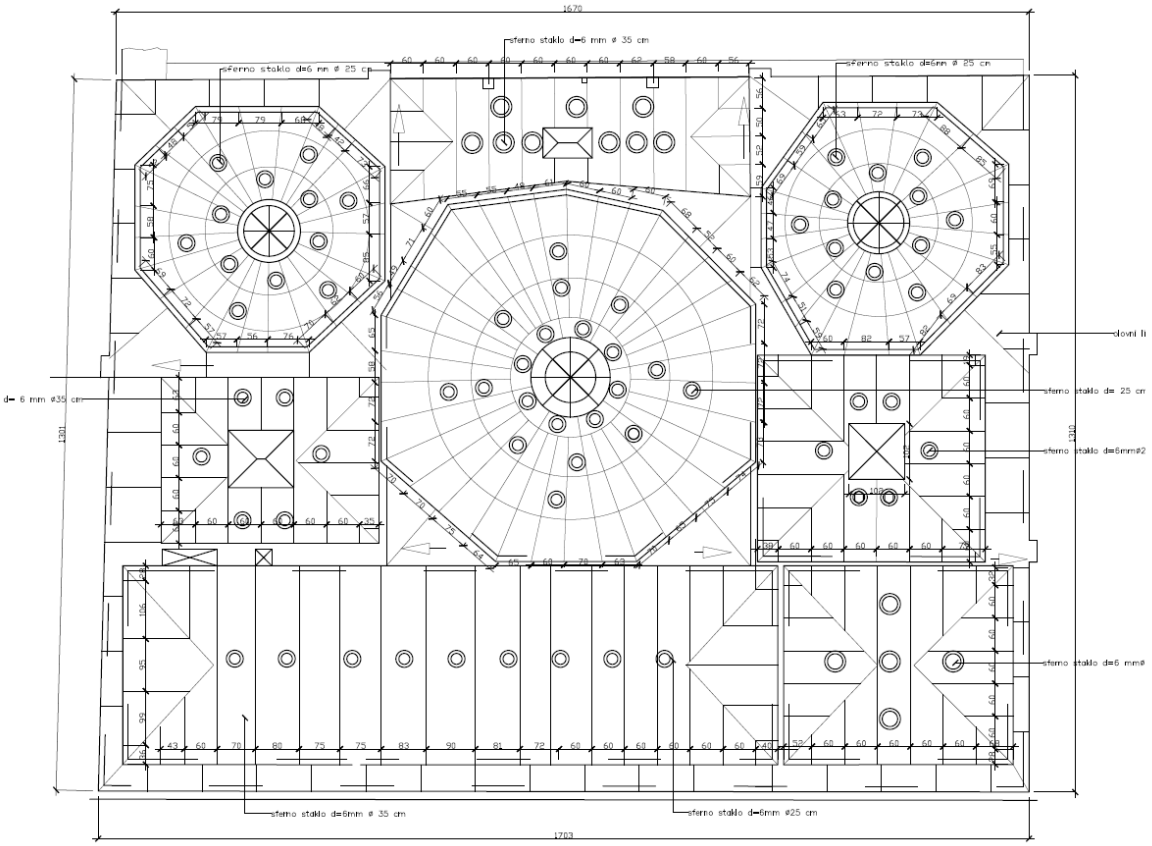


Fig. 5. Čejvan – Ćehajin Hammam – roof plan

3. Description of Hammam

3.1. Layout

The building of Hammam kept all of its basic layout elements except Hazna and Ćulhan at the north side. These parts were demolished probably during the 19th century and become part of a private estate on the north and west side. They are recognizable only in segments of the stone arch that was made of beautifully carved travertine and whose vertical dimensions was significantly lower than the rest of the building. By comparing with similar structures it was concluded that this space was covered by stone slab on slope roof structure. Due to the devastation of the west wall, ceramic water pipes, functioning on the principle of connected vessels, were visible.

South façade and two rooms on the south west were heavily devastated by the building from Austro-Hungarian period. By the survey of the pipes in the western wall, we could determine that small devastated room on that side was probably toilet with only cold

water available. That room was probably covered with groin vault made of tufa stone. Central south room was probably an entrance – no pipes were found in the walls and it was covered by barrel vault also made of tufa stone. From this room it was possible to enter the central space (Šadrvan), through the narrow doors.

Central space of Šadrvan was divided by the pointed arch to two separate ceilings - dome on bigger span, and small barrel vault on the north side. Entire structure of the dome is based on four pointed arches made of beautifully chiseled limestone. On three sides the arches were within the massive walls.

The layout of the Hammam was symmetrical – on the western and eastern side from Šadrvan we have two rooms with groin waults, from where we can enter two separate rooms on the north-west and north-east corners covered with domes.

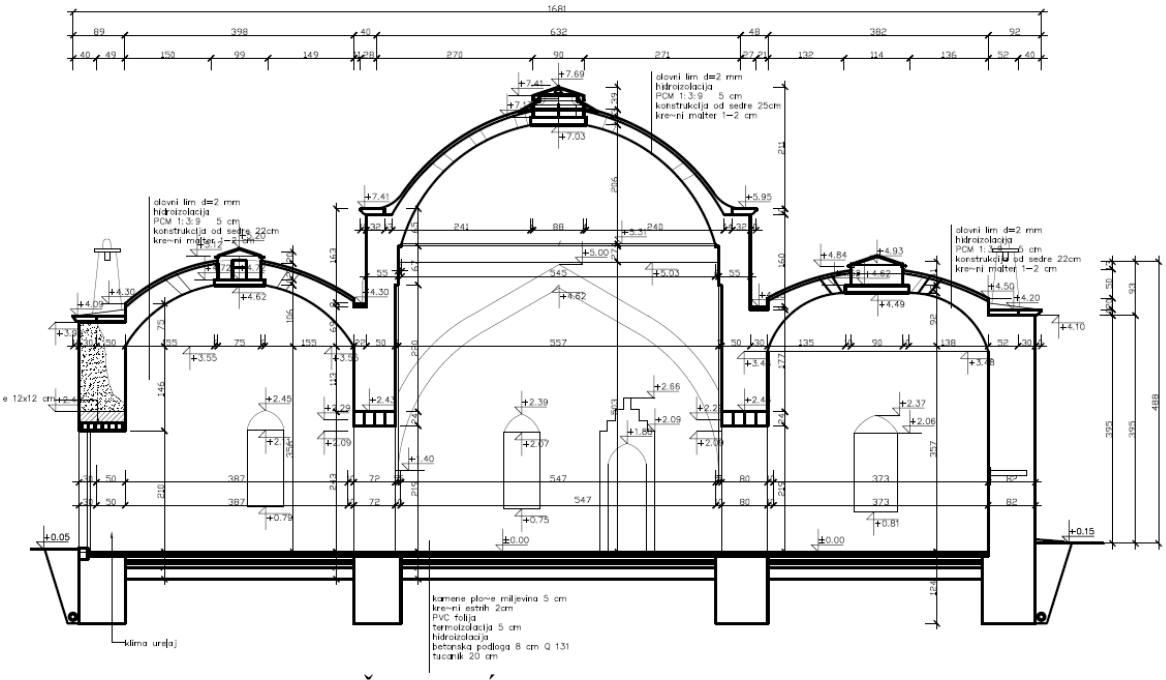


Fig. 6. Čejvan – Ćehajin Hammam – cross-section

3.2. Construction and Materials

Foundations of the Hammam were made of big limestone blocks and their depth is approximately 130cm and width 100.110cm. They are well preserved except under demolished parts of Hazna and Ćulhan.

The base of the entire structure is stone wall, 80cm thick made of chiseled blocks on both sides with filling of crushed stone. As the stone blocks on the outside face of the walls were not representative, it is most probable that it was plastered with lime mortar. All original mortars were lime mortars, cement mortar was used to consolidate and build elements from 1954 reconstruction.

Big dome and all barrel and groin vaults were made of tufa stone, and two small domes were made of thin brick blocks. North-east small dome was reconstructed in 1954 and was made from contemporary brick in cement mortar. Under all domes and vaults there is one row of thin brick that was placed on top of the stone walls.

The entire structure was originally covered with lead coat with convex openings,

but the lead eventually disappeared and in 1954 they covered the domes and the vault with cement mortar.

The interior of the Hammam was plastered with lime mortar except pointed arches that were made of quality limestone, painted white.

The floor of the Hammam was heavily destroyed. The survey showed that it had system of hypocaust heating with channels for hot air. The floor was paved with 8cm thick limestone pavement blocks.



a) b)

Fig. 7. Hammam in 2003: a) north-east dome; b) ceramic pipes

4. The Reconstruction

The project for the Reconstruction of the Čejvan – Ćehajin Hammam took into consideration archeological survey and current layout of the building. As it was impossible to reconstruct the two missing parts important for the functioning of Hammam (Hazna and Ćulhan), it was decided that the building is going to be reconstructed as multi-purpose facility. The main entrance to the building was from the south façade. Entrance hall was equipped with the installation for possible bar on the west part (water and sewage). The toilet was positioned in south-west room where it probably was originally. Other rooms were multi-functional, equipped with electrical installations and lighting. Because of the new allocation, the building was equipped with air-conditioning system, with distribution of air through the hypocaust channels. The main unit was installed above the toilettes.

The works on the Hammam started with careful cleaning of the demolished parts and removal of remnants of Austro-Hungarian structures within the body of the walls.

First it was important to consolidate the foundations on the south side. After that it was possible to start with masonry works on the south wall. Clear distinction of the new and old wall was made by performing the line between them in form of wider joint. After the wall was finished, the layer of thin bricks was laid as the base for the barrel vault made of tufa stone. With that, the Hamam was ready for the winter – the works inside of the Hammam could start. As the walls inside of the Hammam were partially unstable and some of the arches needed serious repair and change of the blocks, it was necessary to build the scaffolding and centering for the arches.



a) b)

Fig. 8. Hammam in 2004: a) repaired pointed arch in main room; b) entrance barell vault

The domes and vaults were repaired and covered with thin lime mortar coat under the lead shroud. Special convex glass elements were ordered for the openings on the roof, and above the central dome we installed the skylight similar to the ones on same structures.

The important issue was also the capillary moisture we noticed in all the walls, but as the Hammam is now surrounded with other structures, it was possible to install the drainage pipes only on small part of the west walls. That is why it was decided to plaster the bottom part of the walls with lime mortar with addition of bauxite earth – in order to make waterproof layer at least from the inside. The entire interior of the Hammam was plastered in traditional way by the thin layer of lime mortar. The floors were paved with 8cm thick slabs of tenelija limestone (same as the one used for the Old Bridge).

5. Conclusion

Instead of being one of the most popular reconstructions in post-war Mostar and Bosnia and Herzegovina, the Reconstruction of Čejvan – Ćehajin Hammam was put to margins because of unsolved relations between two institutions. That is why the Hammam, twelve years after the reconstruction, still did not make its way to the List of National Monuments in B&H.

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THE STRUCTURAL DEFINITION OF EIFFEL'S BUDAPEST NYUGATI PALYAUDVAR, LINKED BY ITS ARCHITECTURAL DESIGN

Prof.Dr.architect Yeşim Kamile Aktuğlu[1]

Dokuz Eylül University/Faculty of Architecture/Department of Architecture/ Structure-Construction Branch/İzmir/TÜRKİYE

***Abstract**: Budapest Nyugati Palyaudvar is one of the four railway stations in Budapest. It is in the West part of Budapest, Hungary. Its iron-steel framing system is a unique one from the point of steel architecture through its structural solution, and it has to be learned with its all details. It was constructed by Eiffel Company and opened in 1877.*
In the paper, the structural definition of Eiffel's Budapest Nyugati Palyaudvar, linked by its architectural design will be explained through its main framing system, with column, beam and roof detailing. Also its site plan will be discussed to catch how Nyugati Train Station is still in use from the point of sustainability.

***Key words**: Nyugati Railway Station, Budapest, Gustave Eiffel et Cie., Polonceau Truss*

1. Introduction

Nyugati Palyaudvar is the Western Railway Station in Budapest, Hungary. It stands up at the intersection of Szent Istvan krt. From Margit Bridge over Duna, with Terez krt. in the same direction and in the other direction, with Bajcsy-Zsilinszky from Szent Istvan Bazilika and with Vaci ut. The front entrance of Nyugati Railway Station is from Terez krt.(Fig.1), while the other entrance from the main road is from Vaci ut [1].

August de Serres planned the station and the Eiffel Company built it. There was another station, built in 1846, in the same place. It was the end station of the Pest-Vac, the Hungary's firt railway line, and later it was demolished. The present station was opened on 28th of October in 1877 [2]. Nyugati Palyaudvar is in the service just for 139 years.

The new plan was matched with the old plan to be able to use the tracks for trains[3]. The gable-shaped central hall spans 42 m.[4], and at both ends it has glazed facades, surrounded by brick pavillions with traditional ornaments [5] and also supported by iron structural elements especially in the corners of the pavilions.

2. Structural features of Nyugati Railway Station

Nyugati Railway Station has several buildings with different function at the same site. There is a central hall for trains and masonary pavillions around this central hall for passengers to depart from Budapest or to arrive to Budapest.

[1] Prof.Dr.architect Yeşim Kamile Aktuğlu, yesim.aktuglu@deu.edu.tr



Fig.1. The front facade of Nyugati Palyaudvar from Terez krt.
(photograph taken by Yesim Kamile Aktuglu, 05.09.2011)

2.1 Central Hall

The main part of the railway station is its Central Hall, which has a height as 25 m. and a width as 42 m. and a length around 189 m. as covered area over train tracks. There are 16 portal frame with Polonceau trusses at both sides of the gabled-shaped roof [3] [5] [4].



Fig.2. The view of Central Hall of Nyugati Railway Station, from the entrance
(photograph taken by Yesim Kamile Aktuglu, 05.09.2011)

2.1.1 The Columns

The columns of the portal frame is built with two parts, which one part is the real iron column in I- form, cladded by prefabricated iron pieces, up to the starting point of the Polonceau trusses. The thickness of the frontal flange of I-form, facing to inner hall, is more than 100 mm. where the width of the next flange touching with the wall behind, where it stands up, is wider than the frontal flange. And the name of the company which constructed the columns is on the base of this column composition as G.EIFFEL & Cie. (Fig.3 and Fig.4) that was found as a limited company under the name of "Gustave Eiffel at Cie." [6].

There are double rainwater pipes at both sides of the columns under the cladding for the column (Fig.5). In every two columns, one has these pipes.







Fig.3 The name of the company over the cladded iron
(photograph taken by Yesim Kamile Aktuglu, 20.08.2014)
Fig.4 The place of the name of the company over the base of the column omposition
(photograph taken by Yesim Kamile Aktuglu, 20.08.2014)
Fig. 5 Double rainwater pipes to down at both sides of the column
(photograph taken by Yesim Kamile Aktuglu, 20.08.2014)

2.1.2 The Polonceau Truss

The Polonceau Trusses are letting the inside space having a clear view through the most economical way to solve the structural system. The upper chord of the Polonceau system is a lattice beam, to make the structural solution be stronger and more transparent. By using the Polonceau truss, it is being let to be easy to follow the load transfering through the structural elements, which saves the unneeded expenses also. The cables are connecting with the eave level supporter of the beam with a dog-bone connection, letting the whole system an easy movable feature (Fig.6 and Fig.7).

The Polonceau Trusses were spaced at around 10.5 m intervals and firmly braced by lattice girders in between the lattice girder top chords of Polonceau truss, under the solid roof top and then by knee-braced lattice girders over the lattice girder top chord of Polonceau truss, when the roof cover was transparent to get daylight in and also in the area, from covered to transparent, knee-braced lattice girders were used (Fig. 8).

2.1.3 The Front Wall of the Central Hall

The Front Wall of the Central Hall is having two parts. One part is the masonary part up to height around 1.0 m as a parapet wall or a basement wall for the glass part over up to the roof top.



FIg.6 The end part of Polonceau truss over column
(photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig.7 Dog-bone connection of the Polonceau Truss
(photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig. 8 Polonceau Truss with lattice girders in between the
trusses and also knee-braced lattice girders over the trusses.
(photograph by Yesim Kamile Aktuglu, on 05.08.2011)

This wall materlal seems to be sandstone, due to its damaged views. There are nine parts to compose the glass facade, to be carried by columns in between these parts. These nine parts also mainly 4 parts, carried by stronger mullions than the others, form the next two parts inside these 4 parts. Finally in every piece, there are 8 partitions to compose it. The top part of these glass facade is having arch mullions for every 4 segment to define better. And at the bottom of this glass wall, there is an ending lattice girder with crossings in every segment of the girder to close the whole surface in a stable manner. What is very interesting is the balcony part, in the mid of this facade, both inside and outside. In the outside part, its function is to cover the entrance as a shed. For this roof balcony is from one brick pavilion to the next brick pavilion at the ends of the glass facade and also the last egde is being carried with at least 10 columns, ending over the colomns on the walls, this part is supporting the whole facade in a very magnificent way of structural solution through architectural design to create a very transparent welcome for the passengers to come in. Also the daylight is able to go inside directly. The outside columns are also giving a service to be a vertical way to down for rainwater.

For the inside part of the glass facade, there is a balcony, continues along the facade and also turns over the masonary walls of the brick pavilions at both side of the glass entrance facade. Even though the width of the balcony is around 1.0 m., there are columns in rectangular form to support the balcony and also there are supporters over the every facade columns to the bottom of the slab of the balcony.

At the top of the glass facade, there is a Vierendeel Girder as the top part of a Portal frame for the whole glass entrance wall. There are also bracings inside the every part of Vierendeel Girder. There are two Vierendeel Girders, from the columns on the walls of the brick pavillion to the top point of the roof, from two inclined surfaces, where later they are carried by the Polonceau Trusses (Fig.9).



Fig. 9 The total view of Entrance facade from inside,
with the Vierendeel.Girder at the top of the facade
(photograph by Yesim Kamile Aktuglu, on 05.09.2011)

2.1.4 Entrance Facade for Trains

This entrance facade for trains is also a glass facade, having a structural system, different from the front entrance facade for passengers. There is a deep solid I-beam from smaller brick tower pavillions at the end of the central hall at both side, spans 42 m. with a two columns at the distance around 10.5 m. from the tower pavillions. In this facade, there are balconies at both sides to stabilise the system better, as pillow beams in a manner at both sides. Additionally, there is a real Portal frame with Vierendeel beams starting from the solid beam, passing the span (Fig. 10).



Fig. 10 The Entrance facade for the trains from inside of the central hall
(photograph by Yesim Kamile Aktuglu, on 05.09.2011)

2.1.5 Lateral Walls of the Central Hall at both sides

There are walls in between the columns at around 10.5 m intervals, constructed by sandstone up to around 1.0 m height from the ground level, till the ground floor windows, having I beams as lintel to span the openning. Behind the damaged parts of the sands, it is seen that the Stones are connected to each other with lead. And also behind the damaged plasters, it seems they are double I-beams and also there may be three I-beams connected to each other over the window openings. Also it has the same structural solution for the first floor windows. This is the pattern for the outer perimeter walls surrounding the whole complex. Here there are I-beams at the first floor level to span the opennings, then the rest is a complete structure, composed by mullions for windows and doors altogether (Fig.11, Fig 12 and Fig.13).

Above all, there are transparent glass walls up to the eave of the gable-shaped roof in 5 sections. All sections have 2 smaller sections, may have a width a little more than 50.0 cm. in distance. At the top of these glass windows, composed by 5 parts, having an arch ending, just under the Vierendeel Girder, continuing at the top of these arched window mullions, along the side walls (Fig. 14 and Fig.15).

For there are two storey high masonary buildings for housing the waiting rooms and other facilities, at both longitudinal sides of the area, there is no need for additional support unless for the three columns having no masonary building behind.

What is excellent is these supporting double iron supporting frames outside of the buildings, seen from the garden. The defined road map for the loads coming from the anex of the building through Polonecau truss to the columns, then from the columns down to the foundations through the supporting framing can easily be seen with bare eyes, from far away (Fig.16).





Fig.11. The columns and the walls behind the columns (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

Fig. 12 The I-beams over the opennings (photograph by Yesim Kamile Aktuglu, on 20.08.2014)





Fig.13 Lead connection between the sandstones. (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

Fig.14 Top windows with Lunette design, under the Vierrendeel Girder (photograph by Yesim Kamile Aktuglu, on 20.08.2014)





Fig. 15 The top windows inside one interval from column to column, in 5 pieces, with 4 sub-pieces to compose Lunette-windows, and all with the Vierendeel Girder at the top of these windows, (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

Fig. 16 The supporting structural frame outside the wall, is in connection with the column, to get the loads coming through the Polonceau truss inside (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

2.2 Other Parts of the Railway Station, mainly brick pavilions

There are additional buildings besides Central Hall, constructed with iron framing together with masonary system. The roof heights are also supporting the whole (Fig.17).

There are brick pavilions, especially at the corners of the central Hall and nearby the Central Hall, where there are corridors, connecting the spaces in a covered manner, with an iron-framing system, similar to waffle system for the ceiling level. The outer wall of the corridors are totally constructed by glass, supported iron structure and also there are some supporters, for the longitudinal glass walls also (Fig.18).

Ticket Office Pavilion has cantilevered sheds for protecting the entrance, from rain and sun in a way. This part is hanged from the columns going up for the perimeter walls (Fig. 19). In the inner part of the Ticket Office Pavilion, there are iron columns, connected by iron beams in arch-form. The large openings for windows and doors are supported with iron circle designs to get the stability of the perimeter wall around (Fig.20 and Fig.21).





Fig.17 The view of the roofs behind the complex (photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig.18 The corridors in front of the waiting rooms at right (photograph by Yesim Kamile Aktuglu, on 20.08.2014)







Fig.19 The outside view of the ticket Office (photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig.20 Inside of the ticket Office with iron coloumns in front of the wall, connected with iron arch-formed beams at the top (photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig.21 The perimeter wall of the ticket Office (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

The canopies for the passengers are cantilevered towards both sides from a double beam composition, connected with columns, composed by 2 rectangular columns, with sheet metal pieces to act as one column. And the cantilevered roof are carried with 6 iron bars hanged from every column top also (Fig.22).



Fig.22 Tha canopies for the passengers
(photograph by Yesim Kamile Aktuglu, on 20.08.2014)

The oldest part of the Nyugati Railway Station has an entrance canopy over the columns with small diameters to carry the roof (Fig.23). There is a shed to protect the entrances for the station, in between this old pavilion and the next pavilion in Terez krt. (Fig.24). This protection has transparent parts to get the daylight down (Fig.25). When the long cantilevered shed touches the brick pavilion in the front line, this adds stability to the shed, because the total structure is in the mid of masonary walls, even though it is hanged from the columns of the building, behind (Fig.26).





Fig.23 The oldest part of the complex, the entrance canopies are being carried by slim iron columns, connected with the core through iron castellated beams.
(photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig.24 The cantilevered and hanged sheds to protect sunshine
(photograph by Yesim Kamile Aktuglu, on 20.08.2014)





Fig.25 The cantilevered sheds also get daylight
(photograph by Yesim Kamile Aktuglu, on 20.08.2014)
Fig.26 The sheds are connected between two brick pavilions, which are supported with iron framing, exposed. (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

The difference between the roof levels over the central hall lets the fresh air in. With the next lower roof level of the nearby building and then the lower roof level of cantilevered shed give a nice picture not only to see all structural elements in the same row, and also the architectural balance can be easily seen (Fig.27 and Fig.26).

At the main entrance from Terez krt. to the Central Hall, the solid web design of the beams over and between the slim columns is both logical and also very aesthetic. For there is a solid web, with flower design, in the Vierendeel Girder, it prepares a very stiff compositon, where the next beams under this Vierendeel Girder, having less solidity, and more metal sheets to compose a beam with and arch as lover flange with hidden arch-beam pieces in between upper and lower flanges (Fig.28).





Fig.27 The differences between the roof levels of the Centrl Hall let the fresh air in and also the differences betwen the height of the buildings give a nice view for the total frame from the point of architecture. (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

Fig.28 While the solid web with flower figures to compose the girders, both for the vierendeel and also for the beam, lower flange is in the arch-form over the slim columns, is supporting the whole structure, also it offers a delicous architectural touch for the entrance stage. (photograph by Yesim Kamile Aktuglu, on 20.08.2014)

Even though there are more details about structural solutions of the Nyugati Railway Station, these are written above, are the main ones.

3. Conclusion

The Nyugati Railway Station is a very important landmark, not only from the architectural point of view, but also through its structural solution.

When Camille Polonceau invented Polonceau Truss, it was in 1839 [7].

When Gustave Eiffel built Nyugati Railway Station, it was in 1875-1877.

With a very logical truss solution and with a very carefully solved details by the contractor, today we are very happy to get the service of Nyugati Railway Station by ourselves in every moment, while we are in Budapest.

To compare the building complex with other examples, some books, [8] [9] were read to see the similarities with other built examples and also whether there are some more infos about Nyugati Railway Station.

What is seen in today's frame of this built example , is it has an encyclopedia about how to build a central hall with iron framing mainly and also halls with masonary additionally, to compose a balad, nice to hear always to give the most correct inspirations for the designers, who want to plan and to build the Landmark of the Universe.

The Central Hall with its non-seen structural solution, can easily get the daylight in, even though the time may be very late (Fig.29, Fig.30 and Fig. 31). This is the utmost conclusion.





Fig. 29 The front facade, from inside. (photograph taken by Yesim Kamile Aktuglu, 20.08.2014)
Fig. 30 The back side facade, from inside. (photograph taken by Yesim Kamile Aktuglu, 20.08.2014
Fig. 31 Entrance from Terez krt. (photograph taken by Yesim Kamile Aktuglu, 20.08.2014)

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AND

First when I was in Budapest in September, 2011, to present a paper in EUROSTEEL 2011, for I know that Gustave Eiffel built a Railwy Station, I decided to meet with Nyugati Railway Station and I did meet with it with pleasure. I got 377 photographs on 5th of September in 2011.

Second, to know more about Nyugati Railway Station also, I was 2 weeks in Budapest to make researches. I got 699 photographs on 20th of August in 2014.

Mainly I did learn more and more about the structural solution through 1076 photographs of mine.

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НАПРАВЛЕНИЕ 5

**Европейски директиви за съхраняване на културно историче-
ското наследство на континента.**

TOPIC 5

**European Directive for preservation of historical cultural heritage
on the continent**

КОНСТРУКТИВНАТА АВТЕНТИЧНОСТ НА АРХИТЕКТУРНИЯ ПАМЕТНИК В СВЕТЛИНАТА НА СЪВРЕМЕННИТЕ ВИЖДАНИЯ В ОПАЗВАНЕТО НА НАСЛЕДСТВОТО

Елена Малджиева

Университет по архитектура, строителство и геодезия - София

Abstract: *Дискусията върху разбирането на автентичността на паметника, особено интензивна след публикуването на Документа от Нара, често се представя като избор между материя и форма, наложен от съвременното състояние и обхват на наследството, или като доктринален спор за подхода към материалните и нематериалните стойности и за отношението "оригинално – автентично" в опазването на наследството. В тази дискусия на конструкцията на сградата се придава по подразбиране смисъл на част от материята, като се запазва, но и значително се банализира научно-историческата й стойност като документ.*

Предлага се едно виждане за конструктивната автентичност на паметника, основано върху разглеждането на конструкцията в два аспекта: на нейната взаимовръзка с другите елементи на паметника, разглеждан като архитектурна творба, от една страна, и на собствените й материални и нематериални характеристики – от друга страна.

Така дефинираната автентичност позволява насочване на проучванията и анализите, а така също на избора на намеса в сградата към запазване на възможно най-висока степен на автентичност на конструкцията и на архитектурната творба като цяло.

Стремежът към съхраняването на конструктивната автентичност на сградата има особено значение в контекста на някои специфични ценности на българското архитектурно наследство.

Key words: Authenticyty, Preservation of architectural heritage, Building construction, Conservation, Structural restoration.

Въведение. Въпросът за конструктивната автентичност – основания и актуалност

Въпросът за конструктивната автентичност на архитектурния паметник представлява част от общата проблематика на автентичността в опазването на архитектурното наследство през XXI век.

В европейската практика проблемът се изостри особено във връзка с голямото по обем и разнообразно по функция архитектурно наследството от XIX и XX век, което трябва да бъде адаптирано към нови функции и различни съвременни нормативни изисквания. При това, особено за по-старите паметници от периода, проектирането на намесите се извършва по твърде различни методи в сравнение с прилаганите в периода на строителството на сградите – налице е обособяване на

архитектурното и конструктивното проектиране, новите поколения специалисти са обучавани предимно по съвременни конструктивни системи и т.н.

Анализът на извършените намеси изявява множество негативни явления в съвременната реставрация [1] и на фона на развитието на традиционните основи на опазването поставя въпроса за приспособяване на реставраторската теория към променящите се реалии.

В световен план, инспириран от опита с култури и наследство извън Европа, се появи възгледът, че опазването на наследството се основава на съответстващо „управление на промените" и на нарастваща роля на местните общности в определянето на опазваните ценности. При това не всички обекти, признавани за наследство могат да бъдат опазвани чрез цялостно съхраняване на тяхната форма и субстанция, а задачата на реставратора е така да управлява преобразуванията, че да бъдат запазени избрани ценности, които даденото наследство представя, или които са разпознавани от съвременните общности като ценности в дадения елемент на наследството [2].

Дискусията върху разбирането на автентичността на паметника, особено интензивна след публикуването на Документа от Нара за автентичността (1994), често се представя като избор между материя и форма, наложен от съвременното състояние и обхват на наследството, или като доктринален спор за подхода към материалните и нематериалните стойности и за отношението "оригинално – автентично" в опазването на наследството. В тази дискусия на конструкцията на сградата се придава по подразбиране смисъл на част от материята, като се запазва, но и значително се банализира научно-историческата ѝ стойност като документ.

Въпросът за конструкцията като съществен елемент на архитектурния паметник не е нов. Той се разисква в процеса на прецизиране на реставраторските методи, положени върху принципите на Венецианската харта. В развитието на вижданията, отразени в различни документи на ИКОМОС, може да се забележи тенденция към придаване на известна самостойност на проблемите на носещата конструкция, като се започне от заключенията на III, IV и VII Генерални асамблеи на ИКОМОС [3, 4, 5] и се стигне до специално посветения на това документ от 2003 г. [6]. Тази самостойност следва да се приема с необходимата степен на условност. Тя не означава изолиране на носещата конструкция извън контекста на сградата[1].

Основание за такъв специален интерес към конструкцията на паметника са именно методите на цитираната по-горе широка адаптационна намеса в паметниците от една страна, а от друга – фактически придаваната на конструкцията стойност на документ (информационен източник) за „специфичните за времето си строителни технологии"[2].

Включването в обхвата на опазваното наследство на уникални в конструктивно отношение обекти със зални пространства и покрития с големи подпорни разстояния, в които конструкцията придобива формообразуваща роля, също предполага търсенето на специфично съдържание на конструктивната автентичност и респ. на критериите и методи за нейното установяване и опазване.

Конструкцията на сградата като документ (информационен източник)

Тук е мястото за нашия опит за съвременна, отнесена към носещата конструкция на сградата, интерпретация на основни, отдавна възприети в теорията на опазването категории.

[1] Срв. т. 1.5 от ICOMOS Charter – Principles for the Analysis, Conservation and Structural restoration... [6].
[2] Срв. т. 1.3, пак там.

Въведените от Алоис Ригл и допълнени от Валтер Фродл [7] категории ценности на паметника могат да бъдат отнесени (с необходимата условност) към носещата конструкция на сградата. Особено съществена от гледна точка на автентичността е историческата (по Ригл) и научно-историческата (документалната – по Фродл) стойност на носещата конструкция на сградата.

Ясно е, че най-висока стойност на документ има запазената оригинална конструкция, от която като „видимо материално запазено доказателство" [8] могат да бъдат прочетени технологичните и конструктивните методи. Това разбиране подкрепя стремежа към максимално съхраняване на оригинала, което често се води до консервация на елементите и пренасяне на товарите върху заместваща конструкция. Но тук възниква въпросът каква стойност на документ има една конструкция, която не функционира? По дефиниция носещата конструкция на сградата поема и пренася в земната основа всички натоварвания, породени от различни въздействия. С други думи тя има собствена функция и действие, което може да бъде проследявано исторически и представлява свидетелство за поведението ѝ (като интегрална част на сградата) по отношение на специфични за мястото външни въздействия (земетръс, вятър и т.н.), а оттам и информационен източник за традиционно установени начини за поемане на тези въздействия.

Аспекти на конструктивната автентичност

Значението на носещата конструкция на архитектурния паметник като информационен източник може да се търси в аспекта на две нейни качества:

– на интегрална част и съществен компонент на архитектурната творба (паметника);

– на условно самостойна система.

Съществуващата сграда, разглеждана като архитектурна творба, представлява реализирано единство на конкретни архитектурно-естетически, утилитарен и градостроителен компоненти[3], взаимообвързани по специфичен, еднозначен за сградата начин. Тези компоненти и взаимодействия се проявяват на пространствено (структурно) и детайлно (дискретно) ниво.

На пространствено ниво компонентите се проявяват чрез пространствено-структурните си характеристики, а взаимодействията между компонентите се изразяват в степените на автономност, съподчиненост или тъждественост (съвпадение) на структурите.

На детайлно ниво архитектурно-естетическият, утилитарният и градостроителният компоненти се проявяват чрез присъщите им материални носители и параметри в конкретната реализация. Взаимовръзките между компонентите на това ниво се изявяват в ролята на отделния материален носител или параметър в осъществяването на качество извън компонента, за който е присъщ. Така взаимодействията на детайлно ниво също изявяват автономност, съподчинение или съвпадение.

В този модел на сградата значението на носещата конструкция (съществена част на градостроителния компонент) и на нейната автентичност за стойността на паметника лежи в полето на взаимодействията.

Взаимодействието, взаимната обвързаност между архитектурно-естетическия и градостроителния компоненти изявява органичността на единството композиция – конструкция в степента, в която съществува в реализирания архитектурен обект, чрез конкретните измерения на осъществяването му.

На пространствено ниво те се демонстрират като:

[3] Съгласно даденото преди векове и актуално до днес определение на Витрувий.

– степен на съвпадение/припокриване на основните пространствено-композиционни елементи с конструктивно-структурни единици, а оттам

– автономност на пространствената композиция по отношение на конструктивната структура.

На детайлно ниво се изявяват като:

– тъждественост на конструктивни и композиционни елементи и детайли и

– композиционно въздействие на материали и строителни технологии.

Взаимодействието между сградостроителния и утилитарния компоненти изявява обусловеността/зависимостта на сградостроителните решения от утилитарните изисквания и функционалната гъвкавост на конструктивната структура като следствие от признаци:

На пространствено ниво:

– степен на съвпадение на функционалната и конструктивната пространствени структури;

– съотношение функционална единица – конструктивно-структурна единица (конструктивен модул).

На детайлно ниво:

– конструктивно осъществяване на функционалните връзки;

– реализиране на утилитарните изисквания чрез определени материали и системи; присъщи на конструкцията материали, детайли, системи като елементи на средата[4].

Условно отделената от сградата носеща конструкция има самостойно значение на документ с научна (и научно-историческа) стойност в два аспекта:

– със собствените си основни структурни и строително-технически характеристики;

– с начина, по който работи в конкретните условия на средата, т.е. с поведението си спрямо различни, характерни за тази среда въздействия. Това поведение, наблюдавано и описвано, представлява ценен материал за изучаването на конструкциите, а така също за създаването на адекватна нормативна база.

Основните, съществени по отношение на автентичността, характеристики на носещата конструкция на сградата са:

– конструктивна структура и конструктивна система;

– конструктивна схема[5];

– собствена структура, материали и особености на изпълнението на основните вертикални и хоризонтални елементи на носещата конструкция;

– връзки и взаимодействия между отделните елементи;

Първите две характеристики, да ги наречем атрибути – конструктивната структура и конструктивната система, са определящи за начина, по който се разпределят усилията в системата. В зависимост от вида на елементите, по които протичат усилията – линейни или повърхнинни, конструктивната структура се определя като „клетъчна – решетъчна", а конструктивната система като „безскелетна (с носещи стени) – скелетна". Конструктивната система и особено конструктивната схема определят начина, по който конструкцията реагира на приложените върху нея сили, и начина, по който се осъществява нейната пространствена устойчивост.

Съществена в това отношение е и материалната еднородност или разнородност на вертикалните и хоризонталните носещи елементи, според което носещата

[4] Този аналитичен модел на сградата е разработен в труда „Адаптиране на масиви сгради ..." [9]

[5] Приемам определенията според проф. П. Петров [10]

конструкция на сградата се определя като „моноструктурна – полиструктурна"[6]. Останалите характеристики се отнасят до материалите и детайлите и имат отношение към автентичността на субстанцията.

Степени на конструктивна автентичност

Изведените дотук характеристики на конструкцията, както и компоненти и взаимодействия на архитектурната творба, позволяват да се очертаят степени на конструктивната автентичност, респ. степени на нейното опазване в контекста на ценностите на паметника. Те са инструмент за анализ както на конкретната носеща конструкция, така също и на методите за нейното усилване и/или възстановяване. Наличието на автентични атрибути[7] и взаимодействия може да се разглежда като критерий за автентичност заедно със съхранеността на оригиналната субстанция.

Не подлежи на съмнение, че носещата конструкция на изцяло запазения архитектурен паметник има най-голяма стойност като документ с научно-историческо значение и най-висока степен на конструктивна автентичност. В него са съхранени всичките й основни атрибути и нейната интегралност в архитектурната цялост е автентична.

Следваща, по-ниска степен на автентичност притежава паметникът, в който са реконструирани отделни елементи на носещата конструкция, но са запазени нейните основни атрибути. По този начин в целостта на сградата са налице автентични взаимодействия на пространствено ниво и нарушени (в различна степен) взаимодействия на детайлно ниво.

Със значителна загуба на автентичност от гледна точка на обсъжданото по-горе функциониране на конструкцията на паметника се отличават обектите, в които оригиналната конструкция е запазена като субстанция, но не поема носещи функции, те са възложени на заместващи елементи.

Най-ниска (или нулева) степен на конструктивна автентичност притежава паметникът, в който носещата конструкция е изцяло заменена с нова конструкция с атрибути различни от тези на оригинала. Такъв е например случаят когато една скелетна сграда е пресъздадена като сграда с носещи стени. Краен вариант е т.нар. „фасадизъм", практикуван при исторически сгради с носещи стени, в които се въвежда скелетна конструкция, а съхранените носещи стени не участват в поемането на товари от преустроената (не я наричам реставрирана!) сграда.

Възприемането на предложеното дотук разбиране за конструктивната автентичност на паметника задава определени насоки на реставраторската практика по отношение на:

– проучването и документирането на паметника;
– избора на методи за усилване на носещата конструкция и/или нейни елементи;

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[6] Възприемам определенията на В. Борушевич [11], който разделя масивните сгради на полиструктурни и моноструктурни, като основна характеристика на конструктивния организъм.
Сградите с моноструктурен конструктивен организъм се отличават с това, че всички главни носещи елементи са изпълнени от материали с еднакви или много близки физикохимични характеристики и образуват монолитна конструктивна структура. Силите в този тип структури се предават плавно от елемент на елемент, дори тогава, когато някои от елементите престанат да действат.
Сградите с полиструктурен конструктивен организъм са създадени от материали с различни физически качества и химически свойства или от еднородни материали, но носещите елементи не образуват монолитен организъм. Към тази група спадат структурите със зидани подпори и подови конструкции, чиято връзка с подпорите не може да се третира като монолитна (напр. гредовите подови конструкции). Отделните конструктивни елементи на тези структури не са достатъчно твърдо свързани, поради което могат независимо да се преместват и деформират.

[7] В този случай „автентично" означава „същностно, присъщо на оригиналното".

– реконструирането на изчезнали или компрометирани носещи елементи.

Проучването следва да извлече и опише основните признаци на носещата конструкция и нейното място в целостта на паметника на пространствено и детайлно ниво. В резултат от него ще бъде изведен моделът на конструкцията, ще бъде изяснено и описано неговото конкретно осъществяване в сградата и в зависимост от състоянието ще се определи предмета на опазване с цел да бъде съхранена статическата достоверност на конструкцията, а с оглед на това ще се определи необходимостта и допустимостта на мерките за възстановяване и/или усилване. Това означава, освен всичко, че изследването на конструкцията трябва да се извършва съвместно с архитекта реставратор, а инженерът конструктор трябва да има съответната за такова изследване нагласа и задълбочено познаване на историческите конструкции.

Необходимо е също разработването и прилагането на методи за анализ, включващи и резултатите от историческо проучване на поведението на сградата през периода на нейното съществуване.

Решенията за усилване и/или подмяна на конструктивните елементи трябва да запазват основните атрибути на носещата конструкция като цяло и нейното място в целостта на архитектурната творба. В случаите, когато се прилагат заместващи или разтоварващи конструкции, което означава невъзможност за запазване на атрибутивната автентичност, следва да се търси минимално нарушаване на пространственото взаимодействие на запазената конструкция, т. е. необходимо е прилагане на диференциран подход към конструктивната автентичност.

При всичко това се подразбира, че изборът на нова функция и/или програма на преустройството ще бъде в съответствие с аналитично определените възможности на обекта като цяло.

В по-широк план опазването на конструктивната автентичност на паметниците предполага допускане на известни отстъпки в прилагането на съвременни нормативни изисквания.

Някои проблеми на конструктивната автентичност в българското архитектурно наследство

Пример за необходимостта от прилагане на очертания диференциран подход към конструктивната автентичност са нашите масивни сгради от края на XIX век до 20-те години на XX век. Те имат обща архитектурно-историческа принадлежност – към еклектичния историзъм, и обща сградостроителна определеност – сгради с предимно носещи стени и характерни за периода елементи и строителни изпълнения. Не на последно място тези сгради са част от материалната култура на обособен исторически отрязък – на формирането на българската държавност след Освобождението и на възприемането на европейски културни образци.

Строежите до края на 20-те години на XX век представят цялата европейска функционална типология в подобно на западноевропейското разпространение на типовете според големината на градовете и според разположението в градските зони.

Първите дипломирани архитекти и инженери, които работят в България, са чужденци, а първото поколение български архитекти, които започват работа в началото на XX век са възпитаници на западноевропейските архитектурни академии. И едните и другите по най-естествен начин пренасят европейските архитектурни и строителни образци и култура – някои своевременно, други с известно закъснение.

Достиженията на европейските строителни технологии навлизат и се усвояват у нас в относително кратък срок. Прилагането им започва от големите държавни строежи, проектирани и надзиравани от чужди специалисти, и постепенно се разпростира до еднофамилните жилищни сгради. Това са полиструктурни

конструктивни организми с предимно клетъчна структура, образувана от носещи, преобладаващо тухлени стени и двустранно подпрени подови и/или покривни конструкции. Конструктивните схеми са предимно напречни и смесени. За разлика от последвалото дългогодишно и почти повсеместно приложение на стоманобетонния скелет, тези сгради представят богата структурна типология:

1. Едноетажни и етажни сгради само с носещи зидове – еднофамилни и многофамилни жилищни сгради, общежития и казарми, училища, болници, учреждения, някои ранни банкови сгради.

2. Етажни сгради с носещи зидове и елементи на скелет в партера – жилищно-търговски сгради, вкл. доходни здания и хотели. Елементи на този тип смесена структура срещаме и в някои училищни, учрежденски и банкови сгради.

3. Етажни сгради с носещи зидове и елементи на скелет в отделен тракт – банки, гари, клубни и други сгради със салони.

4. Етажни сгради с външни носещи зидове и скелетна конструкция във вътрешността – производствени сгради и складове.

5. Едноетажни еднопространствени сгради с външни носещи зидове и зално покритие – производствени сгради, търговски хали, култови сгради и др. Към този тип могат да бъдат причислени и сградите със зални покрития в отделен тракт.

Тези сгради са носители на научно-исторически ценности от областта на сградостроителството, които не са разкрити, защото не са целенасочено търсени. Те могат да бъдат търсени като:

– Общоевропейски стойности – запазени цялостни решения или елементи като исторически свидетелства на европейската строителна техника, доколкото образците, които са пренасяни на българска почва през тези десетилетия, принадлежат към добрите постижения на европейското строителство. Разглежданите сгради представляват и ще представляват ценно свидетелство за поведението на заимствани от немско-австрийската школа конструкции в сеизмичните условия на нашата страна. Този аспект също може да бъде разглеждан като научна стойност на обектите в общоевропейски план.
– Ценности за българската строителна история като например първи за страната и/или просъществували относително кратко изпълнения на конструкции и елементи. Такива са пруския свод със стоманени или дървени греди, плоските подови конструкции със стоманени греди от типа под на Клайн, първи стоманени ферми, първи изпълнения с елементи на стоманен скелет и др.
– Свидетелства за влиянието на българската строителна традиция при усвояването на европейското сградостроителство, разглеждани като българско, но и като общоевропейско достояние. Възприемането на нова строителна технология в сравнително кратък срок е факт, който заслужава да бъде разгледан в светлината на българската строителна традиция с нейната конструктивна и технологична специфика, такава каквато е била и каквато е пренесена от Средновековието. Липсата на системни изследвания на тясно сградостроителната проблематика на нашето строителство от разглеждания период засега не дава възможност да се идентифицират местни технологични особености, но също така не дава основание да се отхвърли хипотезата за наличие на такива.

Казаното дотук означава, че на конструктивната автентичност на нашите паметници от края на XIX век до 20-те години на XX век може да се придаде специфично научно-историческо значение на документ и тя трябва да бъде опазвана във всичките й аспекти според посочените по-горе насоки, като се започне от избора

на адаптационни изисквания, адекватни на конструктивните възможности на сградата. В случаите, когато запазването на оригиналните елементи на конструкцията е невъзможно, трябва да се запази автентичността на нейните атрибути – на полиструктурна система с носещи стени с двустранно подпрени подови конструкции.

Така ще бъде запазено едно богатство на нашето архитектурно-строително наследство, за да може да бъде оценено преди да бъде загубено.

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ARCHITECTURE, IDENTITY AND CULTURAL SUSTAINABILITY IN CONTEMPORARY SERBIA

Nadja Kurtović Folić[1], Nataša Živaljević Luxor[2]

University of Novi Sad[1], City planning Institute of Niš[2]

***Abstract**: Distinctive architecture is usually considered as one of the crucial elements for identifying peoples and places. It has now, around the world, been recognized as one of the forces to determine history. Built environments still reflect the conceptual, spatial and physical construction of communities, though genuine correlation between particular forms of architecture, places and people can no longer be taken for granted. If we try to analyse how definitions of culture might be differently expressed in the urban context, it is obvious that it is a problem of more formalized and self-conscious architectural attempts to include tradition and modernity, as well notions of broader collective identity. But, the issues of conservation and heritage in Serbia are rendered complicated by the allusive definition of the national architectural history. The paper deals with the problem how to ensure that built environments do not become battlefields where national and cultural identity is tangibly negotiated in a context of globalization, population growth and migration, and technological progress.*

***Key words**: Architectural force, collective identity, cultural sustainability, built heritage, Serbia*

1. Introduction

Through the history the relative autonomy and sometimes isolation of local cultures and traditions meant that affiliated buildings could readily be identified with particular places and groups of peoples. Until now most locations in Serbia, however, have been overlaid by expressions of ideology and political changes, religious intolerance, nationalism, transition in different social and cultural fields and consumerism. Built environments have become battlefields where national and cultural identity is vulnerable and is tangibly negotiated in the context of transition, globalization, population migration growth and technological change.

To identify the key issues in the field of cultural heritage, it is necessary to point out that Serbia has a diverse topology and complex history, resulting in a rich and valuable cultural heritage. Historically, some parts of Serbia were mainly developed in different ways and at

[1] Dr Nadja Kurtovic Folic, Faculty of technical sciences, University of Novi Sad, Trg D.Obradovica 6, 21000 Novi Sad, Serbia, nfolic@uns.ac.rs

[2] Natasa Zivaljevic Luxor, PhD student, City planning Institute of Nis, 7.July 6, Nis, Serbia, nluxor@gmail.com

different times under the strong influence of the civilization of ancient Rome, Byzantine, Turkish, and the Austrian or the Austro-Hungarian Empire cultures. Society in Serbia is pluralistic one, so that in addition to the Serbs, there are ethnic groups of Albanians, Hungarians, Muslims, Roma, Croats, Slovaks and other minorities, which have their own identity and cultural heritage. Serbia is one of the independent states that emerged after the breakup of Yugoslavia, and is still suffering the consequences of this act. The recent history of the country abounds in conflicts and problems in various fields, social development, economy, politics, culture, religion, society ethics, and especially in the field of treatment of cultural heritage. All this and a number of other influential factors which are acting in the field of cultural heritage could be generally clearly observed, and in some segments partially implied problems of different nature, from general to regional and to local. They can be divided into issues relating to the state of cultural heritage in physical terms, the status of cultural heritage in the context of culture, cultural heritage status within the state, and political relations in the country, the legal status of cultural heritage, and cultural heritage implementation in spatial, urban and rural planning. [2]

Built environments, especially those with heritage values, provide locations for complex negotiations between multiple communities, as they draw on their own cultures and histories as well as adopting elements from their surrounding and distant environment and the wider world. Analysing the built environment today the conclusion could be drawn that it remains integral to the conceptual, as well as the spatial and physical skeleton of communities, whether these are connected by kinship, shared experience, civic or national identity iconography, but straightforward correlations between particular forms of architecture, places and peoples can no longer be kept in compact form. As built environment constantly continue to develop, however, identity remains contested, as does the notion of cultural sustainability in relation to architectural values. The problem which has to be solved is how architecture can be engaged with its traditional role as the embodiment of cultural symbolism, constantly updated with new cultural flows, while at the same time remaining open to constant reinterpretation, rearranging and reimagining of its physical body, its spaces and its surroundings.

2. Context of discordant and dissonant heritage

The heritage architecture has become the subject of numerous speculations, but still remains the subject of attention when the strategy of sustainable development of a country is considered. In such strategy, usage of building heritage is most frequently viewed in the domain of tourism. Offering of the heritage as a commodity for rest and entertainment cannot ignore the fact the society can confront the consequences of discord of the heritage. The remembered past, can be dissonant to certain people because it is distorted, unpleasant, displaced or which has lost the properties of the heritage. This topic is in fact one of the most complex ones in terms of heritage usage, and it would require much more extensive explanation than available by the scope of this text. For the purpose of a clear identification of the problem, a brief explanation of basic groups can be provided here. [1]

2.1. Distorted **(changed)) heritage**

If we adhere to the point that heritage is neither complete nor authentic evidence of the past, then it is clear that evidences of the past are always distorted in some way. The extent of distortion depends on for whose benefit and how the distortion was performed. Distortion can be performed by selecting which structures would survive and which will be removed, as judged by the conservationist and as dictated by the market. The tourist market, for instance, will be more selective for its reasons, and it will employ different criteria for that selection, than those applied by everyday, domestic users as can be seen on **Fig. 1**.



Fig. 1. Belgrade - Hotel Radisson blu consists of old, but not the most valuable, mill, and new glass tower which covered one of the most important representative building of Modern architecture

2.2. Unpleasant heritage

The heritage a society wishes to use in commercial tourism is usually represented as a "credible" history of progress, harmony and success. In addition, public political heritage is used for providing legitimacy to the current society and its hegemonistic values, by featuring appropriate personalities – heroes and places with such characteristics. It is based on the fact that the long history of Europe is dominated by wars, pogroms, persecutions, migrations, and acts of vengeance between nations, classes, races and religions. [5] History of almost any contemporary country and Serbia is an outstanding example, bears evidence about wild rage, blind prejudice, destructive hatred and malicious cruelty of individuals, groups and states. Those horrible acts had to remain recorded through architectonic, literal and human memory; therefore, concentration camps are also an integral part of human heritage same as monasteries and churches, battlefields and medieval music festivals, and locations where individuals were tortured or murdered just as monuments to gods, kings or wise people are, as a rule, part of the cultural heritage. Management of such heritage is very sensitive and complex, and largely neglected in our country as on **Fig. 2**.

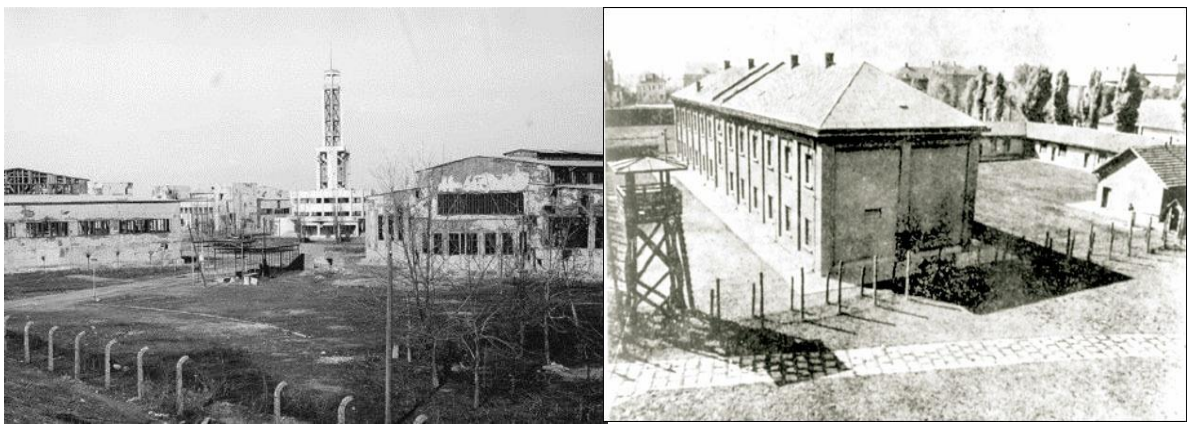


Fig.2. a) Old Belgrade fair was transformed in 1941 in concentration camp for Jews, Serbs and Roma-today in process of devastation; b) Complex Crveni krst in Nis was installed as concentration camp in 1941 for communists and un-loyal citizens-today is memorial museum but completely neglected

2.3. Displaced heritage

During history, the peoples of Europe have been very mobile, they migrated and sometimes returned to their original habitats, so that "tide and ebb" of forces, populations and ideologies left behind itself material and cultural relicts which do not reflect the real symbolism of a location. The changes in the dominant ideologies act by confronting the

memories of previous values with current interpretations. The best example for this is the experiences in the parts of post-communist Europe, which differently treat the heritage of the age of socialism. After the fall of communism, there were several ways the individuals remembered this period. Many preserved symbols or placed them into a new context, while the others tried to revive them through various presentations and manifestations. On the other hand, many other tangible examples of heritage (artistic objects, but also architectonic structures), become moveable, that is, are moved or displaced as spoils of war, object of trade, collectors' trophy, into often very distant areas with completely different culture, relationship towards heritage and attitude towards the value of the displaced heritage. (**Fig.3**)



Fig.3. Dudik – detail of Memorial park dedicated to those who fell in WW II was completely dilapidated during the war between Serbs and Croats, and is renovated in 2016 as historical site of the Republic of Croatia

3. Potential forms of loss of heritage

Possession of heritage by an individual, group or a nation means that some other individuals or nations lose it. All heritages represent the choice of various pasts, where some segments have been chosen, while some others have been not. Homogenous national heritage, as a rule excludes certain social, ethnic or religious groups, by neglecting or distorting their different or specific historical development by the dominant community. Whether such a position can be maintained or even insisted upon as desirable one, depends on the assessment of how much such a procedure is needed for the national common goal or on the ability of the dominant nation to create an image of itself in comparison to the others. By all means the result of such procedures represents depletion of the total potential of heritage of a country. Although majority of the countries declares that they do not implement the mentioned policy of the relations towards heritage, such procedure is often implemented in practice, so the loss of a part of heritage seems unavoidable. The only question is what and whose heritage does not fit the prescribed norms and attitudes, and how the groups whose historical heritage will be omitted are selected, and what the consequences of these actions will be like at the moment, and what in the future. [5]

The historical opinions, made upon the long term experience and monitoring of events mostly in European countries represent the side effects in comparison to the general care and management of heritage in those countries. An independent observer needs only to find an answer as to what part of heritage has been selectively omitted and whose history has been blurred with it. In those countries without wars, considerable migrations for a long time, and in which the state borders mostly outlined homogeneous national or religious entities, those actions which throughout history erased the heritage which was

seen unfitting for creation of an ideal image of the country in question are nowadays almost forgotten. It suffices to mention the relationship towards the Jews and their cultural heritage in Spain and England to corroborate the previous statement with facts. In the recent decades, economic and political changes in central and Eastern Europe brought about change of the heritage role, which served for various purposes: for providing legitimacy to creation of new political, social and religious relationships, for the construction and tourist trades development, etc. In certain countries, there was an intensive affirmation of heritage, and it was rehabilitated in rapid and quality way, while on other countries, conversely, heritage was mainly selectively destroyed, and the principles of heritage protection were deliberately suppressed to the margin of political, social and economic interest.

Poland, Czech Republic, Slovakia and Hungary can serve as examples of the countries in which heritage as a whole, and particularly building heritage was directly employed for political rapprochement of those countries to the European Union. Their heritage, during a long time, developed along the identical stylistic principles, with local variants, as in the west European countries. In economic terms, usage of this heritage for touristic purposes represents one of the most income-generating industries of those countries.

On the other hand, certain areas of former Yugoslavia, Bulgaria and other countries formed by the dissolution of the Soviet Union underwent gradual degradation of the relationship towards heritage caused in part by economic decay, and in part by the systematic destruction of the service dealing in heritage protection, and mostly by the political intentions to create more nationally homogeneous countries than before. In such circumstances, heritage suffers from all the mentioned theoretical possibilities of deterioration. At any rate, diversity of cultural and ethnic intermingling of people, external intervention in the ideological and religious conflicts, consistent conducting of political and social fragmentation which creates small environments where heritage is mostly concentrated in the cities, or is expressed through the value and symbolism of a city per se.

This part of Europe, whose periphery is constituted by the territory of our country, underwent considerable changes, expanded and contracted throughout centuries. At the beginning of the 20th century, it was battleground of the neighbouring forces that projected their political and military aspirations by including or excluding parts of these areas, according to their needs and diplomatic interests. The last decade of the 20th century was characterized by fanning back to life the previously smothered enmities, hatreds, fears and dreams of "glorious past". In such circumstances, the area of former Yugoslavia, or at least a part of it, is treated as a zone of political and economic instability and insecurity. [4]

In such circumstances, usage or abusage of heritage, as required, can be classified in four distinct modes.

- Heritage in the clash of political options
- Nationalization of heritage
- Suppression of nationalistic heritage
- Re-emergence of nationalistic heritage

3.1. Heritage in the clash of political options

In certain countries of central and southeast Europe in 1919 there occurred changes in political options, and monarchies were replaced by the republics. It was not the case with Serbia, which became only a part of the Kingdom of Serbs, Croats and Slovenes, i.e. Kingdom of Yugoslavia, but the changes were considerable, too. Undoubtedly, there were certain changes in treatment of heritage, which was the most strikingly evident in the newly created Soviet Union. Ideological and religious changes, created in our country after WWII had a direct impact on the attitude towards heritage, which then underwent massive devastation. Even though immediately after the war, the cultural monument protection

service was formed, even though legal regulations were passed, even though the state accepted international charters and declarations, totality of heritage irreversibly withered away and vanished. The most frequent justification was that it was done in the name of prosperity and better life of all the members of the state community. The culture of certain ethnic groups, Germans for instance, was destroyed, because they were classified as defeated enemies. Churches and other edifices in monastery complexes became deserted because of the unpopularity of religion in the society which opted for atheism. According to the field reports, certain structures, in the first decades after WWII, sustained more damage from the people who deliberately dismantled them than from the ravages of time and weathering. (**Fig.4**)



Fig. 4. Beocin - Castle of Spicer family, members of the German minority in Vojvodina, expelled after WW II. The castle is a remarkable example of Art Nouveau, for decades in collapse.

3.1. Nationalization of heritage

Political nationalistic movements which triumphed during the talks in Versailles after WWI are the result of various national movements created as early as in 19th century. Development of awareness of national heritage was for them one of the instruments of struggle for their causes.

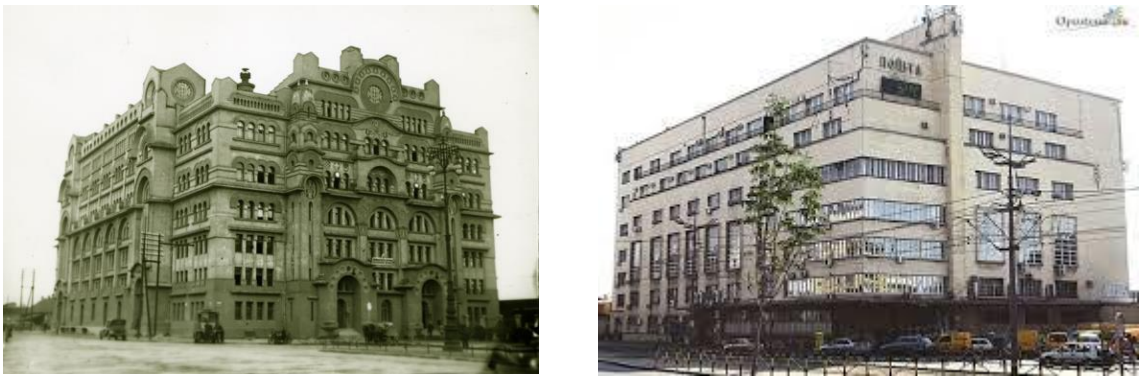


Fig. 5. Belgrade – Palace of the Post N02 was built in the Serbian-Byzantine style of the thirties of the twentieth century. After it was damaged in WW II facades were not restored because socialist government was strongly opposed to the renewal of reminiscences of Serbian medieval architecture.

In our circumstances, if only architecture and town planning is considered, it meant accelerated destruction of all the oriental elements of architecture and town planning, and an attempt of the individual to attempt creation of something called "national style restoration" and whole-hearted acceptance of west and central European cultural styles.
When, after WWII, the attitude towards the national question was changed, and when because of socialistic and communist ideas, vestiges of monarchy were subjected to deletion, heritage was either destroyed or altered and adapted to the new ideology. (**Fig. 5**)
The cities became representatives of national "liberation" although none knew for sure what they were liberated from and who liberated them. Belgrade, for instance, was in all tourist guides of the time represented as a city which synthesized total Yugoslav history and beauty of the country, even though it had become the capital of the state barely twenty years earlier, by and agreement of unification of several (territorial) entities of different origin after WWI. [1]

3.3. Suppression of nationalistic heritage

The European countries in which socialism was the political option for more than fifty years after II World War occasionally used heritage as an instrument to express that ideology and glorify such a way of life. From the present day perspective, the policy towards heritage can be defined as ideologically insufficiently determined. On the other hand, the new states strived to reflect a new society which decisively cut the ties with the past, which is rejected in most of its manifestations. (**Fig.6**)



Fig. 6. Belgrade - ascending stairs to the National Museum. Caryatids of plaster were set after WW II to cover the marble slabs with inscribed names of donors which the socialist government declared state enemies.

Those manifestations feature prominent or selective suppression of history and physical destruction or concealment of the parts of heritage which survived from those historical times. The surviving heritage obtained a new and important educational role. Even the rejected past could be put to service, by demonstrating the triumph of socialist society over the misery and poverty and by reminding the people of the "folly" and injustice of the previous regime.

3.4. Re-emergence of (im)moderate nationalistic heritage

The relatively unexpected and fast disintegration of the Soviet Union, among other consequences, allowed a number of other countries to abandon international socialistic fraternalism, which encouraged re-emergence of nationalistic heritage, to the extent which suited the current ruling apparatus. This ideological overturn brought about partial benefit

and damage to heritage. The changes of street, towns, cities names, removal of sculptures and portraits, new interpretations of archaeological findings, reassessment of literary heritage happened incredibly fast. Certain locations and edifices, which were neglected or deserted by the official powers, regained their symbolic meaning and importance. In the long run, it is even more important to observe the double treatment of the preserved built heritage. The built heritage found itself in this situation due to the attitudes of new liberal democratic ideologies towards it. On one hand, the number of interested stakeholders who would engage in professional or amateur salvaging and renewal of building heritage is growing, while on the other hand, the professional system of study, protection and rehabilitation of heritage, which was created in a long time, passes through extremely difficult organizational, legal and economic crises. [4] In certain countries, including our country, the existing protection of heritage as a whole and especially of the built heritage is criticized and rejected in ideological and practical terms as a part of the previous system which is completely rejected by the current administration. The modes in which marginalization takes place differs in certain countries, varying from dismissal of a large number of professional conservationists, such as was the case in Bulgaria, to the declarative support which is not accompanied by the sufficient economic incentive, such as the case in Serbia. For this reason, there is a need for "renewal of legitimacy of protection and rehabilitation" of the countries which were rejected in the transition countries as relicts of the previous system.

4. Final remarks and conclusions

It can be observed that in all the mentioned forms of attitude towards heritage through which the countries of central and southeast Europe are passing, the most topical ones are the political, ideological, religious attitudes, which are, deliberately or nondeliberately built independently of universal values which heritage, in whatever form it is expressed, has for the people of future generations.

One of the reactions to the long-time created, complex heritage, which was sometimes unfortunately or inexpertly remodelled, so that it could serve to the legitimate ideology to dominate a group or an individual is to reject it wholesale. In numerous public speeches, which have, also, become part of the heritage and which survive in the archives, one may find the sentence "the past must be buried, and one should turn to a better and more beautiful future, which should not be built upon such heritage". Politicians in Serbia often do not feel how senseless their ironical words of comfort are when a historical building is devastated.



Fig. 7. Monastery Djurdjevi stupovi – the souvenir shop was built in the hole with the archaeological remains of the mediaeval water thank

They, most often, say that a more beautiful one will be built in its place. On the other hand, many ideas to use the physical remains of the past as economic resources adapted to the entertainment, recreation and tourism market, can often banalize the attitude towards heritage, or even worse, represent a potential threat to the actual, original value of the heritage.

The inexorable argument, which can be observed at two levels, can assist in avoiding the downside of all the mentioned problems. Past is the main source for existence of tourism, which is used in creation of different tourist products, and which sustains a very successful tourist industry around the world. In Europe, can be found the data about the capital cities entertaining thousands and millions of tourists, selling the visits to museums, galleries, cathedrals, and to music, wine, folklore and literary festivals or offering only visits to the building heritage, therefore to the physical structure of the city itself. In such environments, the past is not used only to generate main economic activities, but to provide financial and political support for sustaining the very source of income, that is, heritage. In such an economic process, thousands of people are having a good time, having fun, learning or just satisfying their curiosity or nostalgia. These results are public and tangible for anyone who desires to contribute to the number of tourists or economic profit of a country which skillfully utilized its heritage. In this case, a question can be asked, why the heritage of our country has not been utilized in the same or similar way. Archaeological, architectonic, urban, artistic heritage is very abundant, and it can represent a tourist offer and thus contribute to the economic recovery of the country.

The fundamental precondition is awareness about the fact that the past cannot be erased from human memory, nor can heritage be denied, much as it is suppressed or deleted, at some point it will re-emerge. For that reason the present must continuously generate its past with a goal of realizing and giving sense to its existence. Since one may consider several "presents" which mutually confront or contend, the past will always be a resource in conflict. Exactly for this state of mind, the question is not if heritage should be used, but how. Occasional collective amnesia of the society regarding its own or other's heritage was never a long lasting condition. Intellectual and moral dilemmas are increasingly directed towards the heritage management issue, with several possibilities.

Successful sustainable management of the past cannot pre prescribed, because it depends on a number of factors, but it should include several items:

- Firstly, one should know what has been done up to date, since heritage is a contemporary utilization of the past, and not an assumed, fixed and unscathed legacy of the past.
- Secondly, every tourist use of the past is coordinated with other forms of use. Several forms of use is not only a possibility but a necessity, but as an executive strategy and not as an automatic response.
- Thirdly, tourism is very selective. A tourist uses the heritage so as to satisfy himself, and does not consider it as a political or economic support to a museum, archaeological site, municipal administration or the country in which he spends his time.
- Fourthly, heritage can be exported as any other resource, and made profit from, only if the clear collective goals were defined, and if the financial and legal instruments were created with infrastructure and commercial basis capable of responding to the tourist demands. [3]

Thus, heritage of the countries in transition, Serbia being one of them, can therefore be observed as a cure which can recover many ailing aspects of life, but also as a problem which requires delicate decisions within a total sustainable development strategy.

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HERITAGE SCIENCE – RECENT DEVELOPMENTS IN A NEW SCIENTIFIC DISCIPLINE

Miloš Drdácký[1]

Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences

Abstract:
This paper presents a brief history of the application of scientific investigations in art and architecture conservation. Long-term cooperation between conservation master craftsmen and interdisciplinary researchers within the natural and technical sciences has led to the emergence of a self-contained scientific discipline – conservation science, which has gradually transformed and expanded into heritage science. The aims and goals of these scientific disciplines are summarized. The history is illustrated by the development of conservation science and heritage science in the Czech Republic, where a modern research infrastructure for cultural heritage has recently been built up, enabling the country to contribute significantly to the growth and development of heritage science.

Key words: *conservation science, heritage science, research infrastructure, history of conservation science*

In recent times, efforts to safeguard and preserve cultural heritage monuments have made increasing use of interdisciplinary research results and findings from the natural and technical sciences. This has led to the emergence of a self-contained scientific discipline, usually referred to in English as Conservation Science. Conservation science involves more than just conserving monuments. It is a science that supports the conservation of cultural heritage as a whole.

So what is conservation science? In relation to cultural heritage, this is an interdisciplinary field of science that applies its methodology to safeguard and preserve works of art, architecture and other cultural objects. In recent times, it has also focused on documenting and protecting immaterial heritage. Conservation science generally involves research on the technological and structural parameters of artistic and historical works and the materials from which they are made. It applies scientific methods and principles for conserving and restoring art and architectural monuments, and also in support of caring for objects of cultural heritage in museums and in other collections. Conservation science includes identifying the material substance of cultural heritage objects, taking into account their chemical composition, studying and classifying changes that lead to decay, and also developing methods, materials and technologies which prevent or retard decay to cultural heritage.

[1] Professor, Dipl.Ing., Ph.D., DrSc., Dr. h. c., Director, ITAM, Prosecká 76, 190 00 Praha 9, Czech Republic, drdacky@itam.cas.cz

Three broad categories of conservation science are typically distinguished: i) comprehensive investigations and analyses of a historical object or material, ii) studies of material or structural degradation and decay mechanisms, iii) research and development of materials and techniques for safeguarding and preserving cultural heritage monuments. Cultural heritage conservation science involves first of all chemical, physical, biological and engineering studies. However, applied research in this field not infrequently makes use of knowledge and methodologies from fields of humanistic research. Investigations are often inspired by empirical experience, which however must be used only for formulating hypotheses. From then on, it is necessary to investigate in a thoroughly scientific way. In particular, the reproducibility of the results must be verified.

The need for broader interdisciplinary cooperation, and for including socio-economic relations and links, initiated the emergence of a new, broader scientific discipline in about 2006 in the UK[2]. This development is known as Heritage Science. This science carries out research that provides access to cultural heritage, together with conservation, interpretation and management. Heritage science thus involves not only research aimed at conserving cultural heritage (i.e. conservation science), but also other fields of research. These include the development of new informatics tools for preserving intangible heritage or for facilitating access to cultural heritage, research and interpretation of cultural heritage, including archaeometry, i.e. research into dating or provenience of historic artefacts, research into cultural heritage management, for example the development of tools and knowledge in support of strategic decision making, as well as research investigating wider societal integration of cultural heritage.

In the British approach to heritage science, long-term sustainability of cultural heritage is the declared aim. It is to be achieved through cultural heritage management and through controlling changes and risks. Maximized social, cultural and economic benefits are to be achieved for the present time, and, simultaneously, preservation for future generations. The most important benefits from heritage science are expected to come through research for museums, galleries, libraries, archives, archaeology, and research on the environment of historic architectural and technical monuments.

A researcher working in the narrow field of conservation science thus uses a scientific methodology to carry out research on cultural heritage buildings, structures, art objects, historic artefacts and other monuments. Researchers carry out mainly applied research and scientific investigations aimed at investigating material, structural and technological aspects of cultural heritage. The results of their research and of the technical data that they gather are used by conservators, curators and monument care authorities to decide on the most suitable conservation or restoration interventions for investigated objects. The results also extend knowledge about monuments, about their material composition, production or building processes, their authenticity and originality, and about previous restoration works carried out on them.

Non-destructive or considerately destructive methods are usually used for *in situ* testing or on small samples extracted from a historical object. The data that is acquired often serves for designing preventive measures or a safeguarding intervention on a monument. In the case of built cultural heritage, the data forms a basis for assessing the safety and the serviceability of structures.

Studies of material decay mechanisms and of the structural degradation of buildings is another important research activity. Chemical and physical analyses usually provide sufficient data for making hypotheses about degradation processes. In modern research, these hypotheses are tested and verified by means of complex experimental investigations. Analyses of defects and failures on buildings and structures usually require long-term

[2] More references e.g. on https://en.wikipedia.org/wiki/Heritage_science , 25.12.2015

monitoring of the response of the monument to external forces or to environmental influences. Some of these processes can be modelled and tested in the laboratory or in special testing facilities.

New materials and technologies for restoration or repair interventions are under constant development, together with tests on ways to reintroduce traditional materials and modes of construction. The immediate impact and the longer-term impact of new materials and technologies on historical substances need to be investigated carefully and thoroughly. This is another very important and very necessary field in conservation science. Research of this kind helps to safeguard and extend the life of a monument under optimum conditions in relation to its age and condition. Conservators and cultural heritage authorities usually rely on the knowledge and skills of scientists in developing new conservation materials, and frequently require a basis for assessing and evaluating the efficiency and the safety of new materials and technologies. Conservation science aims to develop materials and approaches that retard degradation and avoid damaging the treated object. Many tasks that are undertaken extend from the scope of conservation science into the scope of heritage science.

Intimate knowledge of special problems in cultural heritage research is a source of inspiration for further research areas in conservation science. This covers the development and the design of new diagnostic devices, methods and tools, and/or tools for applying consolidation materials or strengthening techniques. A substantial part of this work involves developing new methods for identifying and analysing cultural heritage monuments or artefacts.

The responsibilities and duties of a conservation scientist are thus remarkably different from the duties and responsibilities of conservators and heritage protection authorities, and of curators who need the research results from conservation science, and use them in practical applications. However, cooperation between conservation professionals and technicians, on the one hand, and conservation scientists, on the other, in research on cultural heritage conservation is always useful and always welcomed by scientists.

Unlike conservation science or heritage science, conservation and restoration work on monuments has a long history. However, a very sophisticated research infrastructure came into existence only in recent decades. Before that, repair and restoration works could be performed only on the basis of craft skills and long-term experience. It is known that in ancient times people gave consideration to monuments and made conservation interventions. This statement can be illustrated by a record on a cuneiform tablet about Babylonian king Nabod, from the 6th Century B.C., who had a sculpture of Sargon, the father of Naram Sin, which lacked half of the head, repaired by a skilled craftsman [1]. Similar documents are in existence that describe the conservation and restoration of sculptures and buildings in ancient Greece and Rome[3].

Restoration of paintings throws up technologically complex problems, and this is a field of conservation science that began to develop very early[4]. Restoration of paintings, and especially pictures, was recognised as an independent profession in France in the 18th Century. However, one of the first known restoration interventions was the conservation of frescoes in the Sistine Chapel, in 1565. Pigments have been systematically analysed since the beginning of the 19th Century, and this may be considered one of the starting points of

[3] For example, Jukka Jokilehto: A History of Architectural Conservation, D. Phil Thesis, University of York, 1986 http://mestrado-reabilitacao.fa.utl.pt/disciplinas/jaguiar/jukkajokilehto1986historyofconservation.pdf, 25.12.2015

[4] Important dates in the history of art conservation: https://en.wikipedia.org/wiki/List_of_dates_in_the_history_of_conservation_and_restoration, 18.08.2016

conservation science[5]. Between 1850 and 1853, Michael Faraday performed analytical studies in the National Gallery in London in which he investigated the degradation of varnishes and studied cleaning methods and also the impact of air pollution on the discoloration of surface coatings. His results were mostly ignored, but research by individual scientists continued in Germany and France, namely in the fields of chemistry and physics, (e.g. Pettenkofer, Pasteur). The first chemical laboratory aimed solely at conserving cultural heritage objects was established for the museums in Berlin by Friedrich Rathgen in 1888. This was followed by the research laboratory of the British Museum in 1920, which was headed by Alexander Scott. This laboratory was set the task of improving the poor condition of the museum collections. This was followed by the first American research laboratory of this type, which was set up in the Fogg Art Museum at Harvard in 1928. Further similar laboratories were founded with higher intensity after 1930, when the first international conference on the study of scientific methods for investigating and protecting objects of art took place in Rome on October 13-17. The laboratories in the Museum of Fine Arts in Boston and at the Louvre originated at this time (1931). The first professional journal *Technical Studies in the Field of the Fine Arts* started to appear in 1932 at the Fogg Art Museum, and survived for ten years. The first educational programmes were also set up at this time. Later, special institutions were established, (e.g. Doerner Institut, IRPA in Brussels, and others), focused on scientific support for conservation and restoration, mostly in connection with collections in museums and galleries. Other scientific fields then became institutionally involved, e.g. the Laboratory of Biology for Conservation at the Central Institute for Conservation and Restoration of Cultural Heritage in Rome in 1957. A series of other milestones in the history of close cooperation between scientific work and conservation or restoration work followed, and it can be stated that by the 1980s there was a very serious institutional basis for further development of conservation science in most of the developed countries all over the world.

The historical developments in the field of conservation and restoration of architectural heritage are not so clearly visible or so easy to trace, because it took advantage of general scientific knowledge gained in various technical sciences without being primarily focused on cultural heritage. However, even here records describing technologies for protecting or repairing historical objects are known from ancient times, e.g. protection against fire. Periodic monitoring of the behaviour of buildings for planned repairs or for conservation interventions can be illustrated by the example of the Brunelleschi dome for Santa Maria del Fiore in Florence. The dome exhibited active cracks that originated soon after its completion, the width of which has been monitored since the 16th Century. More intensive research work associated with safeguarding and preserving monuments started after the Second World War, when many architectural heritage objects were seriously damaged or partially destroyed. This was an opportunity to gain more experience and knowledge about historical materials and structures, namely in Central and Western Europe.

However, cultural heritage monuments have been endangered even without wars, for example by earthquakes, windstorms, floods, landslides, and also by man-made threats and disasters. At the end of the 20th Century, air pollution made a substantial contribution to climate change, and to the weather effects that it has produced. These phenomena endanger Europe as a whole, so the European Union has supported research aimed at eliminating or at least reducing the impact of climate effects on preservation of the cultural heritage. However, long-term cultural heritage sustainability also requires research on other themes, because the importance and the value of cultural heritage are not limited to the spiritual

[5] Pigment studies by Sir Humphry Davy (he had a small portable chemical laboratory and travelled around Europe, accompanied by Michael Faraday 1813-1815).

and cultural spheres. Cultural heritage helps in dealing with numerous social and economic issues. Let us take as an example the Czech Republic, where a long tradition of state support for cultural heritage research has kept Czech researchers in leading positions in the world.

After successful programmes in the 1990s and around the millennium, the Czech Ministry of Culture launched the NAKI Programme in 2010. This was a new grant-funded National and Cultural Identity research programme, with projects running for five years. NAKI is a unique programme that reflects the high level of attention that the Czech Republic pays to its monuments, in the deep belief that they are a permanent source of spiritual, cultural, social and economic prosperity for the country. NAKI is considered by many countries to be a paradigm that should be followed. The uniqueness of the programme can be illustrated by the fact that its budget for the period from 2011 to 2015 was higher than the overall budget for the common pot of EU countries gathered within the so-called Cultural Heritage Joint Programming Initiative[6].

The Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences (ITAM), to which the writer is affiliated, has been systematically involved in research on cultural heritage, and has been contributing to the Heritage Science establishment. Since 1995, this endeavour has been supported at national level by about 40 research projects and by more than twenty-five international, mostly European joint projects. We will present recent developments at ITAM as an example of the success story of a Heritage Science institutional establishment on a national level with a strong international influence and impact.

The Institute's cultural heritage research history started as soon as it was founded, in 1921[7]. Major experience was gained from restoration and reconstruction works after the Second World War, e.g. the Ball Hall in Prague Castle, Emaus Monastery in Prague, and numerous churches, and also works in relation to the construction of large dams which required historic buildings to be transferred out of the inundation area [2]. In the 1970s, the Institute contributed significantly to restoration of the metal Colonnade in the Marienbad spa [3].

In 1995, ITAM opened the Centre for Historic Materials, Structures and Sites (ARCHISS), a specialised detached office located in the World Heritage City of Telč. ARCHISS has worked mainly on studies and analyses of failures of historic structures, and on studies of the problems of historic cities, and their sustainability and development.

1999 was a breakthrough year, when ITAM succeeded in a very demanding competition among European Centres of Excellence with its project to establish the Advanced Research Centre for Cultural Heritage Interdisciplinary Projects (ARCCHIP). This became the only Centre of Excellence in heritage science among the 25 European institutions. This three-year project helped to set up a large network of collaborating research institutions and laboratories all over Europe, and gathered data for the state-of-the-art project to review research in the eighteen most important problem areas in cultural heritage sustainability[8]. ITAM ARCCHIP gained an excellent reputation, not only in the scientific community but also in the sphere of European research on sustainability planning and management. ITAM scientists then participated as research partners on numerous joint

[6] Joint Programming Initiative Cultural Heritage, www.jpi-culturalheritage.eu/

[7] This time under another name Research and Testing Institute for Building Materials and Structures.

[8] European Research on Cultural Heritage – State-of-the-Art Studies (M.Drdácký ed.), ISBN 80-86246-21-3 (all), Vol.1 (ISBN 80-86246-22-1) 575 p., Vol.2 (ISBN 80-86246-23-X) 539 p., Vol.3, (ISBN 80-86246-24-8) 760 p., ITAM, Praha 2004; Vol.4 (ISBN 80-86246-25-6) 599 p., ITAM, Praha 2006; ibid (M.Drdácký, S.Simon eds.), ISBN 80-86246-21-3 (all), Vol.5 (ISBN 80-86246-28-0) 368 p., ITAM, Praha 2006

international research projects with important results[9] that have also received international recognition. For example, Noah's Ark was a pioneering project focused on predicting and mitigating the impacts of climate change on cultural heritage sustainability. In 2009, Noah's Ark won the Grand Prix of the EU for the best research on cultural heritage, and also the Europa Nostra Prize. Similarly, the STONECORE project, which worked on problems of consolidating degraded inorganic materials using nanotechnologies, was rated among the 10 best European research projects in the EuroNanoForum 2013 competition.

Combined EU regional development and national funds enabled the establishment in Telč of a Centre of Excellence for research on interdisciplinary problems of safeguarding, preserving and exploiting cultural heritage (ITAM CET) [10].

CET started its research on January 1st, 2014, and is a Heritage Science institutional base of a new type. Research at CET is carried out on specific and complex problems of cultural heritage sustainability and integration. However, the Centre's research infrastructure and methodologies are also exploited for more general research tasks within other priority areas of sustainable development. Examples include ecologically considerate technologies, which are related in many ways with cultural heritage experience and knowledge; materials research, involving scientific references or protected rights for innovations in the field of conservation materials; devices and methods for innovative diagnostics and testing (development of special instruments and tools); the information society (specialised data, databases, monitoring networks), and also safety and security (impact, mitigation and prevention of natural and man-made disasters) in the conditions of expected changes in climate and related weather phenomena, and also in the conditions of societal pressure for intensified exploitation of cultural and natural heritage, which is accompanied by increased natural and anthropogenic threats to heritage monuments.

CET is equipped with a powerful and, in some cases, with a unique research infrastructure. Research is carried out in three broad areas: i) modelling the behaviour of historical and modern materials and structures subjected to synergic actions of climatic factors, ii) studies of life expectancy and degradation processes in structural materials and their surface coatings, using advanced experimental methods, and iii) materials, technologies and methods for long-term sustainability of cultural heritage monuments and sites.

The first group of research themes makes use of the Vincenc Strouhal climatic wind tunnel, which has two test sections. There is a climatic test section for modelling various wind velocities, rain, solar heating and temperature cycling from -10°C to +30°C, and an aerodynamic test section, which is very well instrumented for detailed measurements of various parameters, and is able to model special micro-climate effects, e.g. heat islands. The research includes creating models of the interaction of complex bodies with the surrounding environment, taking into account knowledge gained during numerical and experimental modelling of wind action on building structures, including monuments,

[9] For example: Safeguarded Cultural Heritage (SAUVEUR Project – M.Drdácký, M.Chapuis (eds.)), ISBN 978-80-86246-29-1 (all), ISBN 978-80-86246-31-4 (Vol. 1), ISBN 978-80-86246-32-1 (Vol.2), ITAM 2007; Dupagne, A., Teller, J., Dumont, E., Drdácký, T. et al.: PICTURE – Pro-active management of the impact of cultural tourism upon urban resources economies (Strategic urban governance framework for the sustainable management of cultural tourism), ISBAN 2-87456-043-X, European Commission, 136 p., 2007; The Effects of Air Pollution on Cultural Heritage (J.Watt, J.Tidblad, V.Kucera, R.Hamilton - eds.), Springer 2009; Sabbioni, C., Bonazza, A., Drdácký, M. et al.: The Atlas of Climate Change Impact on European Cultural Heritage - Scientific analysis and management strategies, ISBN-13: 978 1 84331 798 2 (Hbk), ISBN-10: 1 84331 798 2 (Hbk), ISBN-13: 978 1 84331 861 3 (eBook), ISBN-10: 1 84331 861 X (eBook), Anthem Press, London/New York, 146 p., 2010; CHEF - Cultural Heritage Protection Against Flooding - M.Drdácký, L.Binda, I.Ch.Hennen, Ch.Köpp, L.G.Lanza, R.Helmerich (eds.), ISBN 978-80-86246-37-6, ITAM Prague, 2011, 229 p.

[10] www.cet.arcchip.cz

taking into account the impact of other weather factors, e.g. sudden or cyclic fluctuations in temperature and rain. Further goals involve gaining new knowledge by long-term sustainable monitoring and modelling of the behaviour of real structures that are subjected to the long-term action of weather fluctuations and are sensitive to vibrations and fatigue damage. The results are reflected in the design of solutions for aeroelastic and aerodynamic problems, modelling and suggestions for improving the environmental conditions in urban units and in the surroundings of traffic lines, taking into account knowledge and simulations of the most important environmental parameters: wind, temperature, solar radiation, and the impacts of rain and moisture on buildings, historical objects and monuments.

The second group of research themes focuses on studies of material ageing and material corrosion of metals, stone and inorganic composites, and on determining optimum modes for protecting their surfaces. Degradation models are created, and are calibrated and verified using the research infrastructure, long-term monitoring of weather-exposed samples and studies of materials in real climatic situations. Data is gathered on the life expectancy of historical materials, and methodologies for monitoring the behaviour of materials and structures are developed, including monitoring defects and damage to historical structures. For its research, CET has developed and operates MONDIS, a special innovated information system and database of building defects and failures ontology[11]. CET has been systematically building up the necessary experimental and analytical infrastructure, which can also be used for a range of more general tasks. New and innovated experimental methods are developed, including devices and tools namely for testing wood and inorganic composites, e.g. [4]. Researchers make use of radiography and X-ray computer microtomography and also special climatic and analytical laboratories, including a mobile laboratory for *in-situ* testing.

The third group of laboratories investigates, develops and verifies new materials and technologies that are compatible with historical materials and technologies. Their work is mostly on problems of consolidating and restoring deteriorated historical materials and on prolonging the life and the serviceability of cultural heritage structures. In addition, analyses of the impact of natural disasters and other threats on buildings is carried out, with special reference to the sustainability of cultural heritage and suggestions for measures and technologies that will prevent or reduce the damage caused by these hazards. Among natural hazards, earthquakes, floods, landslides and also weathering effects are considered, because in the long term they lead to the loss of cultural heritage buildings, and their impact extends over large territories. This group of research tasks includes investigations aimed at optimizing emergency interventions during and after natural disasters. A further important goal is to devise methodologies and tools for assessing and evaluating the impacts of development programmes, e.g. mass cultural tourism, and new architecture in historical environments on the sustainability of heritage buildings and on the socio-economic qualities of historical sites, and also the development of tools for supporting the integration of cultural heritage into the urban environment.

The Centre of Excellence in Telč provides a unique research infrastructure that is fully dedicated to cultural heritage research, and is one of the partners of the new ERIHS (European Research Infrastructure for Heritage Science) European distributed large-scale research infrastructure which is being set up. The ERIHS project has been included in the ESFRI Road Map[12], which is a very important contemporary achievement in the development of Heritage Science.

[11] http://webcache.googleusercontent.com/search?q=cache:XX2DudRnxT8J:mondis.cz/+&cd=1&hl=en&ct=clnk&gl=cz (MONDIS Portal)

[12] ESFRI Roadmap, www.esfri.eu/roadmap-2016

The Heritage Science approach has also been supported by the establishment of the so-called Joint Programming Initiative – Cultural Heritage[6], which has been agreed by ministers of numerous EU states. This programme should help in planning a joint research orientation, and in securing funding, generating increased synergies and eliminating duplication in the field of cultural heritage. The financial mechanisms are based on setting up a common pot from resources provided by the individual states. However, this system of funding has led to many difficulties, and the anticipated level of efficiency has not yet been achieved.

Nevertheless, Heritage Science benefits from a good level of voluntary worldwide cooperation among scientists within various international associations and programmes. Let us mention here the International Scientific Committees of ICOMOS[13] and the Technical Committees of RILEM[14], which cooperate to develop Heritage Science on all levels and in its wide range of research.

Heritage Science is a young and lively discipline, although it deals with ancient monuments and with history. We are witnesses of its ever-growing development and its newer and newer achievements. This science is very much involved in the present-day life of society, and has the potential to contribute to the solution of difficult societal problems. It is able to react rapidly to adverse situations that may emerge, e.g. illegal mining and trafficking of cultural heritage, destruction of cultural heritage, or a lack of educational programmes[15].

Heritage Science thus seems to be a reasonably robust and self-sustaining discipline with sound development prospects. It profits from a large pool of committed professionals, a stream of focused activities and bright ideas in response to the enormous range of problems that need to be solved in connection with cultural heritage.

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