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SUSTAINABLE REHABILITATION, PRESERVATION AND PROTECTION OF ACCESS ARCH STONE BRIDGE AT THE ENTRANCE TO THE MEDIEVAL OLD TOWN KORČULA

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ABSTRACT

Due to its strategic position, Island of Korčula – Croatia (south Adriatic Sea) has always been a heavily fortified settlement, whose basic layout has not been changed from mediaeval times. This paper is dealing with rehabilitation and minimum and necessary structural interventions on the arch stone bridge, as an integral part of the historic old town, in order to stabilize the structure and contribute, in proper way, for the world heritage list nomination process that is underway.
The stone bridge is located in a busy pedestrian zone, so its rehabilitation is of great importance, both for the city, and for overall security of the population, especially tourists who do not notice the damage and consequences that may arise.
An important first step in developing effective maintenance/preservation and rehabilitation treatments was to understand the properties of the material used to construct the bridge and common types of deterioration associated with them.
Analyses of the model of behavior of the bridge were the basis for evaluation and decision making in regard to intervention and subsequent maintenance.
Proposed intervention aims to ensure the integrity of the structure, restore its integrity and some of the historical and architectural features (openings) with use of the local authentic materials and construction system.
The proper methodology for re-pointing historic masonry, especially on the arch's intrados, should include installation of weep holes. Increasing the capacity of an arch bridge must be done in an unobtrusive manner and should preferably be performed internally to avoid any adverse visual effect.

Keywords: *Arch, Stone bridge, Preservations, Protection, Methodology, Interventions, Management plan*

1. INTRODUCTION

Fortification systems of mediaeval cities represent an ambivalent element in contemporary life of a historic city. On one hand they provide definition of urban form and historic landmarks, and on the other are sometimes barriers or under-used structures that demand maintenance that is unsustainable for the city.
Due to its strategic position, Island of Korčula (south Adriatic Sea) has always been a heavily fortified settlement from mediaeval times, with strict and regular plot division and street pattern. Throughout time it has maintained an unprecedented level of integrity as a whole, even though individual structures are not unique expressions of architectural masterpieces.

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Arch stone bridges at the entrance to the medieval old town Korčula already had inappropriate interventions in the past that made bad influence and have accelerated current structural problems.
The target of this paper is to look at the bridge as an integral part of the historic core, give propositions for inclusion and meaningful function and offer a suggestion for minimum and necessary structural interventions in order to stabilize the structure and present different historical layers.

2. HISTORIC CORE OF KORČULA

Old City of Korčula – Historic core 4,43 ha
Spatial organization and town planning within the city walls, together with topography, interaction with sea is unique also for its fishbone urban tissue, equal parcels, and consistent architectural style of buildings. The origins of the settlement today come from the late mediaeval times, mostly XIII century. Building typology is a mixture of local stone masonry, with late roman, gothic, and reinessance elements. The consistent building typology has been maintained in building up to the XVIII-XIX century.

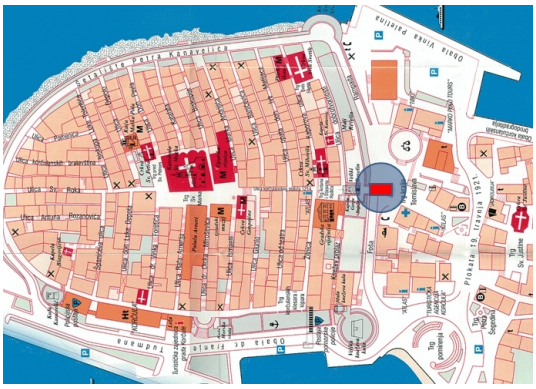

Fig. 1 Map of Historic Core, with fortification system

Fig. 2 Main entrance to Old City of Korčula, Arch Bridge emphasized

3. ACCESS ARCH BRIDGE EXISTING CONDITION

General impression of the existing condition of the Arch Bridge and surrounding objects is some instability and neglected appearance. Obvious lack of care is visible as large cracks, rock dislocation and crumbling, wild vegetation, inaccessibility and practically no maintenance. Exposed to the natural elements, bridge shows signs of structural wear and tear and weakening.

Fig. 3 Degradation process on intrados

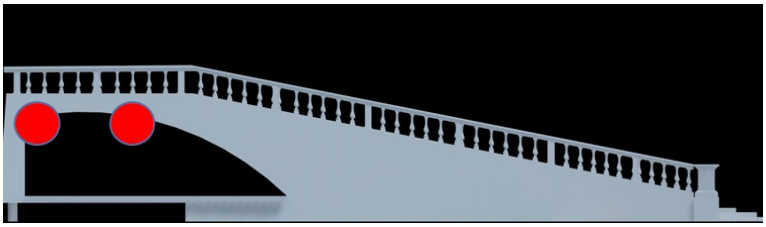

Fig. 4 Critical points

When carrying out detailed survey of the stone bridge, we have noticed the types of damage as follows:

- construction of the vault with visible cracks and falling off the rock
- damage to the joint between the ceiling and walls
- the construction of the bridge on one of its circuits represented visible cracks
- railing of the bridge is moving in two places
- repeatedly movement of the stone railings resulted in damages and cracks
- stair steps are worn and extremely slippery
- visible cracks of floor stone cladding

4. CAUSES OF DEGRADATION

Causes of degradation can generally be placed into two basic groups and those are human factors and natural causes. Further separation would be by following:
Human factor: not maintaining structure of fortress, extracting parts of wall or estrangement from ruins, fire, vandalism and war impacts, lack of originals design etc.
Natural causes are for example: impact of rain and water, movement of lower parts of structure, thermal strains and frost, causes by vegetation affection, rodent activity, effect of wind erosion etc.
Humidity is one of the main causes for degradation of material, and it occurs as result of water infiltration into masonry, caused by condensation of steam from the air, rain that infiltrate through the roof or walls or by groundwater that infiltrates as capillary humidity through foundation. Humidity also depends on porosity of masonry, evaporation and temperature, from the nature of soil, type of foundation, depth of water and cyclical changes of the same. Every material requests defined degree of humidity for its conservation. Surplus of humidity causes for example occurrence of bacteria and fungi. Lack of humidity causes shrinkage of material and it becomes more brittle or sometimes as a dust. Oscillations and sudden changed of humidity are the most dangerous for material because it can activate soluble salts.
Water is one of the main causes for corrosion of embedded stone, decreasing of mechanical strength and in the end its final dissolution and degradation. Often and long-term moisture of stone structures results with stone softening.
Unlike the “water absorption” that indicates on size, and sometimes on character of material porosity, term “capillary extraction” results as indicator for speed of capillary water penetration. Because of certain loss of water needed for binding, mortar somehow loses some plastic abilities.
Absorbed water at porous materials significantly effects on behavior and material characteristics as it: weak cohesion between material particles, weak adhesion between two adjacent elements, weak resistance of material on frost and effects on stability as on aesthetic view of construction.
Presence of efflorescence and crypto efflorescence can be caused by chlorides, sulphates and nitrates. Crystallization of soluble salts in the walls of historical objects causes serious damages of the base. That is called crystallization or sub florescence. Problems related with the sub florescence can be diagnosed and identified over visual traces, presence of capillary moisture and diagnose of sub florescence can be determined by laboratory examination. In the structure of historical value, there is no presence of just one kind of salt than complex mixture of the same.
Process of decay for steel elements is mostly evident through presence of corrosion, due to it occurs reduction process of bearing section and increase of volume due to the presence of corrosion when the steel element is embedded into masonry, stone or marble, where corrosion causes tearing of the adjacent material.

5. THE ANALYSIS AND RECORD OF STRUCTURAL CONDITION

On site survey included analysis of permanent and temporary loads, interactions between ground foundations and structure, estimation of earthquake risk or other dynamic loads and decay of material. The resistance of arch to static loads is usually sound, but not so for seismic since stone structures have low resistance to tension and shear.
The structure is threatened due to effects of thermal variations, and especially the seismic effects (it is in VIII seismic zone).
Analysis of the model of behavior of the arch bridge will be the basis for evaluation and decision making in regard to intervention and subsequent maintenance.

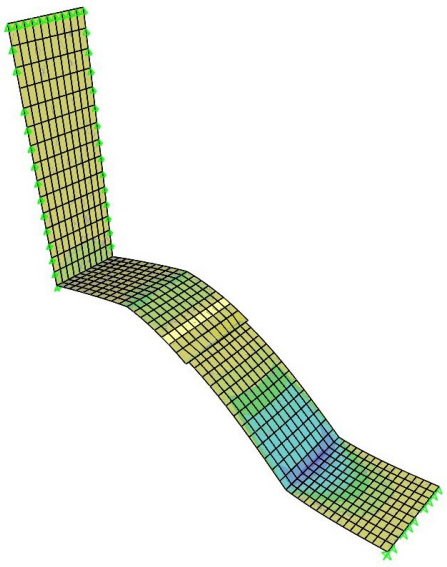

Fig. 5 SAP2000 finite element model

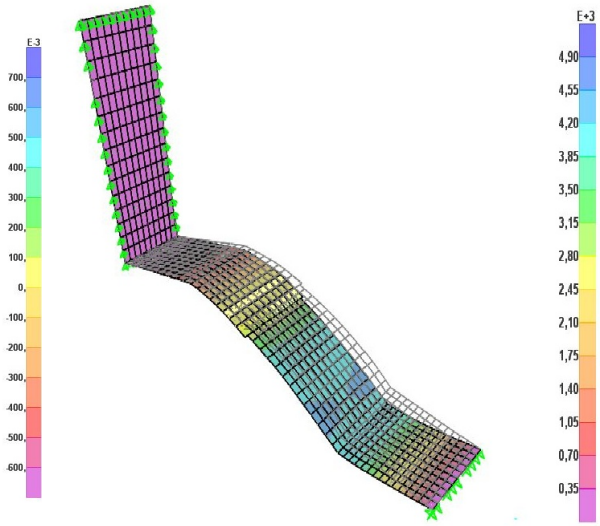

Fig. 6 Deformed shape of the bridge SAP2000 model

6. PROPOSED INTERVENTIONS

Interventions aim to ensure the veracity of the structure:

- Restore its integrity with use of the local authentic materials and construction system.
- Historical and architectural features (openings)
- Presentation of different historic layers
- Use, maintenance plan (as a part of overall management plan for the historic core)
- Increase the static stability, and overall compactness of all parts of the bridge
- Clean all visible parts of the vault
- Emergency repair the stone fences: fix broken columns, reinforce and repair the guardrail, its overall fix for the stone bridge
- Clean the joints on the underside of the arch stone bridge, with the removal of unstable rocks and cracked in a state of decay
- The non-skid treads steps incorporate elements that will not impair the value of the original appearance of the building
- Grouting lower a heart of stone arch bridge, masonry works on arch stone bridge, vault injection

Specific interventions would include: Damaged wall stones must be cleaned of residual mortar and vegetation, and replace individual stones with new ones, in exact manner of the walls of the object. Injection of adequate material in order to strengthen the connective substance, and prevention of further vegetation growth, as well as prevention of further widening of the cracks, through rebuilding sections, possibly inserting appropriate mortar.

6.1. Selection of appropriate mortar mixture

Repointing is the process of removing damaged or over aged mortar from the masonry joints and its replacement with the appropriate new one. Successful repointing returns visual and physical integrity of masonry buildings. Inappropriate done repointing is not just decreasing the value of building appearance, and then it can also cause physical damages on the building walls. Decision for repointing is mostly related with some obvious sign of deterioration as for an example: decay of mortar, cracks in joints, unstable brick or stone, moist walls or damaged mortar. Analysis request explanation, taking into account important factors that effect on the state and performance of material, which cannot be determined through laboratory analysis as are: original contain of water, rate of curing, weather conditions in the time of original structure, type of mixing and placing mortar, and cleanliness and condition of sand. The biggest benefit from information that can be reached from laboratory analysis is identification of gradation and color of the sand. These data provide that the color and texture of mortar will be harmonized as much as it is possible, because the part of sand per volume of ingredients is the largest one.

New mortar has to correspond to the historical mortar, in term of color, texture and volume ratio of ingredients. After laboratory analysis are carried out, it is possible to determine appropriate components

of binder and its proportion in historical mortar, of course under the condition that those materials are available Sand has to correspond to the sand contained in historical mortar. New mortar has to have higher permeability and to be tender or even tenderer than historical mortar. Mortar has greater compressive strength than masonry elements, and will not allow moisture migration causing permanent damage of the masonry elements, as are cracking and scaling, that cannot be fixed easily.

6.2. Techniques to preserve

Decision about the way for repair of objects is proceed by: on-ground and detailed analysis of existing situation, access to the existing technical documentation, verification for integration of provided interventions and reinforcement of existing structure with building outlines, but also constructively, or if provided solution appreciates conditions of construction demands related to the purpose. This method, we could say of conceptual consonance of provided interventions with the situation on the ground, helped us to avoid mistakes that could lead to the additional expensive interventions. Decision to intervene in construction has to be consequence of careful evaluation of construction security in the moment when it is analyzed (current state). Scope and the type of intervention have to be balanced with the aim to achieve new level of security. Same kind of problem can be solved on many ways, looking at the same time general projects and specific techniques that we will adopt. Decision about the solving problem for repair and reconstruction of researched fortress depends after all on: seismic zone of location on which fortress is located; type and level of damage, time left for interventions, available equipment, economic criteria and degree of requested safety. Measures that are taken with the aim of protection from earthquake, include improvement of material characteristics (injection and similar), reinforcement of individual elements of structure, reinforcement of foundation or restriction of movements.

Finding technical solution for repair of structure is much more complicated and dedicated job than to design new object, because very often some very important elements of structure cannot be determined before beginning of the intervention works, when we are facing with the new unknown data that are discovered on the site.

A selection criterion has to be led not only with structural efficiency and economy also with the knowledge of techniques and technologies used in the construction of monuments and respecting original conception. This aspect together with the part written in following paragraphs has to be always present in any project concerning preservation of cultural heritage.

7. MAINTENANCE PROGRAM

The basic starting point of protection of architectural heritage is the desire to prevent the immediate destruction of the landscape, to preserve the architectural monument to its original environment, and thus the value of their spatial and comprehensive meaning. The concept of sustainable tourism has grown from the concept of sustainable development, development that meets the needs of today without compromising the ability of future generations to meet their own needs. Sustainable development is an eclectic concept that includes all aspects of human life that affect the maintenance. It also means sustainable development and conflict resolution among various competing objectives and includes the simultaneous performance of economic prosperity, environmental quality and social equity.

The area of sustainable development can be conceptually divided into: Environmental sustainability, economic sustainability and sociopolitical sustainability. Thus, the translation of sustainability into concrete actions must be a collaborative effort, involving all relevant actors.

Management plan should provide guidance on the heritage or place of valuable remains usage. Tourism can be one of economic aspect or benefit for certain place, which is in a function of its preservation.

Tourism managing requires concrete answer to the problem that bother municipality, problems of managing heritage as sustainable structures. In city core of Korčula there are three national monuments, treated separately, and after restoration they are still not in use as sustainable structures, because there is no plan for heritage managing and tourism.

8. CONCLUSION

As all monuments are precious, one has to respect it and try to intervene as little as possible even though it might lead to taking certain calculated risks in order not to disturb the structure or alter its

authentic concept. The general dilemma is whether to accept and implement the minimum intervention, which will have to be revised after a certain amount of time, or to go to more extensive works once the structure is undergoing an intervention.
In the circumstances today the intervention has to foresee a monument as a whole in its larger context. This is an eclectic task – from structural aspects, conservation but also active use and sustainable development.
The proposed intervention aims to ensure the overall integrity of the monument, perpetuate the character and identity, using authentic materials from the original structural system. These materials are primarily local limestone masonry, with mortar and using local sand. This structure is compromised not only because of the large stresses acting on the bottom, but also sensitivity to the effects of thermal variations, and especially the dynamic effects such as those by the earthquake:
Arch Bridge is in VIII seismic zone with a pronounced seismic activity. The analysis model of mechanical behavior of the bridge is an important basis for evaluating the reliability and the decision on the scheme intervention and maintenance.
The deterritorialization of the modern cultural heritage in a globalized modernity transforms the relation between the places where we live and our cultural activities, experiences and identities throw cultural homogenization and cultural heterogenization.
We must add the sense of the relation between memory, territory and the quality of a meaningful life which underlies the associative heritage work in considering the importance of place; we highlight the concepts of community resilience and risk management, key aspects of a response to change, while we define the word "sustainability", the responsibility of us living people towards the heritage we received and towards the heritage we will leave to our successors, in order to play a pivotal role.
We believe this sense of responsibility is under risks disappearing, together with the ability to interpret and understand the wisdom and the knowledge pertaining to the "past" technologies and techniques, lingering on the present, to leave out the ability of assessing the damage and the future devastation.
What therefore can be considered "sustainable", in the space forms that are familiar to us, from everyday life spaces of our homes, villages and towns, of the places that are part of it but also nature and territory?
There are two phenomena of our contemporary history that represent a consciousness of the reality we are living and, at the same time, a source of uneasiness:

- The rapidity of changes life imposes on us
- The loss of the feeling of distance

We should be aware of the fact that these conditions can express the uneasiness in accepting the condition, defined as "globalization", but also the awareness of the impossibility to resist effectively to this inexorable movement. The loss, yet the uselessness of effective use of memory is a direct and, perhaps, unavoidable consequence of these two degrees of perception of nowadays life.
The best way to preserve a historically valuable building is if one you can make the house owner be aware of the values of the building, see to that he gets the needed knowledge how to maintain the building and that he is proud of being the owner. It is also important that the building is used and that it is used in a way that respects the historical values of the building. Actions that contains management plan, with long-term goals, may include active and passive use, in order to achieve the sustainability of heritage and involvement in modern trends of life and to satisfy main demands regarding aesthetic values, comfort of living areas and environmental sustainability.
The uniqueness of historic structures, with their complexity history, requires the organization of studies in precise steps that are similar to those used in medicine. Main goal of management plan is to set up the conservation and development dimensions in relation to sustainability. Therapy should address root causes rather than symptoms.
In particular, considering what we have said so far, what kinds of modalities have emerged, answering to this question, from the several cultures of which our civilization is composed?
And, above all, can we conceive the existence of a future, allowing the subsistence of an identifying principle of these characters?
Conservation does not make any sense, unless it is considered within an evolving idea of Heritage. This evolution is a process in which memory is a vital function: it is necessary to portrait a representation of the past, but it is also a hope for the future.
This process seems apparently incompatible with our contemporarily perception.
We have learned the lesson, but we have also understood that the vital space of daily life represents the first stage of the Heritage formation process, and, moreover, the greatest hope for its own survival.

As a matter of fact, we cannot define the Heritage, unless we put this concept in close relationship with the conception and the vitality expressed through the spaces of everyday life. The intensity of these factors allows us to understand the role and the function of the Cultural Heritage.

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