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STRUCTURAL INTERVENTIONS ON THE MODERN HERITAGE BUILDINGS: CASE STUDY OF THE HISTORICAL MUSEUM IN SARAJEVO

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Abstract. *As the participants of the current moments of the mankind existence thoughts about cultural heritage invoke deep understanding of the values of all historical periods equally.*
Facing with the time of global culture, contemporary approaches to the conservation and management of cultural heritage in present day seek for the activities that will allow better relationship between where we live and our cultural activities, experiences in order to define identity through a process of cultural homogenization and cultural heterogenization.
This paper will bring forward approach to understand structural interventions on the buildings of Modern heritage respecting its values as the memory of 20th century, describing case study of the Museum of the Revolution in Sarajevo, built in the early sixties, in contrast solid and transparent volume of its refined reductionist geometry in a chapter of Bosnian architecture in the sixties of 20th century, which realizes a specific contribution to the history of international modernism. Although the best way to preserve valuable historical buildings is to raise awareness of the value of the object, in order to gain the necessary knowledge on ways of maintaining the building, it is also important that the building is used in a way that respects the historic value of the building. Well prepared Management plan, with long-term goals will define and propose developments of particular building in order to achieve sustainability and involvement of different counterparts.
All structural interventions in these facilities must provide strength and stability that is at least equal to the original, and often much more, in accordance with well-established rules, and with respect to their structural and architectural originality and authenticity. Ensuring the resilience and structural stability requirements, complying with modern comfort features, and authenticity as a whole and in detail (in terms of architecture, materials and technology) causes difficulties specialized professionals, especially architects and engineers, restorers.

1 INTRODUCTION

Development of building activities has left clear traces of all periods to date, indicating the level of technical and technological achievements of the moment in which certain building or architectural ensemble occurred. As the participants of the current moments of the mankind existence thoughts about cultural heritage invoke deep understanding of the values of all historical periods equally in terms of constructing new facilities given the wide range of materials that can be used as materialization of buildings, but also brings particularly large differences in the approach to the preservation of buildings and monuments of architectural heritage.

Heritage buildings, in numerous cases, go through different stages of change during exploitation period, and thus differences in approach of interventions have occurred.
Contemporary approach to the conservation of architectural heritage requires multidisciplinary interaction, teamwork of specialists in different fields in order to perform the evaluation and to provide proper preservation with optimal interventions and usage of heritage as well.
However, the main objective of the intervention on objects of cultural and historical importance is to clearly preserve recognized values.
Recognition of values of the 20th century architecture, marked as modern heritage, is a challenge, especially if we talk about specific field of research such as the architectural milieu of Bosnia and Herzegovina.

After the World War I the socio-economic conditions in Bosnia and Herzegovina were at very low level and did not result in achievements with specially emphasized values, while elements of historicism and art nouveau were still present. However, influences of Western European achievements slowly penetrated in Bosnia and Herzegovina through architects who were educated in Vienna and Prague.
After the WWII, Bosnian and Herzegovinian pioneers of modern built numerous architectural achievements with great influence of socialist realism especially on many public buildings.
However, this paper will be focused on the Museum of the Revolution, built in the mid-20th century as a good example which illustrates the development trend in Bosnian and Herzegovinian architecture during the Socialist Yugoslavia, but at the same time follows experience of 20th century building shaping.

"I have opposed to the socialist realism by effective and the cleanest torque of western abstract expressions that come out of vulgarization of notion of building that socialist realism was bringing. The problem of this building is that what I was having inside of me could not have been realized. That cube was not planned to be made of stone, it should have been made of metal and crystal – down there clear glass as crystal. This form has crossed the time since it has been characterized by theoretical possibilities of opinions of the time. "-Architect [1]

This fact gives special value and time dimension of this building as a step forward in the approach to the design of new structures at those times. Stressing the importance of preservation of this building and its usage, it is necessary to define all actions that will ensure the conservation and maintenance of this facility in the future but will also ensure the development of museum activities in the future through well-defined management plan that will incorporate all necessary actions. Museum buildings are very often exhibits in the space that also has architectural and historical values; therefore analysis of the current stage of the building has to be performed with special attention.

[1] One of three authors of the Museum Project : Arch. Boris Magaš - interview in magazine“ SVJETLO RIJEČI“

2 BRIEF HISTORICAL OVERVIEW OF THE MUSEUM OF THE REVOLUTION

The museum of the Revolution was established on November 13, 1945 as "National Liberation Museum in Sarajevo," and from 1958 has been located at an attractive site of Marijin Dvor[2]. Right after the liberation of the city, this location has become the subject of expert discussions and planning, since the plan made in 1948 considered this area as downtown. All disapprovals of ideas in that period pointed to the necessity of public competition for design of this space. During that period, several facilities such as Museum of the Revolution, Faculty of Arts, the National Assembly and the Executive Council have been designed and constructed as well. The architectural competition for the building of the Museum of the Revolution has been won by architects Boris Magaš, Edo Smidihen, and Radenko Horvat, and the construction begun in 1958. Today it stands under the name of Historical museum of B&H, but in the past it changed the name many times, and the reason for that was enlargement of the Museum collections including whole history of B&H from Slavs arrivals to The Balkans and to the formation of contemporary independent B&H. In 1949 Museum got the name of Museum of national revolution of B&H“, in 1967 Museum of revolution and finally in June in 1993 „Historical Museum of B&H“.

Elements	Material	Basic characteristic	Photo
WALLS	Reinforced concrete	Wall thickness 20and 25 cm	
FACADE	Stone	Hangings tiles d=20mm	 
FLOORS	Stone	thickness 20-40mm	 
ROOF	Steel Glass concrete	Flat roof	
SLAB	Reinforced concrete Steel	RC coffered ceiling Steel girder	 
OPENINGS	Metal	Angular profile Square profile Single glazing	 

Table 1: Basic components of the building (Sarajevo Museum of Revolution)

[2] Sarajevo city district

The building was built as a contrast of solid and transparent volumes that with its refined reductionist geometry opened a chapter in Bosnian architecture of the sixties, 20th century. According to the high artistic standards it gives specific contribution to the history of international modernism.
Museum of the Revolution, as a monument sample of the public type, has been designed as a simple sheath in the game of empty, light ground floor and full cube over which has been violently degraded due to war-time as well as lack of maintenance.

Figure 1: Historical Museum in Sarajevo

3 CURRENT STAGE OF THE BUILDING OF THE MUSEUM OF REVOLUTION

3.1 Methodology, survey of the site and surroundings of the museum, preliminary level of detection and diagnostic

Preliminary detection phase and diagnosis of building damages include detailed survey of the building and its surroundings, along with the checking whether the object is constructed according to the project documentation, whether some additional interventions were carried out, the identification of the type of the supporting structure, whether the structure as a whole as well as its parts are stable, monitoring and registration of any damages of the roof structure and foundations. In the areas marked as at high seismic risk, in cases of enlargement, changes in the original size, reconstruction or subsequently erected buildings in the immediate vicinity and renovation, upgrading of an existing facility, it is necessary to analyze seismic aspects of such interventions in earthquake areas.

Defining the current state of the building original documentation will provide insight into comparison of original and current stage of the building and special focus should be on predefined values of architectural form of the building in order to define level of destruction.

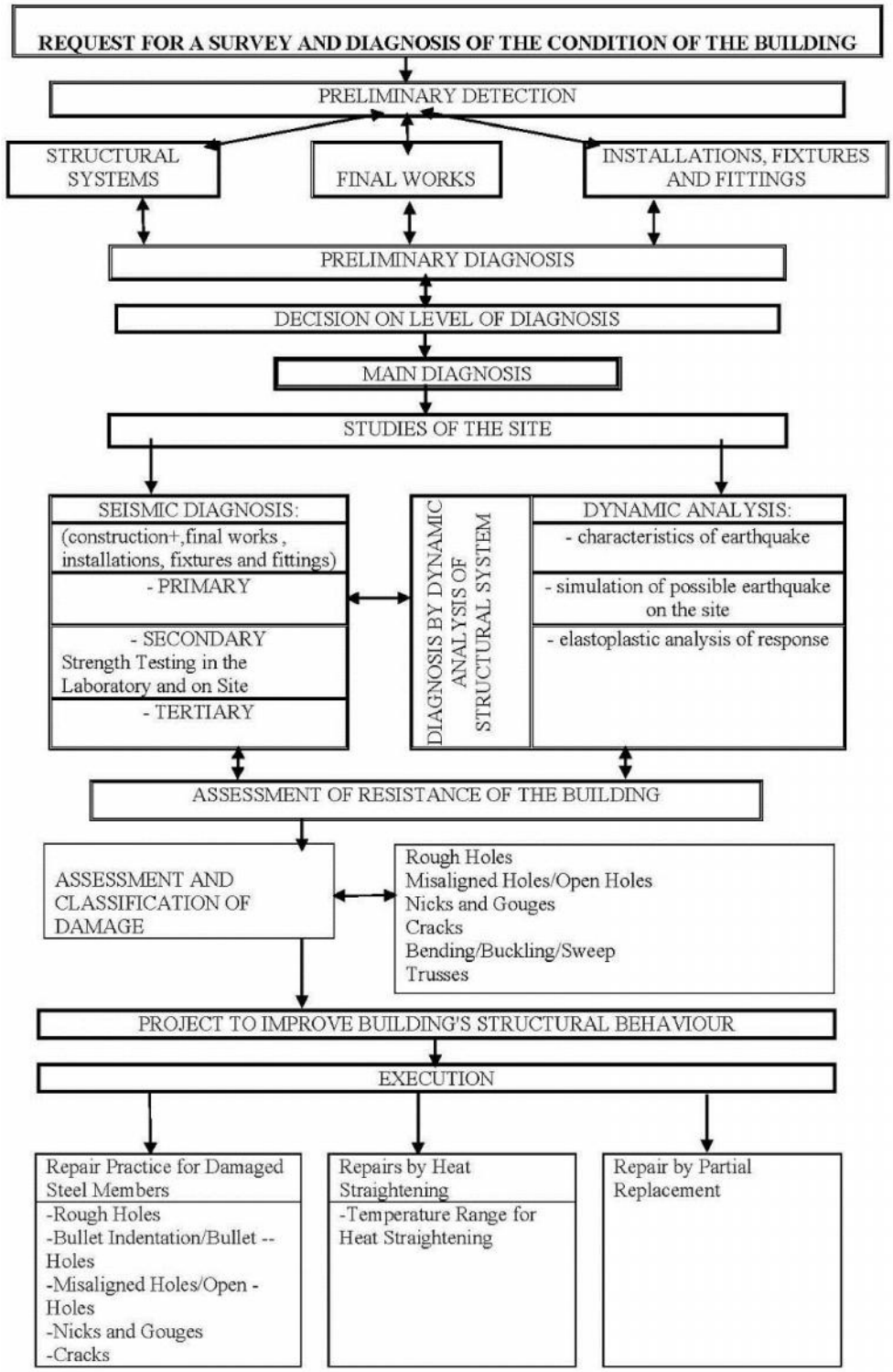

FIGURE 2: Methodology scheme for the restoration of modern heritage properties

4 ASSESSMENT AND CLASSIFICATION OF DAMAGE

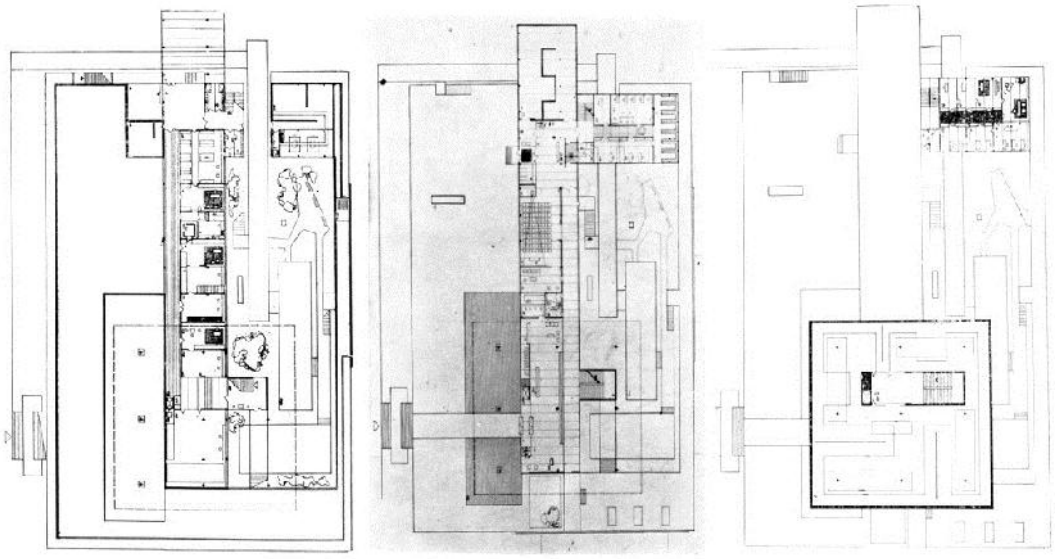

Figure 3: Original drawings

Assessment and classification of damages of the existing structure as a result of investigation detected further damages: rough holes, misaligned holes/open holes, nicks and gouges, cracks, bending/buckling/sweep. Trusses are comprised of both tension and compression members. Distortion in tension members is not as critical as distortion in compression members.

Figure 5: Detail of the existing roof structure

5 JUSTIFICATION BY CALCULATIONS, BASED ON DATA COLECTED AT THE SITE

Ultimate limit states may occur due to: loss of structures equilibrium, structural failure and loss of stability. Serviceability limit states may occur due to: excessive deformation of the structure, local damages of structural elements and structural vibrations (proof that the natural frequency of the structure is less then frequency of disturbance force, in order to avoid the possibility of resonance is required).

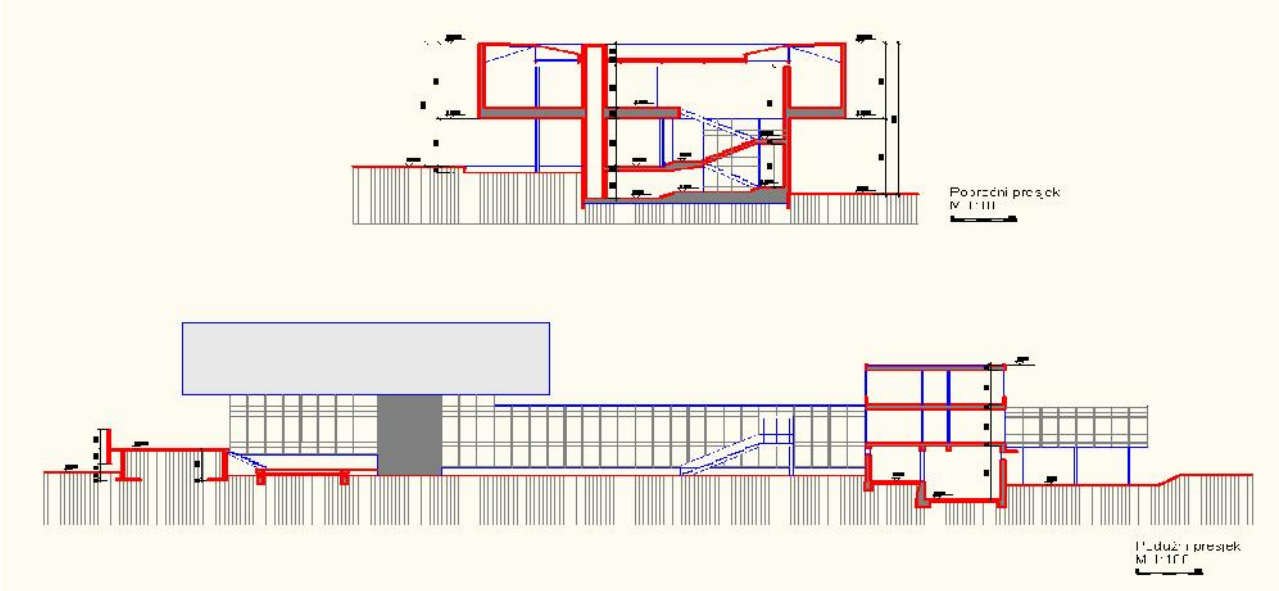

Figure 4: Cross Sections

All ultimate limit states, in accordance with Eurocode must be checked by calculation, which is carried out after the model and load of the structure have been adopted. Also, all loads must be combined in order to give the most unfavorable influence for ultimate limit state.

For the serviceability limit states, combinations in use are: a combination of permanent and variable influence with frequent impact, which provides short-term effects, and a combination of permanent and variable action with their approximately constant values, which provides long-term effects, but it is a rare combination.

Collapse analysis can be used as a flexible and powerful tool to assess the vulnerability of historical buildings under earthquakes and to choose the right structural measures for retrofitting if necessary. Interventions have to be regular and uniform on the structures. The execution of strengthening interventions on limited portion of the building has to be accurately evaluated and justified by calculating the effect in terms of variation on the stiffness distribution. Special attention has to be paid to the execution phase, to ensure the effectiveness of the intervention.

Based on the collected data (the existing project documentation, a detailed inspection of all visible damages and its survey, data on materials and their condition, geotechnical properties of soil etc.) detailed structural analysis and calculations have been carried out, as well as sample assessment that have caused current state of load-bearing structures. The results obtained by the analysis are compared with the current state of the damaged building. Since results of the analysis match with the state of the building it is consider that an idealized model of the structure corresponds to the real situation, and results of the analysis can be taken as a realistic basis for the selection and adoption of technical solutions for the intervention on the construction. The entire process of drafting a study on renovation or restoration is not complete, of course, until the causes of the building's deterioration have not been identified. It is essential that these possible causes be carefully identified and analyzed in order to avoid, or prevent, a repetition of the mistakes that led to the present condition of the building. The repair and strengthening of historical monuments should be carried out without introducing any changes or strengthening of the main structural systems. Many monuments and buildings are today a masquerade of reality, the results of art, nature and history combined, brings us towards the question of what we are trying to achieve through their continued preservation.

The differences of the results obtained by the finite element method (provided by software Tower 7) and those obtained by gradual calculation range within the limits of 10-14%. Differences arise due to the automatic introduction of own weight of structural elements, as well as due to application of loads for maximum impacts on the main structural system. Steel structures are designed in a way that elements dissipate seismic energy, by bending, and by the occurrence of non-linear distortion. In the case when we have approximate systems, nonlinear deformations are allowed at the ends of the rods or the diagonal pair. Buckling and yielding is not permitted in plastic hinge zones. Choosing dimensions of nodes is done so that the node is able to provide transfer limit bending moments and shear forces corresponding from one element to another, without the appearance of large nonlinear deformation in the node zone. Designers, guided by building legislation, design standards and the construction zone, need to decide on the acceptable risk level and then, bearing in mind the costs involved, selecting a method of achieving either full hazard avoidance or an acceptable level of hazard.

6 STRENGTHENING AND REPAIR TECHNIQUES

There is a need to strengthen structural elements that are severely damaged, without replacing them in order to be used for their original purpose. When we consider all the options for interventions, it is clear that constructors must, in addition to a survey on the site of the whole structural system, take into account the types of materials used, the supporting character of the soil, etc., consider - on the basis of causes of damages, static-constructive position of the structure. The execution of strengthening interventions on limited portion of the building has to be accurately evaluated and justified by calculating the effect in terms of variation on the stiffness distribution. Special attention has to be paid to the execution phase, to ensure the effectiveness of the intervention.

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.

It is necessary; during the structural interventions to take into account remaining distortion or deflection that could have impact on usability of these components especially if they are overloaded comparing to the original designed load. During the reconstructions in a small number of cases entirely new elements are proposed, and approach to strengthen the areas of severe deformations. In such situations, especially if the work is complex, it is necessary to do an alternative solution based on economic indicators to choose the most optimal solution. Here, the need for often necessary testing of materials (usually mechanical properties) is emphasized, because visual impressions are not guarantee in terms of their current situation.

In case of introduction of the new structural element, while removing the old one, a major problem is the procedure for their load reduction. It is not an easy task, since the load of this element must be transferred to the temporary supporting elements, sometimes even on existing, and the problem of the end supporters appear, through which load will be transferred on the unloaded surface.

There is also a method for carefully dismantling the historic riveted steel structure. Rivets can be removed by drilling a pilot hole in the center of the rivet head with a reaming head of the same diameter as rivet shank, and removing the head with a chisel or a cutting tool reserved for pneumatic hammer. The remaining part of the rivet can then be extracted from the hole with a drift pin and a sledgehammer. Although this method is not as fast as cutting torches and welding separation, it guarantees the preservation of the original configuration of the connection, requires no special lacing panels, and its application does not expose steel to the

extremely high temperatures. Field rivets usually are identified by their heads, which does not look like those formed at the workshop connections. Fields of removing rivets can be set so that the structure can be dismantled in the same manner in which it was first erected. "Reassembly" in accordance with the original method of construction can be carried out with studs.
Historic structures can also be used as "laboratory" for engineering research. They provide opportunity to evaluate durability of materials and results of various types of used construction. After the proposed period of usage of the building we can better understand the effects of duration of load through research conducted on historical structures.

7 PROPOSED INTERVENTIONS

Future interventions on the building aim to preserve the integrity and authenticity of the building, that will ensure the proper usage and maintenance in the future, adapted to the contemporary regulations considered from the aspect of safety, fire protection, etc., since the fact is that in the time when this building was designed (1958) steel structure protection were not planned and carried out. It is a reason for necessity of the fire protection system improvement.
The steel roof structural system should be adapted to the fire protection measures in order to achieve the fire resistance of the class F30 to F180.
Steel is an inorganic material and is categorized as nonflammable, but the steel bearing structure under load with heating at about 500 ° C lose their load bearing ability, and in the case of raging fire, temperatures over 500 ° C can be achieved within a few minutes. Sprinkler systems are designed to control the fire until the intervention of firefighters, but the biggest problem is the lack of protection of the load bearing steel structure of the building. Protective coatings applied to steel construction are paint, metal coatings or combinations of these two. First coat should be maintained in good condition.
In order to fulfill all requirements of the report on fire protected steel building elements, galvanization can be applied as immersion of steel structural elements in a tub of molten zinc at a temperature of about 450 ° C.
Such fire protection coating creates an insulating layer for girder, columns and girder truss.
After interventions on the building has been finished, steel structure must have technical characteristics that will, during the prescribed maintenance of the steel structure, ensure usage and prevent the destruction of a building or its parts or damages of the building or equipment due to the deformation of the steel structure. Technical characteristics of the steel structure must be prepared that in the case of fire keep the bearing capacity of the steel structure or its part thereof during a certain period of time prescribed by a special regulation.

7.1 Interventions on the roof – roof reconstruction

According to the current stage of the building entirely new roof structure has been proposed for the building. The plan predicts construction of horizontal reinforced concrete beams that will be embedded in the existing reinforced concrete beam. The project envisions the creation of an entirely new roof structure consisting of primary, secondary and tertiary girder.
It is necessary to change flat dilapidated roof completely, and to apply contemporary details, to remove the old improvised details or missing one, to make water protection such as bitumen stripe, which are almost completely melted by the heat – to change gutters, which will adequately drain the water from the roof to worn skylights replaced with new ones, with windows for collecting solar energy - the part of the building used solar panels and energy collected will be used to run the air conditioning.

Figure 7: Tower 7 -3D model of the steel structure and existing condition of the roof structure

7.2 Interventions on façade-details

The existing façade which is mostly glazed glass currently does not meet requirements of the architectural physics, since the heat energy losses are enormous. Due to the emergence of huge heat losses, at the facade is currently visible attempt of alternative solution that will contribute to lower heat losses, but in the same time it was not done in an appropriate way, and also does not meet the basic laws of architectural physics.

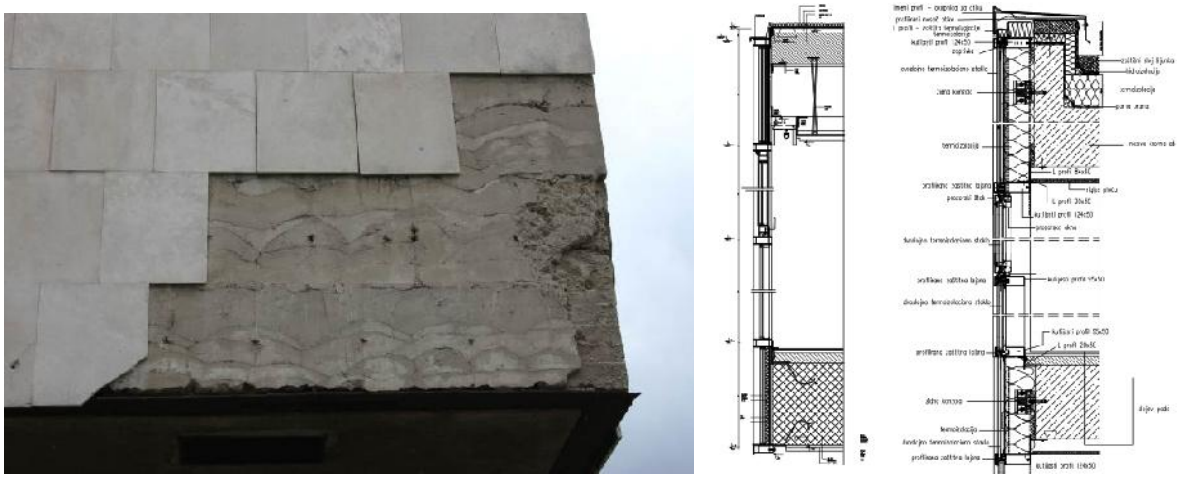

Figure 8: The current state of the facade and the proposed details of the new facade

The museum building is connected to all existing necessary infrastructure.

8 CONCLUSIONS

20th Century Architecture of Bosnia and Herzegovina has not left masterpieces that bear the character of an internationally recognized values, since the 20th century has been the period of two world wars, and as well as devastating aggression on Bosnia and Herzegovina in the last decade when the numerous authentic values, created through previous centuries, have been destroyed which has greatly changed the demographics of Bosnia and Herzegovina that will later lead to a lack of maintenance and deterioration of architectural achievements which tells the story of the tradition and history of the state of Bosnia and Herzegovina.

Recovery and rehabilitation requires a long period in which we learn and leave best practice examples that will serve to the coming generations and provide a clear picture of the historical complexity of the urban development of cities of B&H.

Therefore, it is very important from the point of view of contemporary approach towards architectural heritage, to pay attention to the good examples of architecture of the 20th century that showed the diversity of approaches in the design of buildings.

The existing buildings are under the process of degradation over time that leads to a situation where they are unable to fulfill the purpose for which they were built. Sometimes, there is a need to improve the existing building into compliance with the new requirements, or to adapt to new functions.

Sections of damaged structural elements and, therefore, the elements themselves, are brought into a phase of ultimate limit state of capacity and usability, or at least close to that state if the number of such section is sufficient to become mechanical system. Starting from these assumptions it is necessary, during the rehabilitation particularly to pay attention on: the size of residual stresses and sizes of residual deformity, because they may affect the usability of these elements. In some situations, bearing capacity, as well as for preliminary assessment, a simplified model, on the basis of simple static equilibrium conditions, as well as a graphical method can be useful. However, today, the most frequently used modeling method for checking the behavior of structural elements of the building are numeric, with the formation of the corresponding finite element mesh.

In order to be evaluated as appropriate, a contemporary intervention should meet the following criteria as: physical protection of a historic building or complex, including conservation and restoration actions, active preservation of a historic building or complex, incorporation into the modern urban matrix and permanent use.

Museum of the Revolution in Sarajevo gives a clear picture of the shaping and structural possibilities and understanding of the concept of space of the specific time, which is clearly aligned with the activities of architects in the rest of Europe.

Preservation of architectural heritage must provide a state of building that will enable its usage and function in the future.

Defining all necessary actions relating to the physical actions of preservation and rehabilitation of the building must take into account the function of the building, which has remained unchanged but adapted to the contemporary concept of museum space and should be defined through well prepared management plan.

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