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# REDUCTION OF SEISMIC RISK FOR IMMOVABLE CULTURAL PROPERTY

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**Duško Kuzović[1], Nedeljko Stojnić[2]**

[1]Faculty of Architecture, Design and Fine Arts, Girne, Cyprus
[2]Institute Jaroslav Cerni Belgrade, Serbia

**Abstract.** *The existing legislation for determining the seismic design parameters, which is used in Serbia, is defined by the "Code on technical norms for construction of buildings in seismic areas" ("Sl. List SFRJ" no. 31/81), and its amendments and amendments to ("Sl. List SFRJ" no. 49/82, 29/83, 21/88 and 52/90), as well as Code on technical standards for remediation, strengthening and reconstruction of building structures damaged in earthquakes and for reconstruction and revitalization of building structures ("Sl .List SFRY", no. 52/85) etc. The above mentioned normatives are related to the seismic risk prevention for the newly constructed buildings or their revitalization, and all of them obey to no collapse requirement. Within them, all structures are grouped into appropriate categories comprising allowed seismic risk in their service life. Having in mind their uniqueness and irreparable loss in the event of their destruction it is necessary to take all required actions in order to protect them in the event of an earthquake. All new solutions within regulations of seismic construction should be associated with the provisions of the Law on Cultural Property ("Official Gazette of the Republic of Serbia" no. 71/94). These legislative changes would result in obligation to prevent seismic hazards to which historical buildings are exposed, through standardized legal studies and interventions on buildings.*

**Key words**: *seismic risk, assessment of seismic activity, cultural heritage, preventive measures.*

## 1. INTRODUCTION

"The biggest threat to historical objects comes from engineers who are not aware of their unique values, and apply the Law literally, or are unwilling to accept responsibility for making decisions. It can be said accurately that the most of the historical objects have a choice to either be destroyed by Laws or future earthquakes" [9].

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**Corresponding author**: Dusko Kuzovic, American University, Faculty of Architecture, Design and Fine Arts, Girne, Cyprus.
E-mail: dkuzovic@gmail.com

Immovable cultural property represents an important part of the cultural heritage. They are valuable, among other things, because of their unique value as a repository of evidence on materials, building techniques and multitude of other details that we currently may or may not be able to detect. However, any reconstruction after a potential catastrophic event, deletes a part of the evidence stored in the document – the document being the structure of cultural heritage. Therefore, it is necessary to pay special attention to the protection of this category of structures from destruction by earthquakes. It is necessary to professionally and comprehensively consider the impact, risks and actions needed to protect the buildings from earthquakes.

The study of seismic risk is required for newly constructed or repaired buildings. However, there is no legal obligation to make these kinds of analyses for cultural heritage structures,. We have already concluded that the potential loss of these facilities can be irreparable. Due to various circumstances, we failed to pay attention to such important and valuable documents that are in the area of our social responsibility.

In order to avoid possible loss of the documents of cultural heritage it is required to define a specific category in agreement within the existing legal regulation for seismic protected constructions. This category would be (working) named Cultural Property Stock. It would contain structures that are declared, according to the Law on Cultural Property [14] to be immovable cultural property.

It is necessary to form two groups within the mentioned categories that would be in compliance with the Law on Cultural Heritage and its provisions in Article 2. The structures would be adopted to these groups according to their categorization that was made under the aforementioned Act. These structures represent cultural heritage of great importance and cultural heritage of extreme importance. The Cultural property group would be excluded at this point. That is because the resources of our society are limited and it is necessary to limit the obligation to study the most urgent cases. Those ought to be the structures that have the Cultural heritage of great importance and cultural heritage of extreme importance statuses. The third category (Cultural property) is the most numerous and at this moment its inclusion would be too great a burden which would undermine the efforts to protect the other two higher categories of structures. If the work dynamics were observed, and obligations to other two categories were completed, the structures that have the status of a cultural property could be included in several years time.

These are essentially the same categories that were adopted in the Law on Cultural Property [14], and that would be transferred into standards of aseismic construction. The Law on Cultural Heritage [14] has defined three categories (Cultural property, cultural heritage of great importance and cultural heritage of extreme importance). Two of these categories would be transferred into the aseismic standards (structures of great significance and structures of extreme significance). These categories would then have regulatory obligation of seismic hazard prevention. These regulations would have to be accompanied by appropriate studies and surveys. Their contents and procedures should also be defined in secondary legislation.

## 2. Reduction of Seismic Risk for Immovable Cultural Property

### 2.1. Seismic risk

In cases of buildings of cultural heritage it is a delicate matter to determine the level of seismic risk because of their age which is usually close to or more than 500 years. This means that the maximum magnitude expectancy (Mmax) is in the level of the project (Maximum design magnitude) for the structures II and III categories with expected probability of occurrence of 0.63, (according to Poisson) [12].

In Eurocode 8 (EC8) [16] for structures exposed to earthquake there are also two fundamental requirements: „a) No-collapse requirement (NCR) – The structure should withstand the designed seismic action without local or global collapse, and b) Damage limitation requirement (DLR) – The structure should withstand a seismic action with large probability of occurrence than that of the design seismic action, without the occurrence of excessive damage. In case of No-collapse requirement, the designed seismic action is expressed in terms of the reference seismic action associated with a reference probability of excedence, $P_{NCR}$, in 50 years, with importance factor, $\gamma_1$ , which reflects reliability differentiation. In this case $P_{NCR}$=0.10. Reference return period, $T_{NCR}$, for $P_{NCR}$, in 50 years is 475 years. "

Seismic risks for categories of structures of great significance and objects of extreme significance would also be subjected "to no-collapse requirement" provided that the probability of design seismic action would be less than 0.10 for a period of 50 years, that is, return period greater than 475 years which is caused by the very age of facilities. The seismic action for which they should be considered is generally more appropriate for the return period of 1000 years and more.

This implies that the category of Cultural heritage structures must be defined in the standards. It is required to define two subgroups in it: structures of great significance and structures of extreme significance. All the characteristics of the mentioned groups ought to be defined according to the Law on Cultural Property. Of course, the more important the building, the lower the level of acceptable damage on it is.

### 2.2. Level of acceptable damage

The issue of defining acceptable damage on buildings is partially defined by the situation that most structures include painted interior walls and ceilings. What the acceptable level of damage to these structures is, is certainly an issue that must be defined in multidisciplinary terms. The scope of acceptable damage on cultural heritage structures can be defined in two ways: with respect to the subgroup to which they belong, or individually for each object independently of its category. In terms of acceptable damage both subgroups have in common that there should not be any structural damage. The difference may be only in the degree and size of cracks in the walls. For example, for cultural heritage of great importance, the cracks in the earthquake of certain intensity may be acceptable while for cultural heritage of extreme significance the cracks for the same intensity earthquake may not be acceptable.

### 2.3. Goals of the study on the impact of location on building

According to these statements the legal obligation of making a Study of seismic risk assessment for the structures of cultural heritage must be established. On its basis it is possible to define the necessary interventions on the structure or its foundation soil, all in accordance with the scope of the accepted damage. The main objective of this study is to obtain the necessary data for Study of protection from Earthquake of Heritage buildings. The data necessary for preparation of the Study depend on the type of construction of the facility for which the study is done and on the terrain on which the facility is located.

In terms of structural design of the immovable cultural heritage property in the territory of Serbia, the following structural situations may occur:

1. Completely timber Structure
2. Combination of timber skeleton and filling of adobe or fired brick
3. Structures entirely built of brick
4. Structures built of hewn stone, with single or double face
5. Structures built of roughly hewn stone, with single or double face
6. Structures made of brick and timber or brick and steel
7. Construction of reinforced concrete.

Each of these structural solutions behaves differently during earthquake and requires a specific set of data necessary for proper analysis.

Facilities for which the Study of Earthquake protection should be made should be located in the categories of structures defined by the Law on Cultural Property [14] that is, which are entered in the Register of Cultural Property in accordance with Section 6 of the Act.

According to the type that is the immovable cultural property defined in Article 2, paragraph 2, of the Act: cultural monuments, spatial cultural-historical entities, archaeological sites and places of interest;

According to the category, cultural property of great significance and cultural heritage of extreme significance are classified in the group for which there is obligation to make this analysis. The cultural assets group could not be included, at least in the first round of activities because there are too many of them.

## 3. Study for Evaluation of the Location Seismicity

The methodology proposed for the assessment of seismic activity and the impact on the location of cultural heritage structures involves several steps [12]:

1. Defining the level of seismic hazard
2. Geological and seismotectonic studies
3. Profiling of surface geology
4. Determination of stiffness and layer damping
5. Evaluation of characteristics of potential earthquake
6. Defining the oscillation of the ground surface and the range of responses

### 3.1 Choice of hazard level

Selection of the appropriate level of hazard, should be in accordance with the established standards [12] and provide basic data for quantitative analysis. The choice should be based on two possible scenarios in order to avoid a collapse everything depending on the specificity of the object:

1. Earthquake 500 - year return period,
2. Earthquake 1000 - year return period.

### 3.2. Seismotectonic analysis of the area

Studying regional geology should be aimed at defining the zone through which an earthquake can be released. These data are based on geological, tectonic and seismological data. This study should conclude:

1. Regional deformation,
2. Mapping of characteristic potential hot spots in the zone about 100-150 km from the location for which the study is made,
3. Defining the type of fault,
4. Evidence for and against recent movements along the faults.

### 3.3. Geological, engineering-geological, geophysical and geotechnical characteristics of the location

This analysis should be done on the basis of the boreholes drilled at the site and their geophysical characteristics, velocity of propagation of Vp and Vs waves trough investigated media, [5]. The boreholes should define the location of the bedrock and composition and thickness of the layers from soil surface to the bedrock.

### 3.4. Characteristics of expected earthquake

Basic characteristics of earthquakes are grouped into:

1. Expected magnitude on the Richter scale
2. Rate of seismicity
3. Maximum acceleration and its weakening depending on the fault line site
4. Duration of earthquake
5. Predominant period
6. Time-acceleration ratio at the level of foundation.

## 4. SEISMIC SECURITY PLAN

Seismic security plan for cultural heritage structures is based on the following regulations: The assessment of seismic risk, which includes evaluations of seismic hazard and vulnerability of the structure under the influence of the seismic action. Vulnerability assessment implies identifying structural building system and analysis model. The obtained result of the analysis is evaluation of structural response to earthquakes of various intensities based on which are defined alternative methods of reinforcement and costs of corresponding solutions [17]. Seismic security also comprises a plan of building strengthening development and estimating payback period as well as selecting the most appropriate scheme and making a plan of action [6].

Interior structural features (consisting of structural features of the building, object layout geometry, vertical section geometry, and craftsmanship and quality of building production), External structural features (features are related to the level, quality and awareness of action to prevent deterioration and maintain the facility, environmental pollution by gases and vibration).

The action plan should be drawn up for each object individually because each of them has its own special characteristics and requirements. The development and implementation of the plan requires synchronous work of several experts.

Earthquakes are a natural phenomenon that is an integral part of life. Obligation of the society, in addition to protection of the human lives is to protect the cultural and historical structures which represent the record of the past. History of each structure in Serbia was marked by a series of earthquakes which they have, to a greater or lesser extent, survived. So it can be rightfully said that the structures live between two earthquakes [7] [8]. Earthquakes know no administrative boundaries and we should be ready for them within the limits of our knowledge and economic power.

It should be borne in mind that the earthquake seeks the weakest parts of an object and that weaknesses may not always be visible on the surface. Also, weak details do not always have to signify the material, but can be form of the structure, form of its parts or poor building procedures.

Cultural heritage structures represent a special category in the building stock of the country and they should have a special treatment in relation to other categories of objects in the country. Cultural heritage structures have multiple roles in the society. Firstly, if used as residential or commercial buildings, they have a function just as other facilities that are not considered the monuments of cultural heritage. Then, they represent documents of people's past, culture and ideas that marked one period. Therefore they are unique and unrepeatable and their unique value requires special attention and behavior towards them. Procedures applicable to other facilities may or may not be wholly applied to cultural heritage objects. In addition, especially because of the uniqueness, all the actions taken must be more carefully considered than those taken for new building.

In modern life, these structures are involved in the tourism economy and represent the most common targets of tourist destinations. In terms of the total amount of income from tourism, in comparison to the natural resources that are also offered, heritage buildings generate just as much or more revenue. So, on the basis of today's tourism potential, they can be considered as commercial facilities, of course if they are accessed in a proper and contemporary way.

The physical records comprised by the heritage structures may be grouped in the following three groups: records of the form, record of material and records of construction techniques. Each of these records must be preserved for future generations. Also, their loss due to accident, that is earthquake must be prevented. All the activities conducted in this direction must be in the form of study which must be periodically reviewed due to the time elapsed, legislative changes or because of emergence of new technical knowledge. Study of earthquakes can be done as an independent study or a feasibility study, which is an integral part of the facility maintenance study.

The protection of cultural heritage from earthquake must be an integral part of the maintenance program of each structure. Decisions defined in such detailed studies must not be permanent, but must be periodically renewed in accordance with the needs and improvements in the knowledge about this type of protection. Such studies must be made by experts, exclusively qualified, and not by benevolent volunteers which, due to the lack of funding and staff, is the case sometimes. Also, this must be a team work and not an individual effort, no matter how skilled an individual might be [1] [2] [3] [10] .

Evaluation of structural reaction should be based on existing technical and statistical knowledge. Although one cannot accurately predict the moment and intensity of an earthquake, on the basis of available technical knowledge one can predict the structural response for different scenarios in terms of intensity and characteristics of earthquake. The purpose of such analysis is the first selection of the most optimal method of prevention and maintenance [4]. Information that can be gathered concern the facility and foundation soil on which the same is located. In addition, the response of the structure to an earthquake can be brought into the state of predictability by way of its maintenance.

Assessment of structural reactions can be classified into four basics groups:

1. Analysis of seismic ground with the impact of surface soil on which the facility is located
2. Analysis of the characteristics of the structure
3. Analysis of reinforcement and prevention methods
4. Analysis of the facility maintaining methods

### 4.1. Characteristics of the ground on which the facility is located

Ground characteristics analysis should gather information on the status of land and ground water of the immediate location where the facility is located. Using the terminology of the daily construction practice, this study is equivalent to the geotechnical study that is done in a particular location for the new building. The boundaries of the study intervention are determined on-site in agreement with a geology engineer and architect conservator [11]. The study should provide several groups of information required for further analysis: the characteristics of soil and characteristics of groundwater.

Information for preparation of this study is collected in the field and in the laboratory. As a part of the field work, it is necessary to perform the following actions:

1. The field survey,
2. Make exploratory pits to the depth of foundation,
3. Perform a detailed engineering-geological mapping of the pit,
4. Take disturbed and undisturbed soil samples from exploratory pits,
5. Geophysical analysis.

The laboratory work comprises geomechanical laboratory tests which are performed on disturbed and undisturbed soil samples taken in the course of exploratory work:

1. natural soil moisture
2. particle size distribution of the soil
3. density of the soil, as in the natural, and in the dry state
4. internal friction angle
5. cohesion
6. compressibility modulus

Within the analysis of the characteristics of groundwater it is necessary to obtain information on the level of groundwater and level of material saturation with water.

### 4.2. Structural characteristics

Structural characteristics can be grouped into three basic categories: structural shaping characteristics, constructive characteristics and characteristics of the craft.

Structural shaping characteristics refer to the information on the geometry of the structure layout, vertical section geometry, mass schedule, schedule of eccentric details and schedule of all other elements of building forming that may affect its behavior during earthquakes [10].

Constructive structural characteristics provide information on:

1. Constructive structural characteristics,
2. Characteristics of the material from which the structure is made,
3. Installations in the building.

Those are information about: foundation method, the masonry, method of preparation of the holes and wall surface, the method of making the mezzanine construction, making roof construction, making staircases and all the other specific parts of the building that may affect its behavior during earthquakes.

Information on material of which the structure was constructed. This group provides information on the type and features of stone, brick, wood and metal that was used for construction.

Information on binders in the structure, such as plaster, wood and metal links and so on, provide information on the quality, consistency and composition of the bonding mortar for masonry construction. Further, on the features of wood and masonry, joint timber pieces, metal with masonry and wooden elements.

Installations in the building may be damaged during the earthquake. They can further produce many harmful effects, such as water system leaking in the wall of unbaked bricks or painted surface of the wall or ceiling of the room, rupturing of gas installations that could cause a fire and so on.

Artisanal performance characteristics of the building are equally valuable and equally influential on the performance of a building during an earthquake. They are particularly prominent in masonry where each element takes part in the load reception. Good craftsmanship of a building has a large impact on the behavior of the structure during the service, the cost of service and building behavior during accidents. Poor craftsmanship in building masonry (such as the failure of joints or improper record stone or brick) may nullify much of the quality of building materials and binders that are applied.

For example, improperly prepared mortars may have uneven bonding power regardless of the quality of the material that forms the mortar. Cracks in the wall can lead to infiltration of water and weakening of the wall structure characteristics. Poor details of connections between of the timber mezzanine and stoned wall, or bad details of connection between roof construction and walls can also lead to the destruction of part or all of the facility.

### 4.3. Methods for building strengthening and prevention

Overall scope of building strengthening and prevention methods that can be applied to objects of cultural heritage is defined by the principles and ethics of conservation. Of the total scope of potential interventions it narrows down to interventions that are acceptable for a given object. At this point it should be mentioned that the basic principles of technique that could be applied are: uninvasive, reversible, and easy to install and remove, not damaging the object (or at least not its primary values) for which it was chosen to be cultural heritage monument.

The design of the current status of the object is a document which is necessary in the process of maintenance, repair or reconstruction after the accident. Having in mind that many facilities do not have adequate documentation, the losses caused by the quake may be higher than the level that our society can accept [15]. Therefore, the documentation that is made properly, is irreparable material. In the process of creating documents for this purpose it is necessary to prepare it as if the structure is built from scratch and without any current status. The documentation made in such a way will be a sufficient source of information for someone who did not participate in its production process [9]. The lack of documentation should be regarded as a serious threat to property and diminution of assets value of a nation.

Temporality of work, materials and construction skills. At any intention or intervention it should be kept in mind that the state of technology is temporary. That the building materials and construction techniques improve everyday. That temporary but removable solutions must be found, while waiting for a new technology which will replace them.. It should be kept in mind that reinforced concrete is not anymore considered that friendly to the old structures as it used to be at the beginning of its application, when all its advantages and disadvantages were not yet known.

Technical characteristics of prevention depend on the state of science and technology at the time, available materials and craft skills of available contractors. Methods taken into consideration depend on the aforementioned factors. One should avoid to consider only one solution, and should always have several of them. A final decision on the selection of the final solution should be made after comparison to the economic analysis of each proposal [6].

Economic prevention characteristics participate almost equally in the selection of the technical aspects. Financial ability of the investor, the effects obtained for the invested money, payback period determine the type and scope of intervention [6]. Ratio of technical and economic aspects of the investment provides the final picture of the scope and type of technical procedures.

### 4.4. Facility maintenance

Due to a number of uncertainties about the historical property, which cannot be resolved, in spite of available devices and methods by univasive methods, one should be aware that it is impossible to predict the reaction of the historic buildings to earthquake, as it can be done with facilities designed and built in modern conditions [10].

On the other hand, the location of the new earthquake and its strength is unpredictable to an even greater extent. Therefore, assessments of behavior of a historical structure can be partially predictable and all depending on the level of maintenance and expertise with which it performs. Moreover it should be noted that while defining the current situation the necessary steps of renovation and prevention should be simultaneously provided. Defined elements should always and regularly be re-evaluated in accordance with the situation on the ground and new facts [13]. In any case, it is impossible to achieve complete security, only the acceptable level of risk for a particular structure can be stated.
Three concepts are included in the assessment of risk: the risk (probability of a devastating event happening at a certain place), vulnerability (degree of damage that may occur from an earthquake of a given intensity), and risk (possible damage combined with the previous two concepts. It can be removed, transferred, divided, accepted or concentrated.) [13].

Earthquakes return period is the time interval between two earthquakes with a specific intensity in a specific location. As the assessment is based on human knowledge and statistical methods, very often, for safety, that period is shortened and so this can lead to unnecessary or insufficiently conceived interventions on historic buildings just because of the lack of time needed for research and design.

The work of experts who perform impact analysis and suggest measures should be team one. Complexity of cultural heritage structures can no longer be dealt with only in one person, most frequently an architect. Do not forget that earthquake seeks and finds the innermost and weakest point in the object. Finding these places is a job for the most qualified and most conscientious engineers. These engineers, as well as in any other life situation cannot be as available as other experts in the same industry.

Teamwork is essential for analysis of cultural and historical structures because a quality analysis is a multidisciplinary procedure that combines extensive knowledge and experience that is no longer possible for just one person. The team should include an architect (as holder of the task), geologist, structural engineer, archaeologist and chemist to analyze the material. As it is stated in the beginning, they should be prepared to make decisions and respond for them. This requires also broader conditions apart from the human factor of worker, job contractor.

## 5. Preventive Measures

It should be kept in mind that, due to their age, cultural and historical monuments have been able to survive many earthquakes. This means that the resistance of the structure depends on characteristics of the location and degree of the structure preservation. So it can be said that studying building history, particularly the intervention on the construction site, gives fully informed picture of the events that certain building has survived, what the consequences of on location and structure were, the types of possible measures that can be taken, the reasons for their taking, required materials and construction techniques.

The most important features of the analyzed structures can be classified into following groups: Impacts of location, characteristics of the soil on which its foundations were, ground water features, modern large-scale intervention in the wider area of the building.
Impacts of internal structural properties. This group comprises: structural features of the building (foundations, walls, arches), building layout geometry, the geometry of the vertical section, craftsmanship and quality of the facility superstructure. For example, greatest weakness of the masonry buildings were places of the openings (doors and windows) in walls and bonding with the walls on one and floor or roof structure on the other side.

### 5.1. Overview of possible activities

Analysis of the soil around and underneath the building represents basic and initial operation of the facility preparations. First of all micro-zoning should reveal any weaknesses in the soil and geological strata all around and under the building that may affect the stability of the structure. Then, the groundwater level also provides additional information.

Inspection of the foundation should provide image of their condition and especially: the relationship between the foundation and the underlying soil on the contact surface, the soil condition just under the foundation, the type of building material and mortar and its condition. Inspection of foundations can be very expensive because it is necessary to excavate a sufficient number of probing pits in order to give the true picture of the state of the building foundation. Defining building response spectra is based on expecting earthquake at the particular site [9].

Stiffness of the building in relation to the ground is extremely important. Also the whole building can vibrate at a certain frequency, which can be increased or decreased due to cracks or destroyed parts that may occur in certain parts of the facility and act as a reinforcement of basic vibration [3]. Length of vibrations can have a big impact. In these situations, some parts of the building that do not have the same stiffness degree can operate as independent systems that add new direction and intensity of the vibrations in the system. Some experience indicates that soft ground does less damage to the building than rocky ground because of the speed and modes of transmission of vibrations from the ground to the building.

Building structural analysis can be classified into three groups:

1. Geometry of the building layout
2. Geometry of the vertical section of the building
3. Structural characteristics

Building layout geometry gives file of basic system stability. Circular, square and octagonal forms, that is those which are doubly symmetric provide the best response to the impact of the earthquake. Within this system some elements that might vibrate differently from the building layout body can have a big impact (chimneys, towers, balconies).

Vertical section geometry has its own range of effects. For instance, when it comes to forts which were demolished in most part, and do not retain the original height of the outer walls, they cannot be considered the structures great influence. But if we consider form of forts in their final form, parts of the structure such as machicolations, consoles, asymmetric bay windows, they all support vibrations that are asynchronous to basic rhythm vibrating of the structure during the earthquake.

Structural characteristics are based on the material used for building walls, connecting material that was used, the masonry, and craftsmanship skills during construction. The stone that was used for the construction of forts and housing facilities is usually limestone. Stone processing has been minimal and mostly roughly hewn or crushed one was used. The binder was hot or plain lime mortar. As the stone is stronger than mortar, mortar can be expected to fail in the structure. It should also be added that the mechanical properties of lime mortar decreases over time and so it loses binding capacity. In addition, mortars do not have uniform quality throughout the mass which causes breakage along lines of least cohesive force.

Analysis of the structure must be made observing three aspects: the analysis of the construction as a whole, the analysis of structures at the level of individual elements and analysis of the construction as the material from which it was made [3].

Structural systems that make a building are masonry (brick walls of stone in lime mortar), timber (structural floors and roof constructions) metal (connection details of structural components, generally on a small scale). In the event of an earthquake these three systems, due to differences in the characteristics, react differently. The characteristics of the structural response to earthquakes depend on the weakest point of this composed system.

## 6. Conclusion

Cultural heritage structures represent an important and valuable architectonic document which, due to a number of problems that have afflicted our society, became more and more neglected. Apart from the risk resulting from the lack of maintenance, these facilities are at risk from earthquakes on a daily basis. Resistance of heritage buildings to earthquakes is based on layout geometry, vertical section geometry, structure characteristics and craftsmanship and skills used in their building.

Immovable cultural heritage buildings according to their purpose and significance could not be classified in any of the categories available in the current legislation on aseismic construction. Also, they could neither be defined in evaluation of earthquake impact level which is intended for any of the available categories in legislation. Current seismic vulnerability of buildings now needs to be analyzed depending on the immovable cultural heritage structure category under the Law on Cultural Heritage, building organization, type of processing interior and exterior wall surfaces, material from which it was built, type of foundations, immediate ground on which the building is built and the state of the surrounding area, groundwater regime and various associated effects of suffusion and so on. The aforementioned statements indicate the complexity of evaluation of seismic hazard to which a historical building is exposed (especially the older ones, or made of less durable materials). Also, the previous statements indicate that special attention must be paid to the legal framework that defines the regulations pertaining to seismic hazard.

Cultural - historical buildings due to their values have become more important than the original, current or planned functions. Assuming that we can determine the type of the object and purpose of the of immovable cultural heritage and therefore the seismic risk to which it is exposed from today's point of view it is possible to determine the risk to which the facility is exposed at the moment.

Based on the importance of heritage buildings according to the existing legislation, they should to be designated as the first category structures, or those outside the category (which are the highest in the hierarchy).

Protection of historical buildings from the earthquake effects should be moving in the direction of a detailed analysis of structural and other parameters of the building stability and of the soil where they are located etc. It is necessary to define the repairs for the structures of immovable cultural property within certain categories, which would provide a broader framework for their complete maintenance.

Under the regulations, the conditions under which historical buildings are discussed should be specifically defined. It is necessary to introduce a special category that would be called the cultural heritage structures (working title). In these categories it is necessary to introduce two groups: a group of cultural heritage structures of great significance and the group of buildings of extreme significance.

The plan for seismic security of the heritage facility is based on the following steps: Assessment of seismic hazard, Seismic risk assessment, Identification of the structural system and model of analysis, Evaluation of structural response to earthquakes of different intensities, Defining the type and extent of damage for different expected intensities of an earthquake, Defining alternative methods of reinforcement and estimating the cost of each solution, Developing reinforcements plans and prediction of the payback period, Selecting the most appropriate scheme and making a plan of actions.

Four basic groups of influence that affect seismic resistance of the building can be defined: Seismicity with site soil characteristics (seismic activity in the wider area), Characteristics of the soil on which its foundations were, ground water features, modern large-scale intervention in the wider area of the building, Interior object features (consisting of structural features of the building, building basis geometry, geometry of the vertical section of the facility and the craftsmanship and quality of the building), External object properties (properties are related to the level, quality and conscientiousness of action on maintaining the facility and preventing deterioration, environmental pollution, gases and vibration).

The action plan should be drawn up for each object individually because each of structures has its own special characteristics and requirements. Several experts must simultaneously work on the development and implementation of the plan.

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# SMANJENJE SEIZMIČKOG RIZIKA ZA NEPOKRETNA KULTURNA DOBRA


*Postojeća zakonska regulativa za odredjivanje projektnih parametara seizmičnosti, koja se koristi u Srbiji,, definisana je „Pravilnikom o tehničkim normativima za izgradnju objekata visokogradnje u seizmičkim područjima“ („Sl. List SFRJ“ br. 31/81), i njegovim izmenama i dopunama („Sl. List SFRJ“ br. 49/82, 29/83, 21/88 i 52/90). Pored ovog Pravilnika koriste se „Zbirka Jugoslovenskih pravilnika i standarda za gradjevinske konstrukcije“ (Knjiga 1, 1995), kao i preporuke „Evrokoda 8“ (2004). Navedeni normativi odnose se na procenu seizmičke opasnosti za novogradjene objekte. U okviru njih svi objekti su svrstani u odgovarajuće kategorije za koje je predvidjen dozvoljen seizmički rizik u okviru njihovog veka eksploatacije. Međutim, u našoj okolini postoji mnoštvo objekata nepokretne kulturne baštine koji pretstavljaju jedinstvene dokumente za sadašnje i buduće istraživače. Imajuću u vidu njihovu jedinstvenost, unikatnost i nenadoknadiv gubitak u slučaju rušenja potrebno je preduzeti sve neophodne mere kako bi se zaštitili u slučaju zemljotresa.*

*Neporektna kulturna dobra, su vremenom, i njihovim značajem izašli iz okvira kategorije koja bi im se mogla pripisati prema zvaničkoj regulativi u kategorije objekata višeg značaja. Budući da značaj objekata nepokretne kulturne baštine podrazumeva veću konstruktivnu izdržljivost na seizmička dejstva neophodno je izvršiti izmenu postojeće zakonske regulative o aseizičkom građenju i definisati posebnu kategoriju za istorijske objekte. U okviru navedene kategorije objekata potrebno je uvesti dve podgrupe: objekti od velikog značaja i objekti od izuzetnog značaja. Sva nova rešenja u okviru regulative o aseizmičkom građenju trebaju da budu povezana sa odredbama Zakona o Kulturnim dobrima („Sl. glasnik R. Srbije" br.71/94). Iz ovih izmena zakonske regulative bi proistekla obaveza prevencije seizmičke opasnosti kojoj su izloženi istorijski objekti kroz zakonski standardizovane studije i intervencije na objektima.*

Ključne reči*: seizmički rizik, procena seizmičke aktivnosti, kulturna baština, preventivne mere.*