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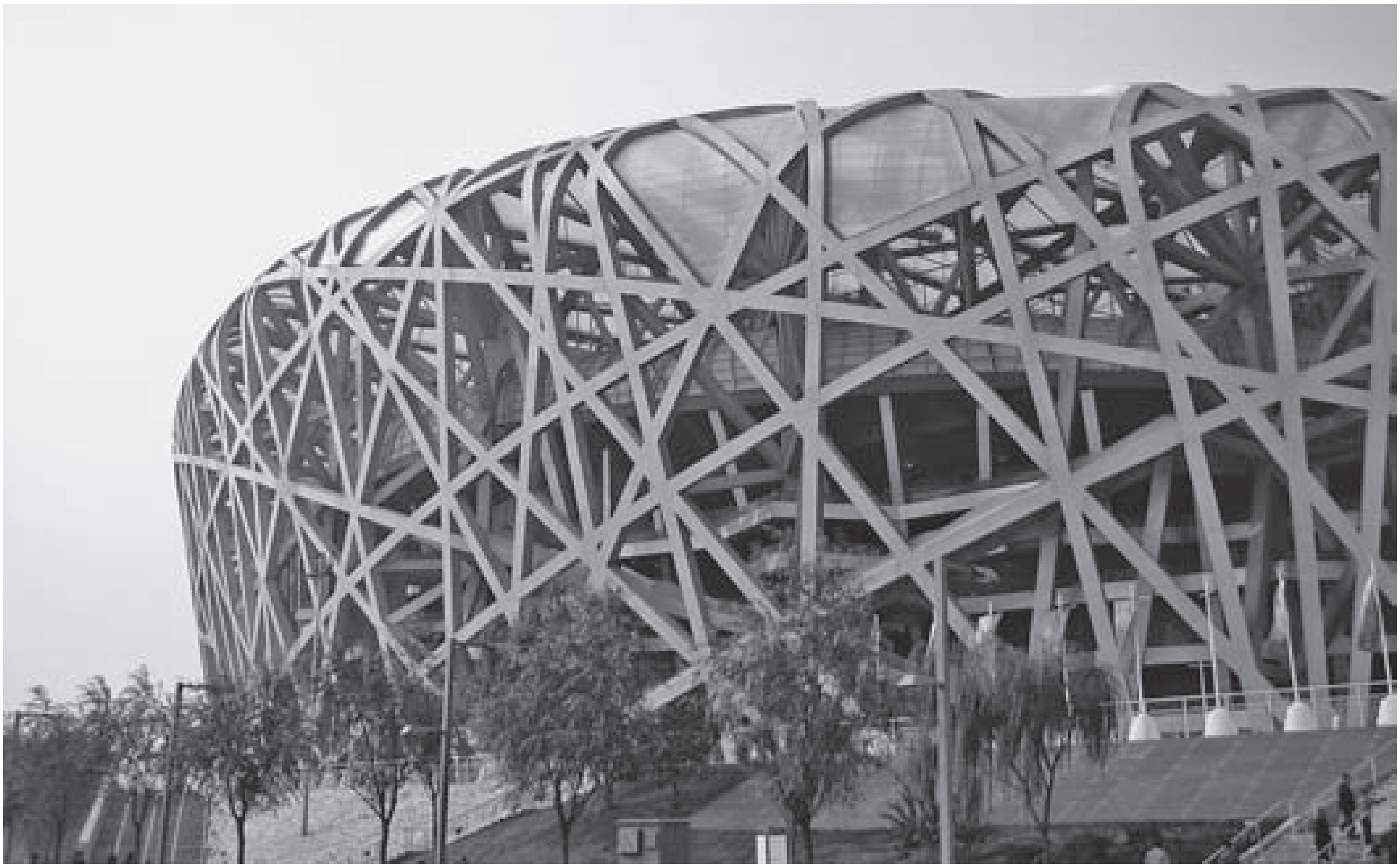

Fig. 1 Example of a building with high level of earthquake architecture index (”force microfragmentation”): project of the Olympic stadium ”Bird’s Nest” in China
Sl. 1. Primjer zgrade s visokim stupnjem indeksa seizmičke arhitekture („mikrofragmentacijska sila”): projekt olimpijskog stadiona „Ptičje gnijezdo” u Kini

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Assessment of Earthquake Architecture as a Link between Architecture and Earthquake Engineering

Procjena seizmičke arhitekture kao veze između arhitekture i seizmičkog inženjerstva

EARTHQUAKE ARCHITECTURE
EARTHQUAKE ENGINEERING
EARTHQUAKE RESISTANT BUILDINGS
EVALUATION CRITERIA
IDENTITY
SAFETY

SEIZMIČKA ARHITEKTURA
SEIZMIČKO INŽENJERSTVO
ZGRADE OTPORNE NA POTRES
KRITERIJI VRJEDNOVANJA
IDENTITET
SIGURNOST

The paper deals with the assessment of earthquake architecture in the sense of the overlapping requirements of modern earthquake engineering and modern architecture, which can use structural logic as an architectural expression. The so-called earthquake architecture has arisen as a consequence of a special approach to architectural design, which draws its inspiration from earthquake engineering and where the elements or measures of earthquake-engineering technology are articulated as special elements of architectural expression.

Ovaj se članak bavi procjenom tzv. seizmičke arhitekture u smislu preklapajućih zahtjeva modernoga seizmičkog inženjerstva i moderne arhitekture, koja može koristiti konstruktivnu logiku kao arhitektonski izraz. Tzv. seizmička arhitektura pojavila se kao rezultat posebnog pristupa arhitektonskom projektiranju koji nalazi inspiraciju u seizmičkom inženjerstvu i gdje su elementi mjera seizmičkoinženjerske tehnologije oblikovani kao specijalni elementi arhitektonskog izraza.

Introduction

Uvod

The paper deals with the problem of the architecture of buildings in earthquake prone areas, where the necessity for a well-designed structure, compliant with the requirements of earthquake resistant construction, is extremely important (Figs. 2 and 3). Structural systems ensuring earthquake resistance can be reflected significantly on the architecture of buildings and they undoubtedly have an effect on modern architecture, which can use structural logic as an architectural expression or as "a determinator of architectural meaning". This method, used by architecture in response to earthquake threats, is precisely the source of special architecture, which, particularly in the last couple of decades, can be identified as specific for earthquake prone areas. (Figs. 3, 4 in 5). The so-called "earthquake architecture" has arisen as a consequence of a special approach to architectural design, which draws its inspiration from earthquake engineering and where the elements or measures of earthquake-engineering technology are articulated as special elements of architectural expression.[1]

Earthquake architecture represents an intermediate link between earthquake engineering and architecture, which eliminates the problems related to the lack of knowledge and the inability to develop special and, within the frameworks of earthquake resistant construction, original architecture. Following are the more important reasons for such a situation:

– inadequate or insufficient response of architecture and architects to earthquake threats,
– disinterest of many architects in the problems of earthquake safety, leaving decisions to technical professions, which can lead to abandoning architectural concepts and to inconsistency in architectural expression,
– lack of knowledge and unfamiliarity with construction methods in earthquake prone areas,
– the problem of cooperation between architects and engineers, particularly in the initial phases of building conceptual design,
– lack of a system ensuring continuous education and information, and
– lack of methods for evaluation of architecture from the earthquake safety viewpoint

The paper concentrates mainly on the last point mentioned above and presents a proposal for a method of evaluating earthquake architecture. Architectural-aesthetic criteria, in the architectural theory of modern times in general, distinguish between technical-utilitarian and aesthetic-architectural evaluation. Evaluation of architecture originates in the process of an architect's activity, the development of which through history also determined the development of architectural criticism. In doing so, it determined – differently through different periods – a set of criteria for evaluating the built environment.[2] Among the general architectural criteria, which primarily dealt with art, composition, aesthetics, functionality and placement in space (context), it was always possible to find criteria which related to structure and strength.

For our research, the proposed evaluation methodology was deliberately limited to the evaluation of the interconnection of architecture and earthquake engineering structural logic. We have established that adequate evaluation of these two complementary fields needs a wide variety of quantity and quality criteria, which shows the complexity and essence of earthquake or seismo-logical architecture. For proper evaluation, we need a detailed insight into the plans and thinking process of the designer, which cannot be replaced by even the most sophisticated visual approach. The methodology for the evaluation and identification of earthquake architecture is usable for practical and educational purposes as well as for theoretical research studies. The main reasons for introducing the evaluation method are:

– recognition, comparison and identification of earthquake architecture,

1 Reitterman, 1985; Charleson, Taylor, 2000 and 2004; Garcia, 2000; Slak, Kilar, 2007

2 Alberti, 1986 (1485); Košir, 2000b; Norberg-Schultz, 1965; Saunders, 1999

3 Gregotti, 1983

– review, evaluation and analysis of the present state in the field of earthquake architecture,

– enhancing the identity of special architecture in seismic areas,

– promoting progress (in earthquake engineering as well as in architecture) and

– promoting cooperation between professions.

The Significance of Structure in Architecture Evaluation

Značaj strukture u vrjednovanju arhitekture

The term ”architecture”, from the first buildings onwards, comprises the knowledge of structures (statics), art (harmony, composition etc.) and trade skills (realization). According to Vitruvius, the work of an architect combines the activities of an engineer and an artist, which means that this also holds true for architecture itself. We can also say that functionality in Antique architecture was subordinated to symbolism and culture (aesthetics), which at the time of the great column orders nevertheless originated in structure or construction. In 1983, Vittorio Gregotti wrote:[3] ”Before transforming a support into a column, a roof into a tympanum, before placing stone on stone, man placed the stone on the ground to recognize a site in the midst of an unknown universe: in order to take account of it and modify it”. Thus symbolism comes first, then strength and then beauty. Later on, when architecture started dealing with more profane, useful buildings, symbolism was increasingly complemented by utilitarianism. The culmination of all this knowledge in one person in the broadest possible sense is experienced by an architect-artist-constructor in the Renaissance. In the middle of the 15th century, L. B. Alberti described an architect as a person he stretched between Art (1) and Science (10). Between them he stated eight intermediate postulates, which are actually concrete criteria for architectural evaluation: (2) Method, (3) Thought and Invention, (4) Execution – realisation, (5) Movement of Great Weights – structure, (6) Conjunction, (7) Amassment of Bodies, (8) Beauty and (9) Adoption to the uses of Mankind – usefulness.[4]

After the Renaissance and the periods of Mannerism, Historicism and Classicism, the Industrial Revolution thoroughly changed the construction profession. The emergence of new materials, new machines, new engineering techniques, and new building requirements made it increasingly difficult for any person or organization to master every facet of building design and construction. The complexities of construction increasingly became the domain of experts, who complemented the architect's efforts.[5] Architecture thus became a legitimate professional discipline with the occurrence of the first scientific research publications in the middle of the 20th century. Together with this, there also appeared the problem of comparability and evaluation in architecture. Evaluation is no longer defined in terms of the architect's work description, but with the definition of architecture as an independent science.

In buildings, a structure has the same role as a skeleton in living creatures, where it defines their figure, proportions (appearance) and functioning. Therefore it can be inferred that the architecture of a building is in most cases defined by a structural system and by current achievements in the construction profession. Throughout the history of architecture, we can observe the effort to conquer the force of gravity, attempts to bridge large spans, and to construct buildings as tall as possible.[6] Engineering achievements were the basis for the construction method which through its own structural principle affected the entire architecture. Since structural design is crucial for architecture, it is entirely appropriate that it takes an important role in architecture evaluation as well.

In searching for evaluation criteria, the most frequent starting point is usually Vitruvius' postulates that in architecture three criteria need to be fulfilled: concerning structure (firmitas), function (utilitas) and beauty (venustas). With the development of architectural theory these criteria were complemented by numerous more detailed starting points and subdivisions, among which we most frequently come across space (urban) aspects, since, as it was established by Norberg-Schultz already in 1965: ”...architecture which controls and regulates the relations between a man and the environment at the same time defines its mission.”[7] Architecture is thus not an idealized form, placed in space, but a consequence of starting points offered by space as it is evaluated, read and analysed in the process of creation. In this way architecture is becoming more objective or at least arguably subjective. Although an entirely objective methodology for dividing (or vice versa: combining in the process of creation) of architecture does not exist, we struggle to be as objective as possible.[8] In doing so, an architect takes full responsibility for space, which he can upgrade, neutralize, mutilate

Fig. 2 Building collapsed in earthquake – consequence of architectural design

Sl. 2. Zgrada srušena u potresu – kao rezultat arhitektonskog projekta

Fig. 3 Buildings damaged in earthquake – consequence of architectural design

Sl. 3. Zgrada oštećena u potresu – kao rezultat arhitektonskog projekta

4 Alberti, 1986 (1485)

5 Lewis, 2001

6 Košir, 2000.a

7 Norberg-Schultz, 1965

8 Košir, 2000.b

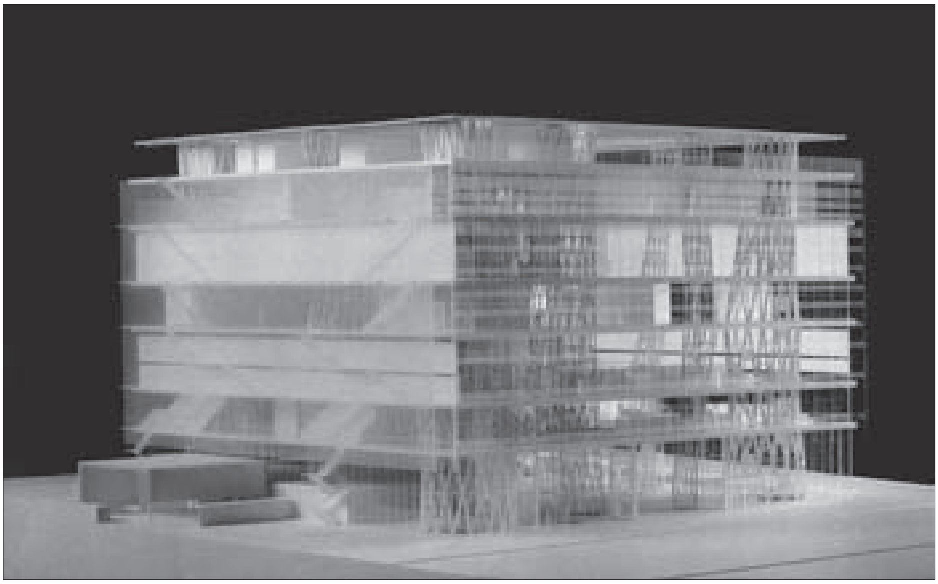


Fig. 4 Example of a building with high level of earthquake architecture index (”force microfragmentation”): Municipal multi-media library in Sendai

Sl. 4. Primjer zgrade s visokim stupnjem indeksa seizmičke arhitekture („mikrofragmentacijska sila”): gradska multimedijalna knjižnica u Sendaiu

Fig. 5 Example of a building with medium level of earthquake architecture index (identification of architecture with seismic design): tectonic (trapezoidal) shape of the Hancock Building in Chicago with visible bracings over the facade

Sl. 5. Primjer zgrade sa srednjim stupnjem indeksa seizmičke arhitekture (identifikacija arhitekture sa seizmičkim projektiranjem): tektonski (trapezoidni) oblik zgrade Hancock u Chicagu s vidljivim zategama na fasadi

etc. The first Vitruvius' postulate ”firmitas” remains through history a somehow obvious condition for the realization of architecture. It is even so obvious that in later evaluations it is almost excluded or marginalized. However, the criterion of strength in evaluation can be one of the most objective and unambiguous.

In more recent systems of evaluation, the number of points used to evaluate architecture has increased, desiring to treat everything that architecture is supposed to include as thoroughly as possible. Unfortunately, such extensive models have led to inconsistency and discrepancy. An older division technique – the theory of categories, formed already in Aristotel's Organon, comprises 12 points; in addition to 1) the introductory one (which is distinctly intuitive, subjective or a matter of the first impression) and 12) the concluding one (which comparatively marks the meaning of created space), also ten analytical ones.[9] For the needs of architecture, they can be simplified and defined as: 2) context, 3) identity, 4) function, 5) composition, 6) experience, 7) position, 8) experience in movement, 9) measure, 10) connection into a whole and 11) texture and colour. We can notice that safety and structure design, except within ”function” (usefulness) and perhaps ”connection into a whole”, is not dealt with separately. But, with regard to meaning, it in no way comes near to the Vitruvian division, where it took up one third. Indeed, the above mentioned criteria treat architecture as art and maybe also philosophy, but they in no way treat it as measurable science. W. S. Saunders states only six most frequent criteria, from which it follows that architecture should: 1) be art, 2) be beneficial to the socially and economically underprivileged or, at least, improve the quality of life for any user, 3) revive the ”best” traditions of design, 4) be well-constructed, 5) allegorically express the spirit of our age and 6) embrace, explore and express the desires and energies of ”ordinary” people.[10] Here structure design presents one sixth (point 4), indirectly almost one third (points 2 and 3) of evaluation, but it is actually present in all six points, which highlights the fact that architecture is complex and complicated.[11]

The Development of Earthquake Architecture

Razvoj seizmičke arhitekture

This paper is interested in the specific problem of construction in earthquake prone areas, as the demands of earthquake safe construction can reflect significantly in the architecture of buildings. Structural systems which ensure earthquake resistance undoubtedly have an effect on architecture, therefore the latter as a complex phenomenon is usually forced to make compromises. Examples where elements of an earthquake resistant structure have a negative effect on functionality, appearance, composition and other architectural parameters are all but rare. But in such cases the stability of a building as a whole is more important, which is emphasized also in Venturi's chapter The Obligation Toward the Difficult Whole, where it is stated that the seeming irrationality of one part is excused by the rationality of the whole.[12]

A real challenge for architecture is to use the structural system as an architectural expression, and to use structural logic as architecture or ”a determiner of architectural meaning”. This thesis is certainly not new, since already back in 1830 Henry Labrouste wrote in a letter to his brother Theodor:[13] ”...then I explain to them [students] that strength depends more on the combination of materials than on their mass, and when they familiarize themselves with the laws of structure, I tell them that they have to derive reasonable and distinctive decoration from the structure itself. I often tell them that art has the ability to embellish anything, but I insist on the awareness that architectural form must always be adapted to its intended function.” This document clearly expresses the connection between architecture and structure.

9 Košir, 2000.b

10 Saunders, 1999

11 Toš, 2003

12 Venturi, 1966

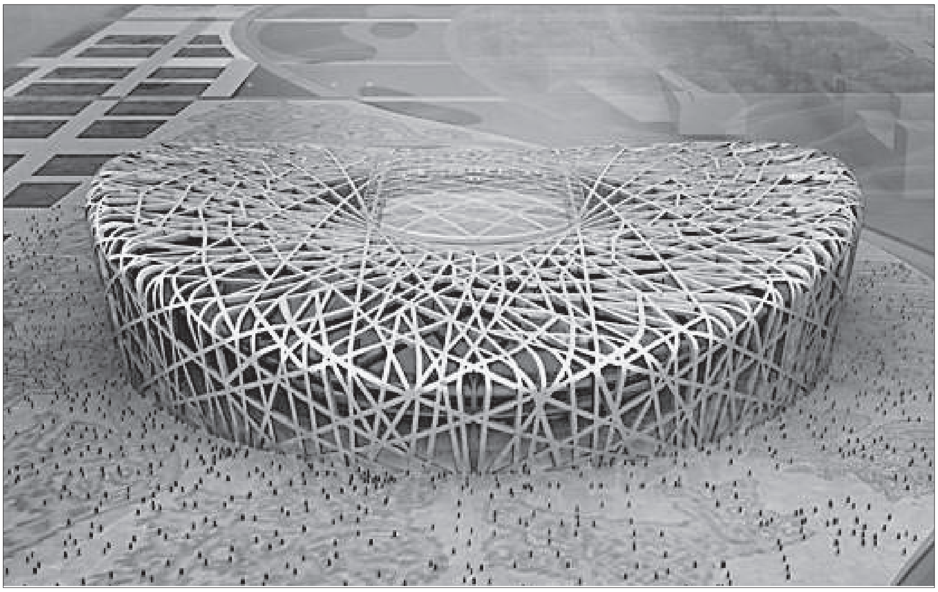


Fig. 6 Example of a building with high level of earthquake architecture index ("force microfragmentation"): project of the Olympic stadium "Bird's Nest" in China

Sl. 6. Primjer zgrade s visokim stupnjem indeksa seizmičke arhitekture („mikrofragmentacijska sila"): projekt olimpijskog stadiona „Ptičje gnijezdo" u Kini

The limits of architectural freedom are determined by the rules and principles of architecture, which are based on natural laws, on the structural logic of construction, on the tectonic logic of construction materials etc.[14] But, as Vodopivec establishes in the continuation: "...today, using new materials, tools and knowledge, we can achieve any architectural expression with much the same effort. For the first time in history architecture is not bound by technological imperatives of the period." The latter is certainly true for simpler, low-rise buildings, where the expression of structure, with regard to horizontal stiffness, is less noticeable and where only a couple of load-bearing elements needed to take over the vertical load are also sufficient to sustain earthquake forces. The situation is completely different with high-rise buildings or where the structure configuration is explicitly unfavourable. Here an architect needs to respond to the earthquake features of a location and approach the design of a building in a special way, which of course includes the above mentioned materials, tools and knowledge. This very way of responding to an earthquake threat is the source of special architecture, which can be identified as special and specific for earthquake prone areas, particularly in the last century.

Earthquake architecture is by definition[15] a combination of architecture and earthquake safe construction, and represents the description of the degree of influence earthquake loading or earthquake resistance has on architecture. This is actually any suitable and through creative architectural transformation argued response of an architect to earthquake loading. Earthquake architecture arises as a consequence of a special approach to architectural design, which draws its inspiration from earthquake engineering and where elements or measures of earthquake-engineering technology are articulated as special elements of architectural expression. Specific local tectonic activity becomes a generator for the shaping of architecture.

If in modern times the first mention of earthquake architecture from 1985[16] was a derivative of earthquake engineering, two and a half centuries earlier, and also throughout the history of architecture, structural order was a consequence of architectural proportioning, based on experience in construction.

With the development of materials and structures it seems that strength and with it earthquake resistance is less decisive for or has less influence on architecture, since modern science in construction and earthquake engineering is supposed to enable more than it used to. This also stimulates an increased need for architectural freedom, which can be reached more easily with the aid of technology. This is precisely the reason why the interference of structure and architecture is increasingly more complex and difficult to control. Technological development requires higher and higher safety standards in construction, and at the same time it faces an increasing need for architectural expressiveness, response and complex incorporation of an (earthquake-resistant) structure in the architecture of a building. A certain degree of control and quality can be sustained mainly with a sufficiently exact and objective system of structure evaluation and earthquake resistance in architecture.

Through interdisciplinary connections it is possible to notice a growing interest in architectural identity arising from the logic of space conditions and an interest in the articulation and establishment of earthquake architecture in modern architecture. But earthquake architecture has not yet defined a system of evaluation, and we also have not detected scientific-theoretic methods or mechanisms for structure evaluation, appropriate for architects and architecture. There are also no exact mechanisms for evaluation in architecture in general, since architectural evaluation uses exclusively descriptive methods usually related to different periods, and even more often to the subjective opinion of an evaluator. Some useful methods have been suggested for architectural-artistic periods, which have already been subjected to

Fig. 7 example of a building with the highest level of earthquake architecture index (identification of architecture with seismic design): Tod's building in Tokyo

Sl. 7. Primjer zgrade s najvećim stupnjem indeksa seizmičke arhitekture (identifikacija arhitekture sa seizmičkim projektiranjem): zgrada Tod's u Tokiju

13 Mušič, 1968

14 Vodopivec, 1993

15 Reitterman, 1985; Arnold, 1996; Garcia, 2000; Charleson et al, 2001; Slak and Kilar, 2007; etc.

16 Reitterman, 1985

Table I: External parameters of the proposed evaluation

Tabela I.: Vanjska mjerila predložene valorizacije

	External parameters	
	Structure	Architecture and symbol response
E1)	The level of the **earthquake threat** (a_s according to earthquake map)	The level of influences deriving from site conditions – **context** (influence of the environment (both built and natural or cultural) on building design and original conditions deriving from site context).
E2)	**The importance** of the building (in compliance with an adopted standard, e.g. EC8)	**Historical importance or cultural significance of the building** (historical importance (classification according to Cultural Heritage Protection Act); cultural significance or whether it is an architectural achievement with regard to the time of creation; 'landmarks': buildings important for landscape identification).
E3)	**Standard** used and the ability to incorporate modern knowledge – **the year of construction** in connection with adopted standards	Assurance of urban and other **technical parameters** which have to be considered and their influence on design, e.g. space between buildings, site ground floor design, building density, safety assurance systems etc.
E4)	The possibility of the **realization and economically** justified cost of the structure and earthquake resistance systems.	**Economic aspect:** justified cost of the architectural solution – rational choice of materials, structure system and realization details.

Fig. 8 Example of a building with high level of earthquake architecture index (identification of architecture with seismic design): Dance centre Aix-en-Provence

Sl. 8. Primjer zgrade s visokim stupnjem indeksa seizmičke arhitekture(identifikacija arhitekture sa seizmičkim projektom): plesni centar u Aix-en-Provenceu

detailed historical analyses, but they usually do not include (or they marginalize) earthquake safety. It needs to be stressed that evaluation should promote and expand seismo-logical architecture as ethical quality in earthquake areas, thus the method itself should indicate what is good (sensible, logical or reasonable) for construction in such areas and what is not.

A Proposal of a Method for the Recognition and Evaluation of Earthquake Architecture

Prijedlog metode prepoznavanja i vrjednovanja seizmičke arhitekture

The proposed method originates from the definition of earthquake architecture itself. It combines an earthquake-engineering (structural) part and an architectural (symbolic) part, which form two basic groups of evaluation parameters:

1) Parameters connected with the earthquake resistance of a building.

2) Parameters connected with architecture and the architectural response to earthquake threats.

Both sets require evaluation of building parameters that can be obtained from detailed drawings of architecture and structure as well as from the general concept, context, installation at a particular location and the overall appearance of a building, including not only visible but also conceptual and concealed characteristics of a building. Some parameters tend to be more objective than others that are more subjective in nature. The most delicate seems to be the evaluation of the architectural-symbolic segment that might depend on the evaluator's personal view. For this reason, it is a must that an evaluator thoroughly familiarizes himself with the architectural content and with the structural system of the building as well as with design requirements and the background of the design process. For a reliable result, the evaluator must have some knowledge and experience of earthquake architecture as well as of structural engineering and it is advisable that each group of parameters is evaluated by a different expert.

The proposed individual criteria were chosen in such a way that it is possible to achieve adequate objectivity in a two-step evaluation. In the first step, each earthquake-engineering or architectural parameter is classified as poor, sufficient or excellent. In the second step, the evaluation is corrected with "-" and "+" intermediate values resulting in a final scale from 1 to 7: 1) **poor**, 2) Poor +, 3) Sufficient –, 4) **sufficient**, 5) Sufficient +, 6) Excellent – , 7) **excellent.**

With the help of the proposed method it is possible to classify a building at different intensity levels of earthquake architecture. A higher evaluation result also means a higher level of earthquake architecture. The results can be expressed as percentages or numerical values from 1 to 7. Here 0% means that there is no influence of earthquake engineering on architecture, and 100% that we are dealing with architecture which is entirely a consequence of earthquake safe construction. Some parameters, are undoubtedly more important than others, hence they must be treated as the exclusive core of evaluation. If their value is poor, the entire project must be classified at the lowest level of earthquake architecture.

Architectural Parameters

Arhitektonska mjerila

Parameters which would adequately present an architect's architectural-symbolic response to an earthquake threat cannot entirely be defined as objective measures independent of the evaluator. In studying evaluation criteria in architecture, we actually have not detected anywhere wholly exact measures, which would represent an objective evaluation, thus we can only speak about objective-subjective evaluation based on certain facts. Evaluation parameters in connection with architectural and symbolic response to earthquake threat are summarized in ten points:

A1) **Artistic impression and harmony** of an architectural solution (general architectural value of a building according to the broader space – landscape-identification and author measure; architectural creations evaluated with regard to context, the project task and possibilities in space; artistic /architectural/ expressiveness taking into account the user's needs and the architect's concept; consistency of the selected concept in material, details, colour etc.).

A2) **Architectural innovation, originality** and **context** with regard to the time of creation (modernity, advance and avant-gardism of architecture; developmental measure; design-artistic surplus (experiments), the use of state-of-the-art materials and principles in architectural design and construction; architecture as a manifest and philosophical view – as pushing back the boundaries).

A3) **Interactivity between architecture and an earthquake threat** (connection of the main architectural concept with the principles of earthquake resistant construction; the effectiveness of combining earthquake-engineering and architectural-design principles into a harmonious whole).

A4) Achievement of **symbolic value,** which derives from earthquake threat (symbolism in general and the level of symbolic/metaphoric response to earthquakes).

A5) **Tectonics** (building morphology in the context of earthquake threat or resistance (composition, form, geometry, proportions etc.); tectonics in the architecture of a building with emphasis on the earthquake-logical design of a whole and tectonics of individual parts; interactivity of individual parts (e.g. dilated units) or the surrounding building tissue).

A6) **Functionality** (The rational use of space and quality of living in connection with earthquake structure design; the influence of earthquake design on functionality and vice versa; the influence of functional building design on its earthquake resistance and vice versa, which means successful synchronization of earthquake resistant design with building functionality in the spirit of the least possible influence or subordination of usefulness and comfort to structure minimums).

A7) **Expressiveness** of earthquake identity **in appearance** (the level of incorporating earthquake-designed structure into the appearance of a building). Earthquake design is usually concealed and does not present the architectural concept or element of buildings. This criterion gives better evaluation to buildings in which earthquake resistance is clearly expressed or emphasised in the building's appearance, which in this way marks the architectural identity of an earthquake area. This criterion is related to criteria A3 and A4.

A8) **Expressiveness** of earthquake identity **on the inside** (the level of incorporating earthquake-designed structures into a building's interior; expressiveness of elements which have an active or passive role in ensuring higher earthquake resistance, which are part of the interior arrangement and with their exposure strengthen the architecture of the interior – earthquake safe – space).

A9) **Expressiveness** of earthquake identity **in the details** (the level of incorporating the details of earthquake-designed structure into the architecture of a building; architectural treatment of structural details, which have an active role in assuring higher earthquake resistance and which, as part of the architectural concept, represent the architectural expression of the entire building; earthquake safety emphasised in the details).

A10) **Expressiveness** of earthquake identity **in the earthquake technology used** (the level of incorporating modern technological systems in the architecture of a building; expressiveness of elements of advanced earthquake technology, which have either an active or passive role in ensuring higher earthquake resistance and which are used as part of the architecture and which through their exposure reinforce earthquake safety of the whole building).

The criteria in the first part (A1 to A6) cover the concept of a building, whereas the ones in the second part (points A7 to A10) are related to the occurrence in space through the details and the expressiveness of architectural identity, which reflects an architect's visual response.

Some parameters (A3 – A7) are more important than others. We can say that they represent the core of the evaluation and can also be exclusive. This means that their negative value can classify the entire project at a lower or even the lowest level of earthquake architecture.

Structural Parameters

Građevinska mjerila

The earthquake engineering field in general is not in favour of simplified integral criteria that are supposed to give reliable information on earthquake resistance of any building without detailed analyses and studies. However, in the case of the seismic evaluation of existing buildings the profession has developed some guidance to trace the most vulnerable objects that present the potential earthquake related risk and need to be further analyzed and retrofitted. The developed criteria for evaluation of existing structural system integrity and its resistance to horizontal loads can be found in the literature as different sets of evaluation parameters.[17] For the purpose of our research, we have selected the most crucial parameters and adapted them for the evaluation of new as well as of existing buildings. We have considered the following structural evaluation parameters:

S1) **General quality, suitability** and **reliability** of proposed **building system** (positions of centres of masses, stiffness and strength, load paths, overturning safety, maximal spans, distribution of load bearing elements, element deficiencies, weak links, redundancy etc.).

S2) Prevailing **material** of structural system (general acceptance criteria for the used material for specific building proportions and element capacities).

S3) **Configuration** of building system and **regularity** in plan and in elevation (weak storey, soft storey, geometrical irregularities,

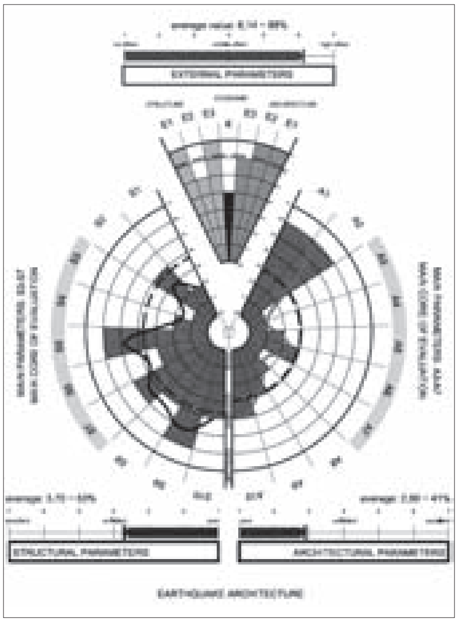
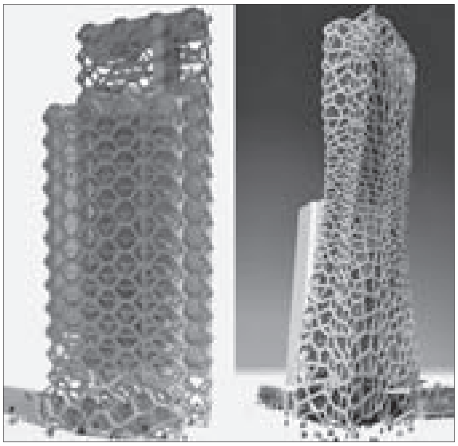


Fig. 9 The results of the proposed evaluation method in a radial graphical form: the earthquake-engineering part (left) and the architectural part (right) with average values

Sl. 9. Rezultat predložene metode vrjednovanja u obliku radijalnog grafikona: seizmičkoinženjerski dio (lijevo) i arhitektonski dio (desno) s prosječnim vrijednostima

Fig. 10 Example of a building with high level of earthquake architecture index ("force microfragmentation"):two projects of residential buildings, one in Santa Fe and the other in Canada

Sl. 10. Primjer zgrade s visokim stupnjem indeksa seizmičke arhitekture („mikrofragmentacijska sila"): dva projekta stambenih zgrada, jedne u Santa Feu i druge u Kanadi



17 FEMA-178, 1992; FEMA-454, 2006; Kilar, 2000, 2004 and 2007, Slak and Kilar, 2007, Tomaževič, 1996 and 2001

Fig. 11 Competition project no. 1 (equal 2nd prize): perspective (upper left), section (upper right), plan (below)

Sl. 11. Natječajni projekt br. 1 (jedna od dvije jednakovrijedne 2. nagrade): perspektiva (gore lijevo), presjek (gore desno), tlocrt (dolje)

setbacks, mass irregularities, vertical discontinuities, torsion etc.).

S4) **Structural system** and its **capability to resist horizontal loads** (periods and capacity versus demand ratios estimations for light frames, moment resisting frames, braced frames, frames with shear walls, frames with infill shear walls, shear walls, pre-cast shear walls with lightweight diaphragms, pre-cast frames with shear walls, masonry walls with lightweight diaphragms, masonry walls with precast diaphragms, mixed type structures etc.).

S5) **Inter-storey diaphragms** and their capability to transfer the horizontal loads to vertical load resisting elements (proportions, plan irregularities, continuity, diaphragm openings immediately adjacent to the shear walls etc.).

S6) **Vertical elements** to resist horizontal loads and their capability to transfer the loads to the foundations (evaluation based on frame column-beam proportions and shear walls-openings height to length ratios or wall shear stress check and frame stiffness/strength ratio check, inter-storey drifts check etc.).

S7) **Foundations** and their capability to transfer the loads to the ground (dimensions, foundation performance, liquefaction, slope failure etc.).

S8) **Quality of structural details** in relation to the requirements of earthquake codes (higher considered ductility class DCH/DCM, quality of connection details, reinforcement details of load-bearing elements, wall anchorages, inter-storey and roof connections, anchorage of girders and beams etc.).

S9) **Non-structural elements** and their influence on the main structural system (appropriate connections of infill walls and non-structural elements of greater mass to main load-bearing elements).

S10) **Advanced technological measures and systems** and their capability to reduce the earthquake induced loads (seismic isolation devices, dampers, mass dampers etc.).

The detailed presentation and argumentation of the selected parameters is out of the scope of this paper. An example of a complete description of the procedure for seismic evaluation of buildings can be found in the bibliography.[18] The proposed seismic evaluation parameters are exact, measurable and their evaluation can be supported by the results of static analyses and comparison studies. A reliable evaluation of the evaluation criteria requires certain structural engineering expertise and should be performed by a structural engineer or other experienced practitioner.

External Parameters

Vanjska mjerila

Structural and architectural parameters are idealized halves of the evaluation, which complement each other. Nevertheless, in a real building we cannot ignore certain factors which are not a consequence of the designer's decisions, but are external parameters, on which the engineer-designer and the architect have no influence. These parameters do not represent the architect's response to earthquake threats, but only certain features (minimal requirements, which have to be considered) to which designers (architects and contractors) can respond more or less adequately. There are certain parallels between them, which are stated separately for both segments of the evaluation (Table 1, E1-E3).

There is also the economic aspect, which is a consequence of the designer's decisions and the economic aspect of their solutions, thus this parameter needs to be a special category, separated from the rest and assessed with regard to the role it plays in the process of planning and realization (Table 1, E4).

Presentation of the Parameters in the Form of a Radial Diagram

Prezentacija mjerila u obliku radijalnog dijagrama

The criteria for assessing the level of the architect's response to an earthquake threat in connection with earthquake-engineering criteria, which indicate the earthquake resis-

18 *** 1992

tance of a building, represent a complex and comprehensive system for assessing earthquake architecture. For its better presentation, the selected parameters can be arranged in a graphical scheme – a radial diagram, which shows the symbolic, visual and conceptual response of the architect and his architectural realizations to earthquake threats on one (right) side, and the actual level of the building's earthquake resistance on the other (left) side (Fig. 6).

Dashed lines present the obtained average values that are shown separately for the architectural and structural part. The average value for the whole building could be misleading, as explained in the discussion at the end of the article. In general, designers should tend to achieve as high a score as possible independently for the architectural and for the structural part of the diagram. It should also be noted that it cannot be expected that the structural and the architectural part get similar scores, unless the design team has paid special attention to balance the requirements of earthquake resistance with the expression of the architecture. A separate part of the evaluation diagram shows the external parameters. These parameters show the external influences on the design which might have prejudiced the architectural solution and/or structural system. In general, the higher evaluation of the external parameters can be expected for all (for any reason) more important and significant buildings in areas with higher seismicity. In this case the whole evaluation process should be carried out with a higher degree of accuracy, since an increased earthquake threat requires a suitable response. The interaction between different radial diagrams of earthquake architecture and relations between architectural and structural halves can be shown best if the evaluation results are compared and analysed for more examples with a selected common denominator – for example for buildings from the same competition as presented below.

Example Evaluation of Three Competition Projects for Ljubljana's Northern Portal

Primjer vrjednovanja triju natječajnih projekata za sjeverni portal Ljubljane

As an example we have evaluated three awarded competition projects for the construction of a skyscraper in Ljubljana (Ljubljana's new northern portal – east side), which

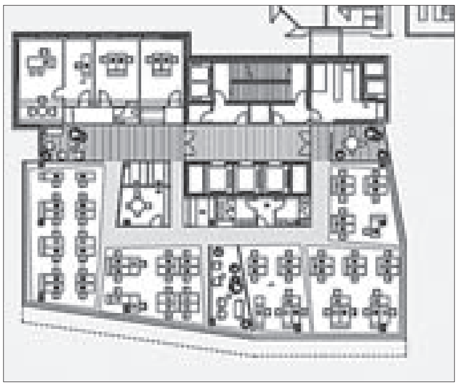
was carried out in May 2008.[19] All buildings are similar in size and content, they are placed in the same context and they had the same design requirements given in the competition documentation (Figs. 7-9). The external parameters are thus the same, except for the cost of investment, which varies from 1,100.00 € to 1,300.00 € per m^2. The competition jury of architects and urban planners awarded two equal 2^{nd} prizes and one 3^{rd} prize.

The decision of the jury was based on different criteria, among them the suitability of the structural system and earthquake resistance were not explicitly and systematically addressed. Using the proposed evaluation method, it is nevertheless possible to quantify the earthquake resistance of the proposed structural system as well as to evaluate the appropriateness of the architectural response. The first two architectural parameters considering artistic impression and originality got the highest scores because these criteria were used by the jury to award these three projects among eighteen proposed projects.

Ljubljana's new northern portal is exceptionally important since it is located in a very sensitive context and represents a location with a high concentration of people and important content. The competition documentation required a tall building, placed close to the already existing skyscraper, and a several-metre shift of the façade in the storeys above the 4^{th} storey, which some projects (also the two winning 2^{nd} prizes) solved by using a long cantilever balconies.

Fig. 12 Competition project no. 2 (equal 2^{nd} prize): section (upper left), perspective (upper right), plan (below)

Sl. 12. Natječajni projekt br. 2 (jedna od dvije jednakovrijedne 2. nagrade): presjek (gore lijevo), perspektiva (gore desno), tlocrt (dolje)



19 www.arhiforum.si (ZAPS – Slovenian Chamber of Architecture and Spatial Planning)

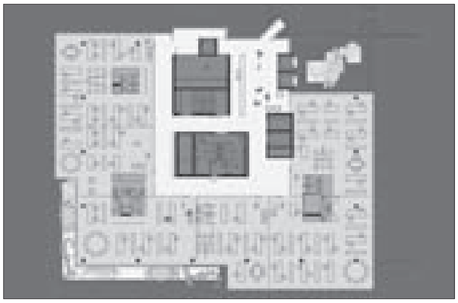


Fig. 13 Competition project no. 3 (3rd prize): perspective (upper left), section (upper right), plan (below)

Sl. 13. Natječajni projekt br. 3 (treca nagrada): perspektiva (gore lijevo), presjek (gore desno), tlocrt (dolje)

For all three selected buildings the evaluation parameters were carefully evaluated, based on extensive competition documentation. The obtained evaluation results for all three projects are presented in Fig. 10. The results show earthquake-engineering parameters (left hand side of the diagram) and parameters of architectural response (right hand side of the diagram) and their average values (dashed line). During the evaluation process, we established several specific advantages and disadvantages which importantly influenced the final scores.

For example, project 1 has the most excessive cantilever parts as well as noticeable irregularities in the plan, which is also visible as a distinctive discontinuity in the building height. Though the strong core can be seen through the transparent façade, it does not provide the adequate feeling of strength and torsion stability. In general, the building does not demonstrate earthquake resistance neither in structure nor in architecture, scoring a ”poor +” and ”sufficient -” for several parameters and got a total final score of 53%.

Project 2, with the outward inclined shape in the architectural sense, provokes the feeling of instability. In this way, it might have solved the problems of the cantilever parts better, but for this reason the centre of masses is unfortunately shifted away from the centre of stiffness. This can be clearly seen also in the architecture of the building with the wall core on one side and curtain-wall on the other side. Also, the building tectonics seems to oppose earthquake logic and such a concept received several very low scores resulting in a total score of 47%.

The best scores have been obtained by project 3, which has a regular shape and distribution of load bearing elements. The problem of long cantilever parts is solved by additional slender columns. The tectonic logic can be clearly seen in the symmetric distribution of the cores and the direct transfer of loads to the foundations. These features brought this project the highest total score of 65%.

It can be concluded that the third project reached a higher level of earthquake logic, in both the structural and architectural part. For project 2, which is ranked below 50%, it can be concluded that it, to a certain extent, ignores earthquake reality and as such might be less appropriate for realization in an earthquake prone area.

Discussion

Diskusija

The proposed method can be used to classify earthquake architecture at different levels of response intensity. Independently of the criteria included in the evaluation method, it is obvious that a higher score on the diagram also means a higher level of earthquake architecture. Earthquake architecture can be ranked in four basic levels of relation intensities between architecture (architectural response) and earthquake engineering. We start at the lowest (zero) level, which represents ”anti- or non-earthquake” architecture, which is followed by three rising intensity levels:

– Non-earthquake architecture: architectural design negates or contradicts earthquake reality (0 – 25%),

– Asymmetry according to meaning: earthquake resistance as a concept is subordinate to the architecture (25 – 50%) or vice versa.

– Equivalence: the concepts of architecture and earthquake resistance complement each other (50 – 75%) and

– Identification: the concepts of earthquake resistant structure and architecture are united (75 – 100%).

We believe that there might be examples where the total grade as an overall average can be misleading. For example, if a building is of extremely safe construction, but this strength is not expressed in the building's architecture, it might get an unreasonably low total score. In such (probably rare) cases the results of the evaluation should be observed separately. The same holds true for a reversed situation, where perhaps only the architect's symbolic response, without adequate earthquake resistance, might obtain

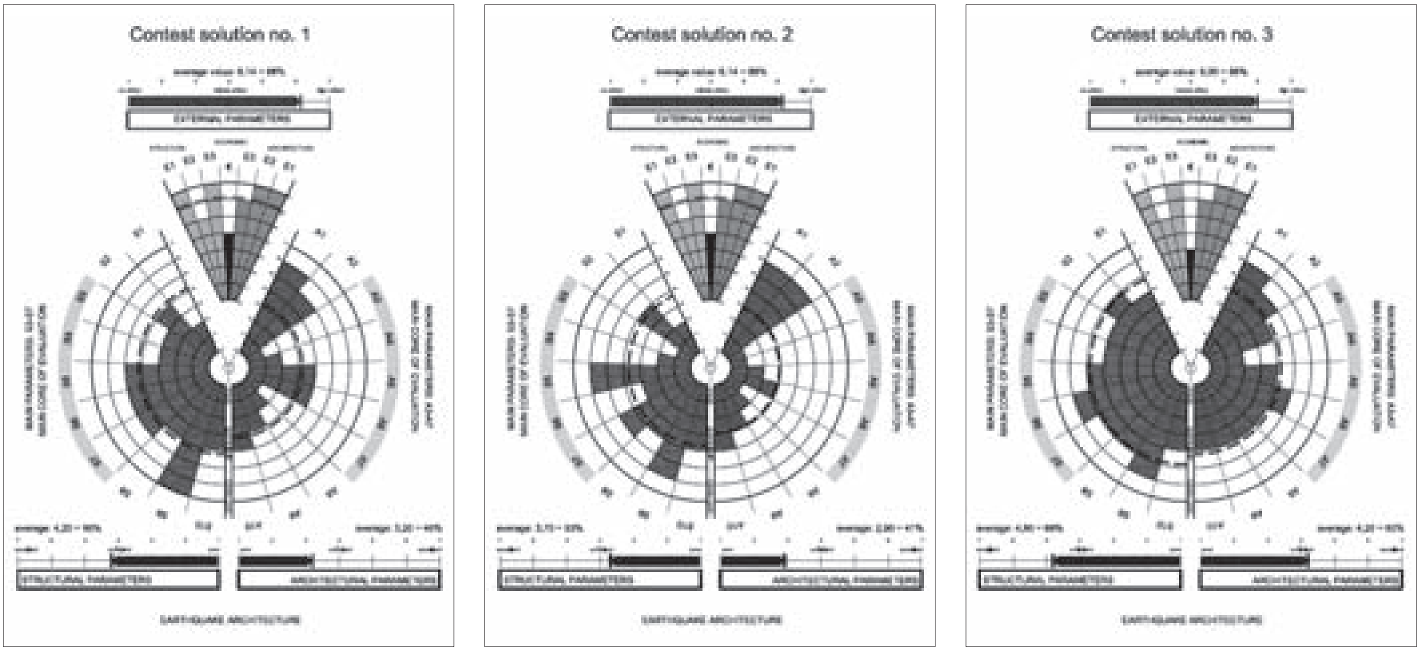


Fig. 14 Evaluation of earthquake architecture of three competition projects for Ljubljana's northern portal – east side

Sl. 14. Vrjednovanje seizmičke arhitekture triju natječajnih projekata za sjeverni portal Ljubljane – istočna strana

an undeserved high score. We believe that such discrepancies are generally unsuitable; nevertheless we should consider the earthquake architecture as only one of the possibilities for increasing architecture identity of seismic areas which presents only one possible argued manner of shaping architecture in earthquake prone areas.

Conclusions

Zaključak

This paper establishes, on the basis of the performed evaluations, that the proposed system for evaluating earthquake architecture represents a widely useful instrument for revealing interaction between architecture and earthquake safe construction. The method is useful for research purposes, comparative studies (among similar buildings or groups of buildings at locations with similar earthquake threats) and as an aid in arguing competition evaluations, that is anywhere where the architectural value evaluation is required in combination with certain technical requirements and guidelines. If needed, we could also add technological or artistic segments from other fields to the radial criterion diagram, which concern the architecture of buildings (economy, sustainable development etc.). Moreover, we believe that the method also has educational value, as it can contribute to eliminating problems related to the lack of knowledge required by good architectural design in seismic areas. It can as well be concluded that earthquake architecture can represent an unexploited architecture potential, which, in today's time of increased care for sustainable and regional development, and in searching for something special in architecture, presents an important source of a stronger architectural identity, characteristic of earthquake prone regions.

[Lektura mr.sc. Ljiljana Šepić]

Bibliography

Literatura

1. Alberti, L. B. (1986), *The ten books of architecture (De re aedificatoria),* The 1755 Leoni Edition, Edward Owen, 1755, Dover Publications, Inc., London
2. Alexander, C. (2002), *The Nature of order – Book 1: The Phenomenon of Life*, The Center for Environmental Structure, Berkeley
3. Arnold, C. (1996), *Architectural aspects of Seismic resistant Design*, Proceedings of the 11th World Conference on Earthquake Engineering, Acapulco
4. Arnold, C. (2001), *Architectural Considerations (chapter 6),* in: The Seismic Design Handbook, Second Edition (ed. Farzad Naeim), Kluver Academic Publishers, Norwell
5. Charleson, A. W. (1995), *Seismic design within architectural education,* Proceedings of the Pacific Conference on Earthquake Engineering: 43-48, Melbourne and reprinted in 1997 in: "Bulletin of the New Zealand National Society for Earthquake Engineering", 30 (1): 46-50
6. Charleson, A. W., Taylor, M. (2000), *Towards an Earthquake Architecture*, Proceedings of the 12th World Conference on Earthquake Engineering, New Zealand National Society for Earthquake Engineering, Paper 0858, Auckland
7. Charleson A. W., Preston, J. and Taylor, M. (2001), *Architectural Expression of Seismic Strengthening*, "Earthquake Spectra", 17 (3): 417-426
8. Charleson, A. W., Taylor, M. (2004), *Earthquake architecture explorations*, Proceedings of the 13th World Conference on Earthquake Engineering, Paper 596, Vancouver
9. Charleson, A. W. (2005), *Structure as architecture – A source book for architects and structural engineers*, Elsevier – Architectural press, Oxford
10. Fernandez-Galiano, L. (2000), *Earthquake and therapy*, Lotus International No. 104, Elmond SpA, Milano
11. Frampton, K. (1985), *Modern architecture – a critical history,* Thames and Hudson Ltd, London
12. Frampton, K. (1995), *Studies in Tectonic Culture: The poetics of Construction in Nineteenth and Twentieth Century Architecture* (ed. John Cava), The MIT Press, Cambridge.
13. Garcia, B. (2000), *Earthquake Architecture, New construction techniques for earthquake disaster prevention,* Loft Publications, Barcelona
14. Gregotti, V. (1982), *Address to the New York Architectural League in October 1982,* Section A 1 (1): 8
15. Kilar, V., Slak, T. (2003), *Zasnova armirano-betonskih in zidanih konstrukcij na potresnih območjih (Conceptual design of reinforced concrete and masonry structures in earthquake prone areas),* AR (Arhitektura raziskave) 1, Faculty of Architecture, University of Ljubljana
16. Kilar, V. (2004), *Ocena potresne ogroženosti stanovanjskih stavb v Sloveniji (Evaluation of earthquake vulnerability of residential buildings in Slovenia),* AR (Arhitektura raziskave) 1, Faculty of Architecture, University of Ljubljana
17. Kilar, V. (2000), *Research report*, Faculty of Architecture, University of Ljubljana
18. Košir, F. (2000.a), *Konstrukcija kot določevalec arhitekturnega pomena*, in: Izbrani članki 1992/1995., Faculty of Architecture, University of Ljubljana
19. Košir, F. (2000.b), *Vrednote: metode in merila,* in: Izbrani članki 1992/1995., Faculty of Architecture, University of Ljubljana
20. Lewis, R. K., (2001), *Architect? A candid guide to the profession,* The MIT Press, Cambridge, London
21. Lyall, S. (2002), *Masters of Structure, Engineering Today's Innovative Buildings*, Laurence King Publishing Ltd, London
22. Mušič, M. (1968), *Veliki arhitekti III – Pionirji in klasiki moderne arhitekture,* Založba Obzorja, Maribor
23. Norberg-Schulz, C. (1965), *Intentions in Architecture*, The MIT Press, Cambridge
24. Reitherman, R. (1985), *Earthquake Engineering and Earthquake Architecture*, in: AIA "Workshop for Architects and Related Building Professionals" on Designing for Earthquakes in the Western Mountain States [http://www.curee.org/architecture/].
25. Saunders, W. S. (1999), *From Taste to Judgement: Multiple criteria in the evaluation of architecture*, "Harvard Design Magazine" No. 7, Harvard University Graduate School of Design, Cambridge
26. Slak, T.; Kilar, V. (2005), *Potresno odporna gradnja in zasnova konstrukcij v arhitekturi*, Faculty of Architecture, University of Ljubljana
27. Slak, T.; Kilar, V. (2007), *Earthquake architecture as an expression of a stronger architectural identity in seismic areas,* in: Brebbia, Carlos Alberto Earthquake resistant engineering structures VI. Ashurst, Southampton; Boston: WIT Press (http://library.witpress.com/pages/PaperInfo.asp?PaperID=17688)
28. Slak, T. (2004), *Vpliv zahtev potresno odporne gradnje na zasnovo konstrukcij v arhitekturi,* Master's thesis, Faculty of Architecture, University of Ljubljana
29. Tomaževič, M. (1996), *Assessment of seismic resistance and criteria for seismic rehabilitation of historic urban masonry buildings*, "Acta polytech." 36 (2): 73-83
30. Tomaževič, M. (2001), *Seismic assessment and retrofit of masonry structures*, in: Seismic assessment and upgrading of existing structures: proceedings (ed. Badoux, M., Lateltin, O., Tissières, P.), EAEE, SGEB, Zürich
31. Toš, I. (2003), *Arhitektura in sistemologija*, Doctor's Thesis, Faculty of Architecture, University of Ljubljana
32. Venturi, R. (1966), *Complexity and contradiction in architecture*, The Museum of Modern Art, New York
33. Vodopivec, A. (1987), *Vprašanja umetnosti gradnje*, in: Iz arhitekture (Koželj, J., Vodopivec, A.) HacVia, d.o.o., Ljubljana
34. Vodopivec, A. (1993), *Temelji in meje arhitekturne avtonomije*, Doctor's Thesis, Faculty of Architecture, University of Ljubljana
35. *** (1991), *Architectural practice and earthquake hazards*, Committee on the Architect's role in earthquake hazard Mitigation, State Seismic safety Commission, Sacramento
36. *** (1992), *NEHRP Handbook for the Seismic Evaluation of Existing Buildings*, in: FEMA (Federal Emergency Management Agency) Publication No. 178, Building seismic safety Council, Washington, D. C.
37. *** (2005), *Toyo Ito 2001-2005. Beyond Modernism*, „El Croquis" No. 123, Madrid
38. *** (2006), *Designing for Earthquakes, A manual for architects*, in: FEMA (Federal Emergency Management Agency) Publication No. 454, Building seismic safety Council. Washington, D. C.
39. *** (2007) *Dance centre, Aix-en-Provence*, „A10, New European architecture",13 (1/2): 29, Amsterdam
40. *** (2008), *Competitions/Completed* [24.07. 2008], www.arhiforum.si, Slovenian Chamber of Architecture and Spatial Planning (ZAPS), Vegova 8, Ljubljana

Sources

Izvori

Illustration Sources

Izvori ilustracija

Fig. 1	Photo: T. Slak, 2008.
Fig. 2	www.ngdc.noaa.gov/nndc/struts/results?eq_0=5&t=101634&s=0&d=1
Fig. 3	www.eas.slu.edu/Earthquake_Center/TURKEY/
Fig. 4	*** (2005)
Fig. 5	www.skyscraperpicture.com/johnhancock.htm
Fig. 6	http://www.inhabitat.com/2007/03/07/beijings-olympic-stadium-by-herzog-and-demeuron
Fig. 7	*** (2005)
Fig. 8	*** (2007)
Fig. 9, 14	Graphics: T. Slak
Fig. 10	www.rojkindarquitectos.com
Fig. 11-13	http://www.arhiforum.si/

Summary

Sažetak

Procjena seizmičke arhitekture kao veze između arhitekture i seizmičkog inženjerstva

Ovaj se članak bavi procjenom seizmičke arhitekture u smislu preklapajućih zahtjeva modernoga seizmičkog inženjerstva i moderne arhitekture, koja može koristiti konstruktivnu logiku kao arhitektonski izraz ili kao „označitelja arhitektonskog značenja". Ova metoda, koju se upotrebljava u arhitekturi kao odgovor na opasnosti od potresa, postala je izvor specijalnog tipa arhitekture koji se, posebno u zadnjih nekoliko desetljeća, može identificirati kao specifična za potresna područja. Tzv. seizmička arhitektura predstavlja bilo koji prikladan i kroz kreativnu arhitektonsku transformaciju prihvatljiv odgovor arhitekta na seizmičko projektiranje, a koje je inspirirano tehnologijama seizmičkog inženjerstva i gdje su elementi ili stupnjevi tehnologije potresnog inženjerstva artikulirani kao posebni elementi arhitektonskog izraza. Ona predstavlja vezu između seizmičkog inženjerstva i arhitekture, a koja eliminira probleme vezane za nedostatak znanja i nesposobnost stvaranja specijalne te, unutar okvira konstrukcija otpornih na potrese, izvorne (originalne) arhitekture. Svejedno, seizmička je arhitektura samo jedna od mogućnosti za povećanje arhitektonskog identiteta potresnih područja i samo je jedan dokazani način arhitektonskog projektiranja u potresnim područjima.

U ovom se članku predlaže metoda valorizacije seizmičke arhitekture koja se može upotrijebiti za: 1) prepoznavanje, usporedbu i identifikaciju seizmičke arhitekture, 2) za reviziju, valorizaciju i analizu sadašnjeg stanja stvari na polju seizmičke arhitekture, 3) za pojačavanje identiteta specijalne arhitekture za seizmička područja, 4) promicanje napretka – kako na polju seizmičkog inženjerstva tako i arhitekture. Predložena metoda kombinira dio koji se odnosi na seizmičko inženjerstvo (konstruktivni dio) i na arhitektonski (simbolički) dio koji čine dvije osnovne grupe mjerila valorizacije. Deset predloženih arhitektonskih mjerila (A1 do A10) tiču se arhitektonskog koncepta i izražajnosti arhitektonskog identiteta u odnosu na glavne zahtjeve koji se odnose na projekt zgrade otporne na potres. Deset predloženih statičkih (strukturalnih) mjerila pokrivaju prikladnost konstruktivnog sustava i njegovu sposobnost na horizontalne sile. U procesu valorizacije svako je mjerilo klasificirano kao loše, zadovoljavajuće ili izvrsno.

U drugom koraku valorizacija je korigirana s „-" i „+" srednjih (među)vrijednosti, što konačno rezultira u skali od 1 do 7. Najvažnije podatke potrebne za pouzdano vrjednovanje treba izvući iz detaljnih arhitektonskih i statičkih nacrta, kao i iz općeg koncepta, konteksta, smještaja na neku lokaciju, te cjelovitog izgleda zgrade, uključujući ne samo vidljive nego i konceptualne i skrivene karakteristike zgrade. Neka su mjerila objektivnija od drugih, koji su po prirodi subjektivnija. Zbog toga je bitno da se valorizator potpuno upozna s arhitektonskim konceptom i konstruktivnim sustavom zgrade, kao i s projektnim zahtjevima i pozadinom projektnog procesa. Za pouzdani rezultat valorizator mora posjedovati neka znanja i iskustva na polju seizmičke arhitekture, ali i statike, te je poželjno da svaku grupu mjerila vrjednuje drugi stručnjak (ekspert).

Konstruktivna i arhitektonska mjerila su idealizirane polovice valorizacije koje se međusobno nadopunjuju. Ipak, kod stvarnih primjera ne možemo zanemariti određene čimbenike koji nisu posljedica projektantskih odluka nego su vanjska mjerila koja se posebno prikazuju i vrjednuju. Rezultati valorizacije mogu se grafički prikazati kao radijalni dijagram koji pokazuje simboličan, vizualan i konceptualan odgovor arhitekta i njegove arhitektonske realizacije na opasnosti od potresa s jedne strane, te s druge strane stvarnu razinu otpornosti zgrade na potres. Općenito, projektanti pokušavaju postići najveći mogući rezultat na dijagramu – posebno za arhitektonski i posebno za njegov konstruktivni dio. Pomoću predložene metode moguće je klasificirati zgradu prema različitim stupnjevima seizmičke arhitekture. Veći valorizacijski rezultat ujedno znači viši stupanj seizmičke arhitekture. Rezultati se mogu iskazati u postotcima, gdje 0% znači da nema utjecaja seizmičkog inženjerstva na arhitekturu, a 100% znači da se radi o arhitekturi koja je u potpunosti rezultat konstrukcije sigurne na potres. Također su dodatno predložena četiri osnovna stupnja intenziteta odnosa između arhitekture (i arhitektonskog odgovora) i seizmičkog inženjerstva, počevši, od „anti- ili neseizmičke arhitekture" koju slijede tri sve veća stupnja intenziteta.

Predložena metoda bila je upotrijebljena na valorizaciji seizmičke arhitekture triju natječajnih projekata s natječaja za visok uredski objekt na bavarskom Dvoru na sjevernom portalu Ljubljane, kojega su rezultati bili objavljeni 2008. godine. Sve su zgrade slične veličinom i sadržajem, smještene u isti kontekst i imale su iste projektne zahtjeve iskazane u natječajnoj dokumentaciji. Žiri je dodijelio dvije jednake druge nagrade i jednu treću nagradu. Odluka žirija bile je zasnovana na različitim kriterijima, gdje nisu izričito ni sistematski bile vrjednovane podobnost konstruktivnog sustava i otpornost na potres. Uz predloženu metodu ipak je bilo moguće kod svih projekata kvantificirati otpornost na potres predloženih konstruktivnih sustava, kao i prikladnost arhitektonskog rješenja.

U zaključku se može ustvrditi da predloženi sustav valorizacije seizmičke arhitekture predstavlja široko primjenjiv instrument za otkrivanje interakcije između arhitekture i konstrukcije otporne na potres. Metoda je korisna za istraživačke svrhe, komparativne studije (između sličnih zgrada ili grupa zgrada na mjestima sa sličnim opasnostima od potresa), kao i za pomoć pri valorizaciji natječaja. Osim toga, vjerujemo da metoda ima također edukativnu vrijednost jer može pridonijeti eliminiranju problema koji se odnose na nedostatak znanja potrebnog za dobro arhitektonsko projektiranje u seizmičkim zonama. Ujedno se može zaključiti da je seizmička arhitektura neistražen arhitektonski potencijal koji u današnje doba brige za održiv i regionalni razvoj te potrage za nečim posebnim u arhitekturi, predstavlja važan izvor snažnijeg arhitektonskog identiteta karakterističnog za potresno opasna područja.

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Biographies

Biografije

Tomaž Slak, Dipl.Eng.Arch., graduated in 1998 on the Faculty of Architecture in Ljubljana, where he attained his Master's degree in 2004. Since 2000 he works on the Faculty of Architecture in Ljubljana. Since 2004, he investigates the special interdisciplinary field: earthquake architecture.

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