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Identification and ranking of factors affecting the vulnerability of urban structures against earthquakes (Study case: Shiraz city)

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Abstract
The high seismicity of most populated parts of the country and the vulnerability of existing buildings against earthquakes based on the experiences of recent earthquakes indicate the need to pay enough attention to correct construction and prevent irreparable damages in the event of an earthquake. The present study aims to identify and the ranking of factors affecting the vulnerability of urban structures against earthquakes in Shiraz city has been done using Vicor method. The tools of data collection in this research are library studies and semi-structured interviews with experts. The statistical population of this study is 27 experts in the field of construction industry who have at least 15 years of experience in this field and at least a master's degree in structural engineering. The findings of this study indicate that the most important factors of the vulnerability of city structures in Shiraz city were ranked under the influence of the following 4 categories of main factors: 1) factors related to human resources; 2) factors related to technology and technical knowledge; 3) Factors related to procurement and material quality and 4) Factors related to infrastructure.
Key words: *earthquake, vulnerability, urban structures, ranking, Vicor method*

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I. Introduction and statement of the problem

Every building goes through the stages of planning, study, modeling and analysis, design and implementation, operation and maintenance from the beginning of its construction. The operation of the building continues until it can perform its tasks. The useful life of a building is defined from the time of operation until the time when the building is able to provide services. Therefore, different stages of design and implementation affect the useful life of the building. Any weakness and error in the mentioned steps shortens the useful life of the building. Obviously, the effective errors are not gross and large (Bernardi et al., 2018). Earthquake is one of the basic natural calamities of the present age, which has always caused major disasters in a very short period of time. Stability and safety against natural phenomena have always occupied the human mind. Earthquakes have always existed as a repeatable phenomenon throughout history and will exist in the future as well. One of the basic challenges in structural engineering is the development of innovative design ideas for better protection of structures and their inhabitants and their contents against the destructive effects of destructive environmental forces such as wind, waves and earthquakes (Ahirwal et al., 2019). In the science of structural and earthquake engineering, with the introduction and replacement of the performance-based design method instead of the force-based design method, many design regulations are undergoing a series of fundamental changes, and now many structural researchers and In order to achieve evolution and reliability in this method, earthquakes have focused their research in this field (Jina et al., 2022).

Iran is one of the most earthquake-prone regions in the world, which has suffered many casualties, economic losses, and social damages during the past decades. The high seismicity of most of the populated parts of the country and the occurrence of large and destructive earthquakes such as Manjabal, Bam, Kermanshah, Maragheh, etc. Negligence of supervising engineers or their lack of mastery of the implementation principles of earthquake-resistant buildings, lack of proper implementation and the presence of many implementation weaknesses are the involvement of non-specialists in the specialized affairs of the structure and other cases.

This is despite the fact that from the point of view of earthquake engineering, it is now possible to construct earthquake-resistant buildings. It is noteworthy that the technical knowledge of the country's engineering community has enough foundation and power to analyze and design as well as prepare executive plans with a little accuracy and responsibility without spending a lot of money and prolonging the design time of the structure. Meanwhile, any procrastination and indifference towards eliminating possible defects and errors in the design stage and entering the implementation stages will lead to an increase in possible costs and damages in the future. Shiraz, as the largest metropolis in the southern region of the country, due to its location on the transit route of the country and the most important administrative, political and population center of the country, has always received a lot of immigrants and a large increase in population. This is located on large faults such as Bazin, Sultan, Qalat, Zarqan and Bid Zard faults, which history investigation with more than 16 major earthquakes in the area of this city during the 12th to 19th AD indicates the high possibility of a major earthquake in this region.

It is a city with more than 2 million people. Therefore, the present study was carried out with the aim of identifying and ranking the factors affecting the vulnerability of urban structures against earthquakes in the metropolis of Shiraz, and it aims to answer the main question of what factors affect the vulnerability of urban structures against earthquakes. What is an earthquake in the metropolis of Shiraz? What is the ranking of these factors from the point of view of structural engineering experts?

Theoretical framework and research background

Reducing the vulnerability of urban communities against earthquakes will occur when safety against earthquakes is considered at all levels of planning. Meanwhile, the middle level of physical planning, i.e., urban planning, is one of the most effective levels of planning to reduce vulnerability to earthquakes (Markos et al., 2017). In many years, many visits and researches have been done in the field of the implementation of conventional buildings, their quality, as well as implementation weaknesses in the construction industry. The most important discussion in seismic design based on performance level is the development of simple and yet accurate methods for the analysis and design of new buildings and the evaluation of existing buildings against different performance levels (Fayaz et al., 2022). Various loading and design regulations and guidelines have been compiled in order to achieve the design and construction of components and structures resistant to various loads such as wind, earthquake, etc. The effort of all these guidelines, while developing the climatic conditions, the type of use of buildings, is to develop suitable and reliable solutions for engineers in the design of structures, so that structures can be designed and implemented that show a satisfactory reaction against the loads on the structure. Since achieving a safe design for the structure requires knowledge of a set of effective factors and parameters without a proper understanding of them, it is not possible to achieve a safe design (Huang et al., 2019).

The harmful effects of a landslide include a combination of physical destruction and disruption of the functioning of urban elements. Loss of life, destruction of residential areas, network of communication roads, basic facilities such as water reservoirs, water bridges and roads, gas, destruction of buildings and facilities, damages caused by secondary incidents such as fires, mountain falls, breaking dams or Clogging of pipes and the spreading of hazardous substances like ice are injuries and damages that failure to prevent its impact or failure to prepare to deal with its consequences can lead to irreparable disasters (Lee and colleagues, 2019).

The safety of settlements and urban planning through compliance with the rules and strategies related to effective spatial, physical and functional factors, physical damage can be minimized when an earthquake occurs. Milgani et al. (2017), in a research titled "Reducing the vulnerability of masonry earthquakes using CFRP integration", acknowledge a significant consistency between the results of finite element analysis, the actual performance of the structure under seismic excitation, and advanced nonlinear dynamic analysis. There is. Also, the damage log and inefficient mechanisms that are found numerically are consistent with the results of the earthquakes that occurred in the stone church. Midhat Fayaz et al.

Himalayan Kashmir, using AGIS, acknowledged that in general, the city center is the most vulnerable to earthquake damage due to high risk of collapse, high building density, and narrower roads with little or no open space. On the other hand, in the modern upper part of the city, it is less vulnerable to earthquakes due to relatively wider roads and low construction density. In order to create a safe and flexible system and reduce the risk of earthquakes, they consider it necessary to carry out measures including the strict implementation of building regulations, strengthening vulnerable buildings and creating awareness against disasters, and informing the citizens. In the research entitled "Investigation of the factors affecting the vulnerability caused by earthquakes in urban areas with informal settlements using GIS (case study: areas 1 and 5 of Tabriz city)", the most important reasons for the vulnerability of these areas in the event of an earthquake due to the high concentration of the population , the quality of the building is low, the life of the buildings and the use of non-resistant materials against earthquakes and the proximity to the fault and the neighborhood context.

research methodology

The current research is a type of descriptive-analytical study. In order to formulate a theoretical framework of the method of comprehensive library studies and review written sources such as articles and texts related to the subject, including domestic and foreign studies, theses and various articles have been collected. The statistical population of this research consists of 36 structural engineering experts in the construction industry of Shiraz, who had at least 15 years of experience in the field of structural design and implementation and had at least a master's degree in structural engineering. The indicators obtained through library studies and face-to-face interviews with experts and experts in the construction industry have been classified and after adjusting them in the framework of questionnaires, they have been redistributed to them and after they have completed them, they have been collected. The research subject has been considered through interviews and questionnaires, and the ranking of the identified factors has been done based on Vicor's method.

Research findings

In this research, after conducting library studies and interviewing experts in the construction industry in Shiraz, finally, four categories of factors related to infrastructure, factors related to human resources, factors related to procurement and quality of materials, and factors related to technology and technical knowledge were identified. The factors affecting the vulnerability of urban structures against earthquakes were identified. The factors are shown in Table 1:

Table 1- Components affecting the vulnerability of urban structures against earthquakes from the perspective of experts

<table>
<tr><th colspan="2">Sub-indexes</th><th>Indicators</th></tr>
<tr><td colspan="2">Old and inapplicable provisions contained in some of the regulations - climatic background (moisture level, temperature, slope, wind, etc.), tissue density and width</td><td>Factors related to infrastructure</td></tr>
<tr><td colspan="2">Design and calculation errors - Errors and problems in building implementation - Negligence in reviewing the design and applying changes if necessary by supervisors - Negligence in preparing technical documents based on quality control standards in the supervision group - Indulgence in periodic and regular control by supervisors and employers - Negligence in determining the method and supervision, work visit procedures by the employer - Negligence of supervisors in periodic inspections and implementation of executive works, compliance with standards and confirmation of their correctness</td><td>Factors related to human resources</td></tr>
<tr><td>The shape and dimensions of connecting parts - the amount of corrosion - the quality of cutting parts</td><td>Metal</td><td rowspan="2">Factors related to procurement and material quality</td></tr>
<tr><td>How to store materials (preventing moisture and corrosion) - Air temperature during concreting - Bending temperature of joints - How to place molds - Proper spacing in molding</td><td>Concrete Structures</td></tr>
<tr><td>The shape and dimensions of connecting parts - the amount of corrosion - the quality of cutting parts</td><td>Metal</td><td rowspan="2">Factors related to technology and technical knowledge</td></tr>
<tr><td>Seismic system is only a bending frame - non-availability of silencers with suitable hooks - lack of suitable cut-off joints between adjacent buildings - non-observance of plastic covering to prevent water absorption of fresh concrete - non-coaxial and non-perpendicular structure members (beams and columns)), failure to implement the correct reinforcement of staircases in the place of elbows - increase in dead weight due to not paying attention to the levelness of the concrete surface of the roofs or the levelness of the clay blocks - failure to observe the angularity of facade and non-facade walls - failure to pay attention to How to connect the column to the foundation</td><td>Concrete Structures</td></tr>
</table>

Ranking factors using Vicor method

At this stage, according to the aim of the research to rank the factors affecting the vulnerability of urban structures against earthquakes:

Step 1) In this step, each of the factors related to infrastructure, factors related to human resources, factors related to procurement and material quality, and factors related to technology and technical knowledge were identified based on criteria and scored using the second questionnaire.

Table 2- Degree of importance of factors affecting the vulnerability of urban structures against earthquakes in Shiraz city

Rating of importance	A range of 9
Not important :1	R1
Very unimportant :2	R2
Nonsignificant :3	R3
Somewhat unimportant :4	R4
Medium importance :5	R5
Somewhat important :6	R6
Important :7	R7
Very important :8	R8
Very very important :9	R9

Data collected from experts based on the degree of importance of the criteria was done in the framework of a questionnaire with a range of options from 1 (very little) for criteria with a negative aspect to 9 (very much) for criteria with a positive aspect.

Table 3- The main criteria of factors affecting the vulnerability of urban structures against earthquakes in Shiraz city

symbol	Normal weight	Identified criteria
X1	0/354	Old and inapplicable provisions contained in some regulations
X2	0/353	,(.Climatic background (humidity, temperature, slope, wind, etc
X3	0/331	Tissue density and passage width
X4	0/329	Design and calculation errors
X5	0/327	Errors and problems in building implementation
X6	0/321	Negligence in reviewing the design and applying changes if necessary by supervisors
X7	0/295	Negligence in preparing technical documents based on quality control standards in the supervision group
X8	0/291	Tolerance in periodic and regular control by supervisors and employers
X9	0/283	Negligence in determining the method and supervision, steps of the employer's visit
X10	0/279	Negligence of inspectors in periodic inspections and implementation of executive works to comply with standards and confirm their correctness
X11	0/277	Failure to properly implement the reinforcement of the stairs at the place of the knees
X12	0/264	Not paying attention to how to connect the column to the foundation
X13	0/259	Non-coaxial and non-perpendicular structure members (beams and columns),
X14	0/251	Non-observance of the dimensional tolerance of the width and height of the column section
X15	0/241	Air temperature during concreting - bending temperature of joints
X16	0/237	How to insert templates
X17	0/234	Proper spacing in formatting
X18	0/231	The unevenness created when cutting the profile
X19	0/228	Failure to observe the proper distance of the welding seam
X20	0/227	The increase in dead load due to not paying attention to the level of the concrete surface of the roofs or the level of the clay blocks
X21	0/219	How to store materials (preventing moisture and corrosion)
X22	0/223	The instability of the column
X23	0/248	Failure to prepare welding instructions
X24	0/236	How to cut the profile
X25	0/215	Failure to remove boils
X26	0/208	Lack of proper contact between the beam and the beam
X27	0/201	No coloring of the profile
X28	0/196	The seismic system is just a bending frame
X29	0/194	Shape and dimensions of connecting parts
X30	0/191	Inadequacy of proper cut-off seam between adjacent buildings
X31	0/188	Failure to comply with the plastic cover to prevent water absorption of fresh concrete
X32	0/175	Quality of cutting parts
X33	0/168	Corrosion rate
X34	0/163	Lack of proper coloring quality
X35	0/157	Non-observance of corner drawing of facade and non-facade walls
X36	0/151	Non-availability of silencers with suitable hooks

Table 4- Evaluation results of different criteria

The degree of importance												**Dimensions and criteria**
M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	
45	34	32	36	38	42	43	44	37	39	36	41	C1
38	41	44	45	40	39	31	31	41	22	40	26	C2
41	44	38	41	39	28	38	38	29	43	42	38	C3
43	39	41	42	44	40	29	35	35	44	38	32	C4
M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	
44	39	45	44	41	36	40	37	34	32	44	44	C1
35	39	44	42	39	43	28	41	41	44	44	41	C2
39	41	42	37	40	43	43	42	44	38	40	36	C3
42	44	39	39	34	41	44	38	39	41	42	39	C4
M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	
43	42	39	35	36	37	40	42	38	38	45	41	C1
40	32	40	44	40	41	28	36	45	40	44	38	C2
38	38	44	39	42	29	38	43	41	32	42	43	C3
45	44	39	41	39	35	44	38	42	44	39	44	C4

Table 5- Importance coefficients of the identified criteria

The degree of importance											
X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
0/354	0/353	0/331	0/329	0/327	0/321	0/295	0/291	0/283	0/279	0/277	0/264
X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24
0/259	0/251	0/241	0/237	0/234	0/231	0/228	0/227	0/219	0/223	0/248	0/236
X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	X36
0/236	0/215	0/208	0/201	0/196	0/194	0/191	0/188	0/175	0/168	0/163	0/157

In table (5), the positive and negative ideal points are determined, the maximum and minimum values of each column are specified. It is worth mentioning that considering that the rating scales are similar, there is no need to scale the values.

Table 6- Positive and negative ideal point of each criterion

	The degree of importance											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
f^+	45	44	44	44	44	42	42	44	41	44	42	41
f^-	38	39	32	36	38	28	29	31	29	36	26	32
	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
f^+	44	44	45	44	41	42	44	42	44	45	44	44
f^-	36	38	39	37	34	37	28	37	39	38	36	38
	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
f^+	44	44	44	44	42	41	44	43	45	45	44	44
f^-	32	38	39	35	36	35	28	38	36	38	38	38

At this stage, the values related to the value of usefulness S (the relative distance of option e from the ideal point) and the value of regret (R) (the maximum discomfort of option i away from the ideal point) and the values of Vicor index (Q) are calculated and the results are in table (7). , it has been shown:
The results related to the values of usefulness index (S), regret index (R) and Vicor index (Q) are shown in table (7):

Table 7- The results of calculating the values of usefulness index, regret index and vicor index

	S	R	Q
C1	0/925	0/351	0/891
C2	1/96	0/943	1/241
C3	1/14	0/682	0/774
C4	1/89	0/854	0/956

Table 8- The results of the effective Otmel priority based on the indicators in ascending order

Vicor index (Q)		Regret Index (R)		Utility index (S)	
1/241	C2	0/943	C2	1/96	C2
0/956	C4	0/854	C4	1/89	C4
0/891	C1	0/682	C3	1/14	C3
0/774	C3	0/351	C1	0/925	C1

II. Discussion

This research was conducted with the aim of identifying and classifying the factors affecting the vulnerability of urban structures against earthquakes. The results of library studies and expert interviews indicate that 4 factors included factors related to infrastructure, factors related to human resources, factors related to procurement and quality of materials, factors related to technology and technical knowledge. In the following, after classifying the identified indicators and setting up the questionnaire, in order to rank these factors from the experts' point of view, he used the Vicor method. Based on the results of the research, the ranking of factors affecting the vulnerability of urban structures against earthquakes in Shiraz city is: 1) factors related to human resources; 2) factors related to technology and technical knowledge; 3) Factors related to the procurement and quality of materials and 4) Factors related to infrastructures. Based on this, it can be acknowledged that many engineers not only do not have complete information about vulnerability and seismic retrofitting, but in the face of the prevailing The usual implementation issues of the building are also lacking. Therefore, the level of knowledge in the technical information of these people should be increased, and a mechanism should be considered to exercise decisiveness and control the matter, and this point should also be considered that the right of the supervising engineer is preserved and the responsibilities are properly divided. Therefore, according to the investigations carried out, the following suggestions should be presented:

- ❖ updating structural design standards according to construction knowledge and technology;
- ❖ updating the regulations of manufacturing quality and quality control;
- ❖ Increasing employers' and supervisors' awareness of construction quality control regulations;
- ❖ Requiring employers to use trained specialists in the important processes of concreting and wharf welding;
- ❖ Adopting control measures for correct and sufficient supervision of supervisors during construction;
- ❖ Employment of expert personnel in the construction phase and their supervision;

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