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SEISMIC RISK FEATURES OF A DESTRUCTIVE EARTHQUAKE ZONE

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Abstract. *The features of changes in the seismic risk of the zone of a strong earthquake, associated with both destructive consequences and the processes of these recovery. These two factors are the main reason for the change in the seismic vulnerability of preserved (not destroyed) and newly constructed buildings and structures, therefore, changes in the seismic risk of a fairly large area. This problem is not well understood, despite its importance in terms of assessing and reducing risk. The article proposes to divide the zone into subzones on the basis of a specific earthquake, taking into account the intensity and scale of destruction of buildings. This approach makes it possible to more reliably establish the general and local features of the change in the seismic risk of the restored earthquake zone.*

Keywords. *Earthquake, seismic hazard, risk, volnerability of buildings.*

Introduction

After the devastating earthquakes, the seismic risk of a vast territory - the zone of its influence, starting from an intensity of 6 points according to EMS - 98, changes significantly both due to seismic effects on buildings and structures, and the processes of restoring its consequences [1,3,4,5]. This primarily concerns the territory of cities, where the seismic risk is usually higher than in other settlements. Buildings and structures located in different areas of earthquake intensity are damaged to varying degrees. As a rule, after an earthquake, areas with strong and medium damage are restored and reconstructed. However, a significant part of its zone, where buildings receive light damage, is often left without proper attention. There are very few works devoted to this problem in the scientific literature, although this problem is important and relevant. The problem is considered on the example of the Spitak earthquake of 1988 (M=7.0; I=9-10 points; H=10 km), which is considered one of the most detailed and comprehensively studied earthquakes in the world [3,4].

1. Main Factors Determining the Features of the Seismic Risk of the Zone of Earthquake

The seismic risk of an earthquake zone is significantly affected by the following factors [2,3,5,6,7].

Seismic hazard. Practice shows that in most cases, after a devastating earthquake, seismic hazard assessments are revised, including the General seismic zonation map (GSZ) of the earthquake zone and maps of seismic microzonation of urban areas. As a result of the revision of maps, more often, the level of seismic increases, the boundaries of the most dangerous seismic zones expand, measures are taken to avoid repeating mistakes.

Vulnerability of buildings and structures. The main damage from earthquakes in most cases is associated with the high vulnerability of residential and public buildings [1,2,6,7]. Unfortunately, in many developing countries, even after devastating earthquakes, the situation does not change significantly. A detailed assessment of seismic vulnerability is a technically complex and expensive procedure that includes a huge amount of data on buildings, their structural types, design features, seismic response characteristics in urban areas, etc. [7]. Sometimes the application of modern methodology [5,7], including dynamic testing of natural buildings in resonant mode, does not allow to reliably assess the vulnerability of buildings, because the quality of their construction is low. The most reliable way to solve the problem is to apply the results of the analysis of statistical data on damage to the main types of buildings due to an earthquake [4,5].

With strong impacts, more often vulnerable typical buildings, in particular residential and public (especially education and healthcare) receive significant damage or collapse [4,7]. It is especially necessary to assess the seismic vulnerability of typical buildings, including general education schools [4,7]. Usually, heavily damaged buildings are dismantled or strengthened, but the attitude of the authorities is ambiguous in the issue of restoring and strengthening lightly damaged buildings. Buildings and structures with so-called "hidden" or invisible damage for some reason are not restored and strengthened [4], as a result of which the seismic risk of the territory built up with such buildings increases. As a rule, as a result of the restoration and reconstruction of the earthquake zone, new earthquake-resistant buildings and structures are built, and damaged ones are strengthened.

Vulnerability of city infrastructure. Lines of electricity, gas, water supply, sewerage, communications, etc. of the city due to strong ground shaking, and partly, rescue operations, are damaged or fail [4,7]. An important role in the vulnerability of infrastructure is played by their technical condition (age, damage) and the geological features of the territory (environment) through which they are laid. Usually immediately after a devastating earthquake, based on social importance, the water supply and electricity lines are restored, and then or simultaneously the rest [4,5,6]. After restoration, the vulnerability of infrastructure lines is sharply reduced, because. most pipelines and cables are replaced with new ones. Often, the areas of cities where the intensity of the earthquake was less than 8 points, individual elements of the infrastructure are not being restored on a large scale, therefore they are more vulnerable.

Seismic effects on buildings. Usually, the earthquake zone is divided into subzones according to the intensity of the ongoing earthquake and the scale of destruction of buildings and structures [4,5]. Vulnerable buildings receive serious damage starting from an intensity of 8 points, at 10 points massive destruction of buildings and structures occurs. On fig. 1 shows damage maps of multi-apartment and public buildings in cities located in zones of different intensity of the 1988 Spitak earthquake: 9-10 (Spitak), 9 (Leninakan and Stepanavan cities) and 8 (Ashotsk). Based on the experience of this earthquake, it is advisable to divide the zone into the following 4 subzones [4,5]: 1. *Strong destruction* (intensity 9-10 points); 2. *Significant destruction* (8-9 and 9 points); 3. *Medium destruction* (7-8 and 8 points); 4. *Weak destruction* (6-7 and 7 points). In general terms, most of the buildings of the first subzone are practically destroyed or receive such damage (3-4th and higher degrees, according to the five-degree scale of building codes of the RA), and they are subject to demolition. In the subzone of significant destruction, buildings are either destroyed or damaged by the 2nd-4th degree (fig. 1). Part of the damaged buildings (2nd and 3rd degree) is subject to restoration, and the other part with damage of the 3rd-4th degree - to be dismantled. The buildings of the last two subzones in most cases receive minor damage and if they are not restored, then their seismic vulnerability increases, and therefore the risk.

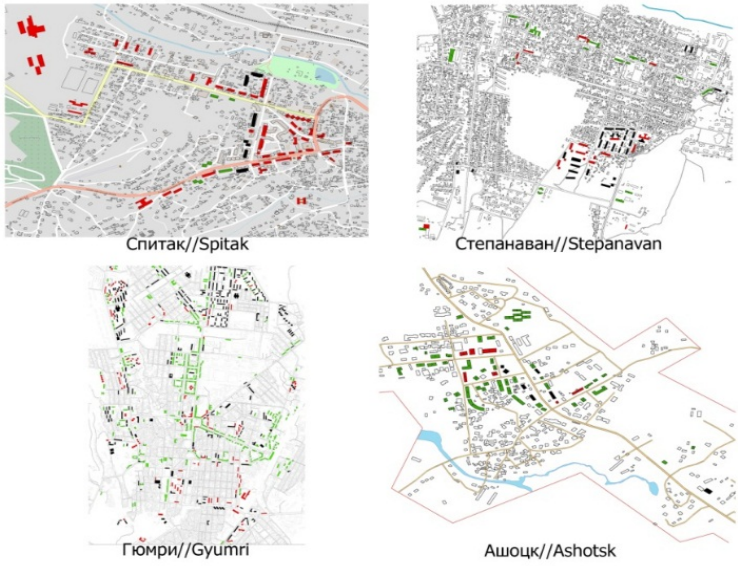

Fig. 1. Maps of damage buildings in the cities of Armenia due to the 1988 Spitak earthquake located in subzones of various destruction: strong (Spitak - earthquake intensity 9-10 points), significant (Gyumri and Stepanavan - 9) and medium (Ashotsk - 8). Buildings are shown in colors: red - completely destroyed (5th degree of damage); in black - dilapidated (4th degree); green - to be restored (2 and 3rd degree) [4].

In [4] the types of residential buildings and the degree of damage received are shown depending on the intensity of the 1988 Spitak earthquake. It is obvious that multi-apartment frame-panel and multi-storey stone buildings, as well as school and hospital buildings built in 1957-1988, are the most vulnerable. The main reason for

the large-scale destruction of the buildings of the former public sector in Spitak with a design seismicity of 7 points is the 9-10-point intensity of the earthquake (fig. 1), because. the difference between the design hazard and the intensity of the earthquake was about 3 points.

2. Maps of seismic risk of the territory of cities in the zone of the Spitak earthquake of 1988.

Specialists seismic service of the Ministry of Emergency Situations of the Republic of Armenia, according to the methodology described in [4,5,6], maps of the seismic risk of 16 cities of Armenia located in the intensity zone of 7 and more points of the Spitak earthquake in 1988 [4,6]. On fig. 2 as an example 5 seismic risk maps are presented, and in table 1 - some important data on seismic hazard and risk of the territory of 12 cities. They are used to identify the features of changes in seismic risk.

Table 1. Some indicators of seismic hazard and risk of the territory of cities in the zone 1988 Spitak earthquake.

N	Name of city	Intensity of 1988 Spitak earthquake	Percentage of territory destroyed	Seismic hazard level according to RA building codes, years of validity.		Risk areas (% in relation to the total area of the city)		
				intensity, 1957- 1988	intensity, acceleration 1994 - 2020	high	average	low
1.	Spitak	9-10	100%	7; 8	9 and more (0.40g)	12	40	48
2.	Gyumri	9	50%	8	9 and more 0.40g)	8	25	67
3.	Stepanavan	9	40%	7; 8	9 and more (0.40g)	3	47	50
4.	Vanadzor	8-9	30%	7	9 and more (0.40g)	20	40	40
5.	Dilijan	7-8	20%	7	9 and more (0.40g)	20	65	15
6.	Artik	7-8	10%	8	8-9 (0.30g)	10	50	40
7.	Tashir	7-8	10%	7; 8	8-9 (0.30g)	10	30	60
8.	Maralik	7	10%	8	8-9 (0.30g)	20	30	50
9.	Alaverdi	7	-	7	8 (0.20g)	15	50	35
10.	Ijevan	7	-	7	8 (0.20g)	10	80	10
11.	Noemberyan	6-7	-	6; 7	8 (0.20g)	7	53	40
12.	Berd	6-7	-	6; 7	8 (0.20g)	27	50	23

3. Important features of changes in the seismic risk of the territory of cities in the restored zone of destructive earthquke

According to seismic risk maps, 12 cities [4] and table 1 the following general features of changes in seismic risk are distinguished:

1. The seismic risk of the territory of cities in the earthquake zone with great destruction is significantly reduced both as a result of strong earthquake shaking and during the restoration (reconstruction) of its zone. The main reasons are as follows:

- due to a devastating earthquake, cities are getting rid of non-seismostability buildings, because badly damaged or destroyed buildings are dismantled and demolished,
- adequately seismic hazard, including new assessments, new buildings are being built and emergency buildings are being reinforced. Sometimes even slightly damaged buildings and structures are strengthened,
- after the earthquake, as a result of a reassessment of the seismic hazard, new, higher levels were set. The standards of earthquake-resistant construction, methods of designing buildings and structures were revised, the quality of construction was more strictly controlled, new technologies and materials were applied, new methods were developed and implemented to improve the seismic resistance of buildings, as a result of which the seismic risk of urban areas was significantly reduced.

2. On the other hand, especially those cities the buildings of which did not receive significant and noticeable damage were left without attention and their seismic vulnerability increased [4]. According to the building codes of Armenia and many developing countries, the operation of buildings that have received damage of the 1st or 2nd degree is allowed, which contributes to an increase in risk.

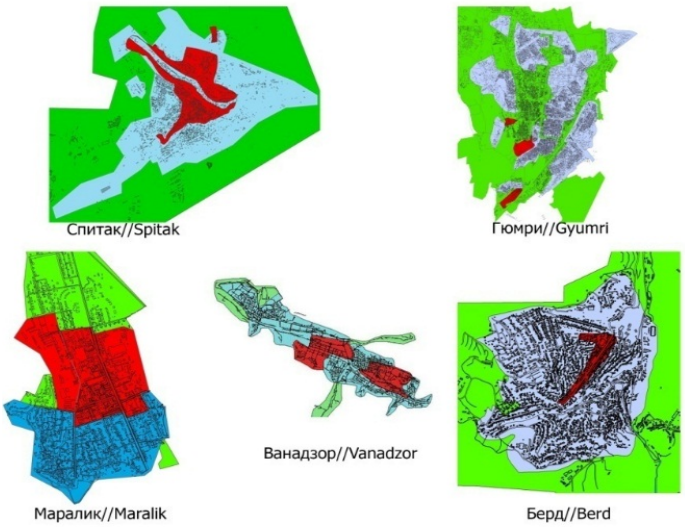

Fig. 2. Maps of seismic risk of damage residential and public buildings in the territory of the cities of Armenia located in intensity zones 1988 Spitak earthquake: Spitak (9-10 points), Gyumri (9), Vanadzor (8-9), Maralik (7), Berd (6-7) [4]. The colors indicate risks level: red - high; blue - average; green – absent.

Conclusion. The seismic risk of the territories of cities in developing countries exposed to a devastating earthquake changes significantly both due to the destruction and damage of buildings and structures, and due to the restoration and reconstruction of the earthquake zone. As a rule, the risk of cities located in the zone of severe destruction is significantly reduced due to the dismantling and demolition of heavily damaged buildings, the strengthening of slightly damaged buildings, as well as the construction of new earthquake-resistant residential, public and other buildings and infrastructure lines of the city. On the contrary, the seismic risk of the territory of those cities, the buildings of which received weak and medium damage and were not fully restored, increases. The problem worsens more if, according to the new regulations, the seismic hazard increases. Practice shows that more often in developing countries located in seismically active regions, for various reasons, weakly damaged buildings are not completely restored.

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