საერთაშორისო სამეცნიერო კონფერენცია „დედამიწასა და მის გარსებში მიმდინარე გეოფიზიკური პროცესები“
შრომები, ISBN 978-9941-36-147-0, თბილისი, საქართველო, 16-17 ნოემბერი, 2023 წ.
International Scientific Conference "Geophysical Processes in the Earth and its Envelopes"
Proceedings, ISBN 978-9941-36-147-0, Tbilisi, Georgia, November 16-17, 2023

MAIN CAUSES AND FEATURES OF CHANGE OF SEISMIC HAZARD ASSESSMENTS IN THE TERRITORY OF ARMENIA ACCORDING TO BUILDING CODES

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Abstract. *8 maps of the General seismic zoning of the territory of Armenia, compiled in the years 1937-2020, were approved as the norm of earthquake-resistant construction (Building codes). These hazard maps vary in scale and accuracy. Capital construction was designed and implemented in compliance with these Building Codes. Unfortunately, mostly until 1989 the prepared maps underestimated the seismic hazard level of the territory of the republic. This is one of the main reasons for the high seismic risk of the RA territory. The article summarizes the characteristics and dynamics of changes in the level of seismic hazard over time, and highlights the main reasons for the underestimation of the hazard. The most important of those reasons are highlighted: mapping methodology, scarcity and low reliability of baseline data, influence of non-scientific circumstances on map makers.*

Keywords. *Earthquake, seismic hazard, seismic zonation map.*

Introduction

General seismic zonation (GSZ) 5 maps of the Armenian SSR, within the framework of similar normative maps of the USSR territory, was compiled several times, starting from 1937 to 1988. Later, 3 more such maps were compiled only for the territory of RA (Fig. 1). These maps vary in scale and reliability. We will not go into the methods and baseline materials of the maps, because that is a separate big issue. We will try to discuss the dynamics of changes in seismic hazard estimates with GSZ maps over time, considering that the designers of buildings and structures took the value of the seismic hazard level of the object's area from the maps. 1988 Spitak earthquake showed that the seismic hazard of almost the entire territory of the republic was underestimated by all the maps composed before that.

Thus, one of the main reasons for the large-scale destruction and many victims of 1988 Spitak earthquake was the underestimation of the level of seismic hazard in the RA territory [1,2,5]. Immediately after the Spitak earthquake in 1989, for connection with the restoration of the disaster zone, USSR specialists compiled a new deterministic schematic 1:500000 scale map of the seismic hazard of the Armenian SSR territory. According to this map to which the hazard level in 1981 instead of 7 and 8 points on the map, 8 and 9 points were estimated (hereafter earthquake intensity according to EMS-98 scales). At almost the same level of hazard, in 1994, through the efforts of the institutes of the system of the National Academy of Sciences of the Republic of Armenia and Yerevan State University specialists, a schematic deterministic map GSZ was drawn up of the territory of the Republic of Armenia, which in 2004 was included in the Building codes of RA and operated until 2020. According to that schematic map, there were three seismic hazard zones with horizontal acceleration of 0.10g, 0.20g and 0.40g (respectively 7, 8 and 9 and more points of intensity) in the territory of the republic. In 2018 republic and foreign professional organizations consortium was prepared new probable seismic hazard map in 1:500000 scale (Report: '' Assessment of probable seismic hazard of the Republic of Armenia''. Project # 7179350; Project Manager: A. Karakhanyan), which was approved as a construction norm in 2020. By that map territory of RA separated 4 seismic zones with acceleration from 0.10g to 0.50g (fig. 1). According to experts, this map was made in accordance with international standards [3].

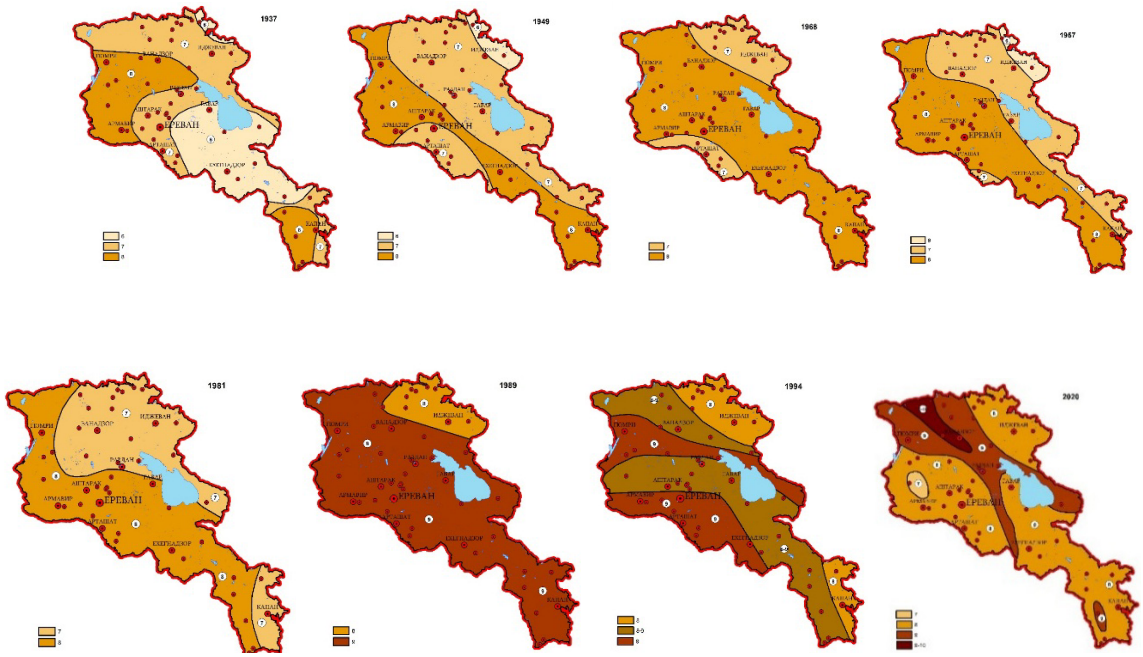

Fig. 1. General seismic zonation normative maps of the territory of Armenia for 1937, 1949, 1957, 1968, 1981, 1989, 1994 and 2020 (scale 1:2500000 to 1:500000). The level of seismic hazard is presented in points according to EMS-98.

1. Dynamics of changes in seismic hazard parameters by GSZ maps

Of two important parameters of seismic zones separated by GSZ maps - location and the maximum level of intensity to be expected in them - are presented in table 1.

Table 1. The area and intensity levels of seismic zones by construction normative GSZ maps (Building codes) of Armenia in 1937-2020.

Year of approval of the norm	The period of validity of the norm (year)	Intensity of seismic hazard zones (by EMS-98) and its area			
		6 points; km ^{2}	7 points; km ^{2}	8 points; km ^{2}	9 points and more; km ^{2}
1937	12	9.1	12. 2	8.5	-
1949	8	1.2	17.1	11.5	-
1957	11	1.0	12.9	15.9	-
1968	13	-	5.6	24.2	-
1981	8	-	12.7	17.1	-
1989	5	-		3.4	26.4
1994	16	-	15.2	4.7	9.9
2020	-	-	0.8	20.6	8.4

It can be seen from the table that since 1968 with all normative maps, the minimum seismic hazard of RA territory became 7 - 8 points, and the maximum intensity increased 9 or more points. Fortunately, according to 1937-1957 maps, the area covered by 6 units of hazards zones was not large and large-scale capital construction was not carried out in RA in those years [8]. Otherwise, the seismic risk of the RA territory would be higher than it is today. It is also important that the area of the 6 intensity zones was smaller compared to the 7 and 8 zones. Since 1957 the area of intensity zones with 8 units has increased dramatically, at the expense of zones with 7 units.

According to all 3 maps created after the 1988 Spitak earthquake, the maximum level of seismic hazard in the territory of RA was raised to 9 points and more.

Since 1937 till 2020 there was relatively little underestimation of the level of seismic hazard in areas where strong earthquakes occurred in the first half of the 20th century [1,3,5]. For example, in Shirak (1926 Leninakan earthquake) and Syunik (1931 Zangezur earthquake). According to estimates in these areas since 1937, the hazard level was 8 points, because the intensity of the mentioned earthquakes reached 8-9 points and it was impossible not to take this into account when making the GSZ maps of the areas. For the same reason, the underestimation of the seismic hazard in most parts of the Ararat region in 1957 was relatively small and later maps, as experts took into account, the intensity of the strong Dvin earthquakes of the 9th century. In contrast to the mentioned areas, until 1988, the seismic hazard of big part the Lori region, including the vicinity of Spitak city, was severely underestimated (it was estimated at 7 points, the 1988 Spitak earthquake with a intensity of 9-10 occurred). All GSZ maps more weak seismic hazard sone is be considered RA: northeast part -Tavushi region (with intensity 6-8 points).

2. Main reasons of seismic hazard level understatement By GSZ maps

Those reasons are a lot, but let's mention the 3 most important ones: GSZ mapping methodology, scarcity and low reliability of baseline data, influence of non-scientific circumstances on map makers.

Methodological foundations. It should be noted that until 1989 the majority of GSZ mapmakers were based on the geosyncline theory of tectonics [10]. Very few people put the theory of plate tectonics at the base of the seismic zonation. Today, almost all specialists admit that the South Caucasus, including the territory of Armenia, is in the collision between the Arabian and Eurasian plates in the zone, which is due to the strength of earthquakes occurrence [3,4,5].

Active faults. As recently as the 1930s, most experts believed that strong earthquakes were genetically linked to regional (deep) faults. If until the 1970s, geologists distinguished faults in the General Caucasian direction, then based on the data of large-scale and diverse geophysical observations, they began to distinguish faults in the Anti-Caucasian or transverse directions [6]. Unfortunately, the accuracy of their location and critical parameters was low. Uncertainties in important parameters of all regional faults and faults displacement rates were generally evident. To date, there is no unified opinion among specialists about the width and depth of regional fault zones.

Data of activity of faults. Since the beginning of the 1990s, when GPS observation points were installed in RA and neighboring areas, reliable data on horizontal displacements of the earth's crust and individual faults were obtained [4,5,9]. Later, the number of GPS points increased, the accuracy of measurements increased, which became essential for studying the rates and mode of displacements with fractures. Before the advent of GPS data, experts used poor and unreliable neotectonic and geodetic data to document fault displacements. Most geodetic observations dealt with vertical movements [1,3,4].

Estimating the seismic potential of faults. For this purpose, until 1988 the methods of earthquake magnitude estimation based on seismostatistical data and the length of regional faults were mainly used. Other parameters and important features of regional courtyards were almost not taken into account [6,10].

Disadvantages of earthquake catalogs. Different earthquake catalogs were used at different times when compiling the GSZ maps. Until 1962 mapmaking all three types of catalogs: instrumental, historical and prehistoric, objective, and subjective reasons—were compiled on the basis of factually poor data. There has been scant record of strong earthquakes in instrumental and prehistoric catalogs, and the rich written evidence of historical earthquakes in the archives has been little used and the facts more often misinterpreted. As a result, if in 1937 when compiling the GSZ map, the representative magnitude of earthquakes was considered to be 4.5 at best, starting in 1962 it became 3.0 [9,10]. The question of the depth of the hypocenters of weak and moderate earthquakes and the accuracy of the focal mechanism parameters is always a topic of debate, even today. Since 1989 in all 3 types of earthquake catalogs, data enrichment and a certain increase in parameter accuracy were performed.

The impact of non-scientific circumstances on the assessment of the level of seismic hazard in the territory of Armenia. In our opinion, the following circumstances contributed to the underestimation of the seismic hazard:

A/ Before 1989 a unified map of the USSR GSZ was being created for a very large territory with geologically, tectonically, seismically very different area with the same requirements (baseline data of different reliability, technologies);

B/ Especially from 1957 to 1989, the cheap and fast construction of a large number of multi-apartment buildings became a state policy, which had a certain effect on professionals;

C/ The influence of the frozen opinion of authoritative scientists on the GSZ map makers was great. They were often the leaders of these works [9,10].

Conclusions

Until 2020 the level of seismic hazard in the territory of RA was reduced with all 7 GSZ maps approved by the construction norm. If in 1937 with the map it was rated 6-8 points according to the EMS-98 scale, then with the current map (2018) it became 7-10 points (acceleration 0.10-0.50g). The reasons for this are both subjective and objective. This fact has significantly contributed to the increase of the seismic risk in the territory of the republic, because the buildings and constructions of the state sector were designed and implemented taking into account seismic norms. 2020 can be considered a significant improvement of the situation. Probabilistic map of GSZ of 1:500000 scale approved as norm, prepared by RA and foreign specialists. It is based on a huge variety of the latest geological, tectonic, seismological and other important factual data, and the map was created using modern technologies [3,4].

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