

DEVELOPMENT OF A SPECIAL MACROSEISMIC SCALE BASED ON THE DATA OF CHURCHES DAMAGED BY THE 1926 LENINAKAN EARTHQUAKE

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Abstract: *To assess the intensity of strong historical earthquakes on the territory of Armenia, a special macroseismic scale was compiled based on statistical data on the damage to the buildings of Armenian churches by the devastating 1988 Spitak earthquake. It is important that the stored data covers a long period of time (about 2000 years) without big breaks. The absence of a macro-seismic scale made it impossible to accurately determine the severity of these earthquakes. Therefore, this information was interpreted differently by different seismologists, and the strength of earthquakes was largely underestimated. A new preliminary special scale was created based on the damage analysis of church buildings located in the 7-10 intensity zone of the 1988 Spitak earthquake. It was necessary to improve this scale with other, well-studied, similar studies of earthquakes. We chose the 1926 Leninakan earthquake having studied in detail the technical condition of the church buildings damaged by this earthquake, the injuries received local factors affecting the seismic intensity (soils, relief, groundwater level, etc.), types of church buildings and written sources about their damage, and summarizing them, we tried to improve a special macroseismic scale:*

Keywords: *earthquake, church, damaged, intensity, macroseismic scale*

Introduction

There is a lot of written information about strong earthquakes in the Armenian Highlands (Eastern Anatolia) over the past two thousand years [1]. These data describe the behavior of the most significant monumental architectural structures-churches, temples, palace buildings, fortresses, etc. In case of strong earthquakes [10]. Despite the available, rather rich historical written information, it is difficult to estimate the intensity of earthquakes on known scales (MSK-64 or EMS - 98, MM, etc.), since there is no data on damage to Armenian churches in the descriptive parts of the earthquake [3,7]. When determining the intensity of historical earthquakes, various experts interpreted the facts in their own way, which could not be objective. Therefore, for a more objective and systematic interpretation of the actual historical data, it was necessary to compile a special scale of seismic intensity based on the degree of damage to the buildings of Armenian churches by earthquakes of our time. Such an initial scale was compiled by S. Nazaretyan, in which the basic principles of the creation of the MSK-64 [5] scale, were observed, in particular the 12-point gradation of intensity [4,6,7,8]. Studies show that Armenian churches can suffer from seismic fluctuations of 7 or more points [6] therefore, it makes sense to create a scale for the intensity of 7-10 points [7].

Structurally, the central dome has an important place in the buildings of Armenian churches, the height of which is often commensurate with the height of the building itself. The buildings studied are divided into two groups – churches with domes and without. Almost all the buildings of Armenian churches are built of dense tuff on lime mortar, masonry type „midis,, and the wall thickness averages 0.8-1.0 m [6].

The method of drawing up a new special scale, which we also used, is as follows [7]. Strong earthquakes are selected, for which reliable isoseismal maps have been compiled and then the damaged buildings of churches located in an intensity zone of 7 or more points are studied. The local ground, hydrogeological and topographic conditions affecting the magnitude of the seismic intensity are studied separately to determine the possible increment of the score. Based on the collected data, a table of the most characteristic damages of churches is first compiled, and then a special macroseismic scale. The number of church buildings on the territory of the Republic of Armenia is quite large (more than 1,500) and they are located throughout the territory [7,9]. Naturally, in order to compile a reliable scale, a data set of as many earthquakes as possible is

needed. However, the choice of such earthquakes is very small. Among such earthquakes is the 1926 Leninakan earthquake. But, despite the diversity of buildings in churches, there are many elements, such as layout schemes, dimensions, building material used, features of construction technology, etc., which allow, from the point of view of earthquake resistance, to combine them into groups and form the basis of a macroseismic scale [6].

1. Parametrs of 1926 Leninakan earthquake and Map of isoseismals

According to macroseismic data, the coordinates of the earthquake epicenter are: $\varphi=40,68$; $\lambda =43,75$, magnitude-5.75, Intensity: 8-9 points.- For our purpose, we chose the map constructed by Bjus, shown in Figure 1. It follows from the map that the isoseismals has a strong attraction in the north-east direction, which coincides with the active breakthrough of Akhuryan. The isoseismals of 8 and 7 points are parallel to each other, and the isoseismals of lower intensity is gradually rounded taking an isometric form. The accuracy of the isoseismals of the earthquakes of 1926 and the Spitak earthquakes of 1988 is quite different: The 1988 Spitak earthquakes isoseismals is more accurate.

2. Investigation buildings of Armenian Churches dislocation on intensity zone 7-9 of 1926 Leninakan earthquake

When describing the technical condition of church buildings, a large place was given to walls, especially the occurrence of through cracks, their size and position, displacements of walls with cracks, damage or fall of domes, damage to foundations, etc.

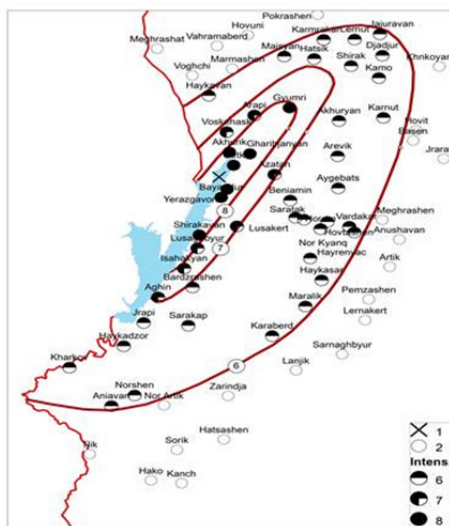


Fig. 1. Isoseismal map of 22.10.1926 Leninakan earthquake [2]: 1- macroseismic epicenter; 2- surveyed settlements.

A format (questionnaire) was developed to describe all church buildings, which included data on the location of church buildings, their plan, year of construction, soil and terrain characteristics affecting the level of seismic hazard, data on the main building materials used, the type of overlap, the presence of a dome, the location of old ones (before the Leninakan earthquake of 1926) damage, etc. Separately, a description of the damage received as a result of the Leninakan earthquake is presented, which are accompanied by appropriate illustrations (Appendix # 1).

Structurally, the centrifugal type has an important place in the buildings of Armenian churches, the height of which is often equivalent to the height of the building itself. Therefore, the buildings studied by us are divided into two groups: domed and without. Almost all the buildings of Armenian churches are built of thick tuff lined with limestone "midis". The thickness of the walls is on average 0.8-1.0 m. (Tokarsky, 1948; Toramonian, 1942-48; Khalpakhchian, 1980) [6,7].

3. Investigation of damage to church buildings from the earthquake

The buildings of all the churches were studied and photographed in detail on the spot. In advance, written data was collected, including fund data, about the earthquakes that occurred in that place and the damage to the churches, the repairs and reconstructions of the buildings. On the basis of all these a table was compiled showing what kind of injuries the buildings received in the same seismicity zone of the 1926 Leninakan earthquake and as a result the special macroseismic scale compiled and improved on the basis of the data of the 1988 Spitak earthquake. It should be noted that there are not many elements of improvement of the scale and changes.

Predictions of possible damage to church buildings in this scale case were reconfirmed. However, injuries not characteristic of the given level of danger were also observed. For example, on the entire 36 m high dome and the south wall of the Mother Church of Harichivank a transverse crack was caused by 1926 Leninakan earthquake, while according to the isoseismal map, the intensity here was 5-6 points. Here, it is appropriate to remember the role of the resonance phenomenon in building damage when a rigid building is built on rock soils [4], as the same effect was observed during Spitak earthquake when large cracks with a different location appeared after intensity seven [7]. However, this is a unique case that needs special research. Basically, especially in the 7-8 scale intensity zone, the damage received by the churches confirms the reliability of the Special Macroscopic scale.

4. Conclusion

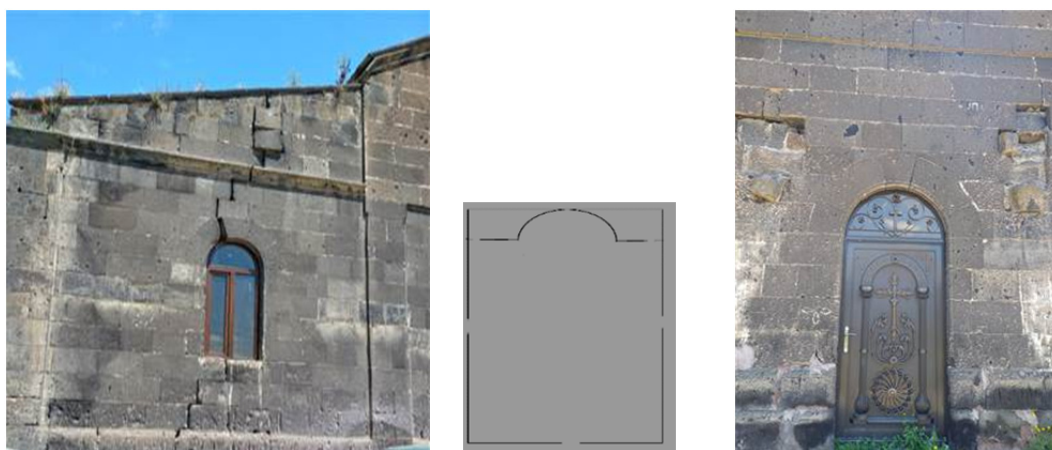
We have carried out special research in order to find out the damaged buildings of Armenian churches from the 1926 earthquake in Leninakan, depending on the intensity of the earthquake, and to obtain their main characteristics. The viability of the Special Macroscopic Scale compiled by S. Nazaretyan for assessing the intensity of historical strong earthquakes was confirmed by the data of the buildings damaged by this earthquake. The same church building, which was located in the same earthquake zone of Spitak 1988 and Leninakan 1926, received basically the same type of injuries. In particular, the new transverse cracks on the walls had approximately the same characteristics. However, they differed in their location on the building. This can be explained by the change in the location of the earthquake's focus in relation to the church. Often the cracks caused by the 1926 earthquake on the church building were widened in 1988 from the Spitak earthquake.

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Questionnaire № 5

Church St. Mary, v. Gusanagjukh



22x15x5 m

General information

1. Time of construction-1910
2. Recovery time- 2022
3. General plan, dimensions- 22x15x5
4. Terrain relief- flat, it is leveled to the west
5. Soils according to seismic properties- 1-2
6. Groundwater level-
7. The presence of the dome, its preservation- it was demolished in 1926.
8. Construction data- black tuff (hard)
9. Old injuries- were not
10. Roof- stone
11. The wave magnitude scale of Leninakan's 1926 earthquake - 8 : (according to T. Babayan).

Description of the damage caused by the 1926 Leninakan earthquake

- All walls have cracks as well as hairline cracks.
- 3 cracks on 3 walls in the western part, 2 cracks (not wide) on the eastern wall.
- 3 cracks along the entire height of the wall.
- The dome was damaged by the 1926 earthquake and demolished in 1933.
- The bell tower built later was demolished due to lack of connection with the building.