Using the Probabilistic Seismic Hazard Analysis Results for Assessment the Provision of a Given Level of Seismic Resistance of Buildings by the Current Tajikistan Seismic Codes

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**Abstract.** The consequences of the destructive earthquakes in Turkey, which occurred in early February 2023, and subsequent earthquakes in Morocco, China, Japan, Taiwan, Myanmar and other countries, have once again shown that none of the existing seismic codes in the world are fully perfect. In this connection, the question of how far the current seismic codes ensure the given level of earthquake resistance of structure is of particular relevance. At present, with the development of probabilistic seismic hazard maps in Tajikistan, a tool for assessing the provision of a given level of earthquake resistance of buildings and structures regulated by the current in Tajikistan seismic codes SNiP RT 22-07-2018 “Earthquake-resistant construction” has appeared.

# Introduction

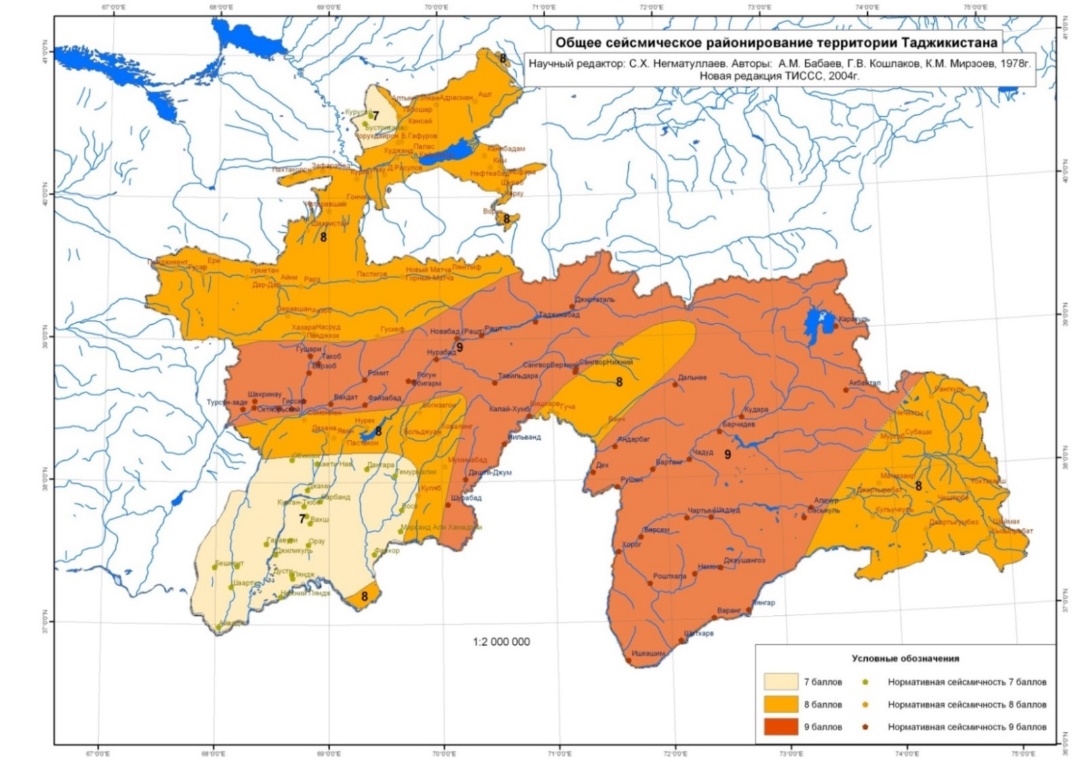
Analysis of the catastrophic consequences of the destructive earthquakes in Turkey, which occurred in early February 2023, and the subsequent earthquakes in Morocco, China, Japan, Taiwan, Myanmar and other countries, once again showed that one of the reasons for the destruction of hundreds of buildings, cause a loss of tens of thousands of people, is, among other reasons, the failure to ensure their specified seismic resistance in accordance with the assessed seismic hazard of the territory.

The assessed seismic hazard is presented in seismic codes in the form of a list of settlement and seismic zoning maps with indicating the maximum ground accelerations, that serves as the basis for determining the design seismic loads.

# Statement of the problem

During analyzing the causes of the catastrophic consequences of the Turkish, 2023 earthquakes, it was paid attention that most of the destroyed buildings were constructed in accordance with the Turkish seismic codes, developed in 2007 and based on the seismic zoning of the territory of Turkey, and worked using deterministic seismic hazard assessment results. At the same time the current Turkish seismic codes, developed in 2018 are based on a new probabilistic seismic hazard map of the territory of country for the earthquakes return period 475 years, which is significantly different of the previous one presented in the seismic codes, 2007. According to published sources, the using of the new probabilistic seismic hazard map has brought to a significant (up to two times) increasing the design seismic loads [1–3].

This circumstance served as the basis for the assessment of providing a given level of seismic resistance of buildings and structures by the current Tajikistan’s seismic codes SNiP RT 22-07-2018 “Earthquake-resistant construction”, in which presents the deterministic seismic hazard map of the territory of Tajikistan, 1978 has developed in intensity points in accordance with the MSK-64 scale (Fig.1) [4].



**FIGURE 1.** Current deterministic seismic hazard map of the territory of Tajikistan

As can be seen from this map, the entire territory of Tajikistan is completely related to seismically hazardous where it is possible the occurrence of earthquakes with an intensity of 7, 8 and 9 points, for which the design accelerations, respectively, compose 0.1, 0.2 and 0.4g.

Seismic design of buildings and structures using the spectral method in accordance with SNiP RT 22-07-2018 is based on the following regulations [4].

The design seismic load Sik in the selected direction, applied to point k and corresponding to the *i*th mode, is determined by the formula:

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where:  – seismic load value for the *i*th mode, determined under the assumption of elastic deformation of structures by the following formula:

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 – responsibility factor;

 – reduction factor, taking into account structural solutions;

 – factor, taking into account the height of buildings and structures, determined by the formula:

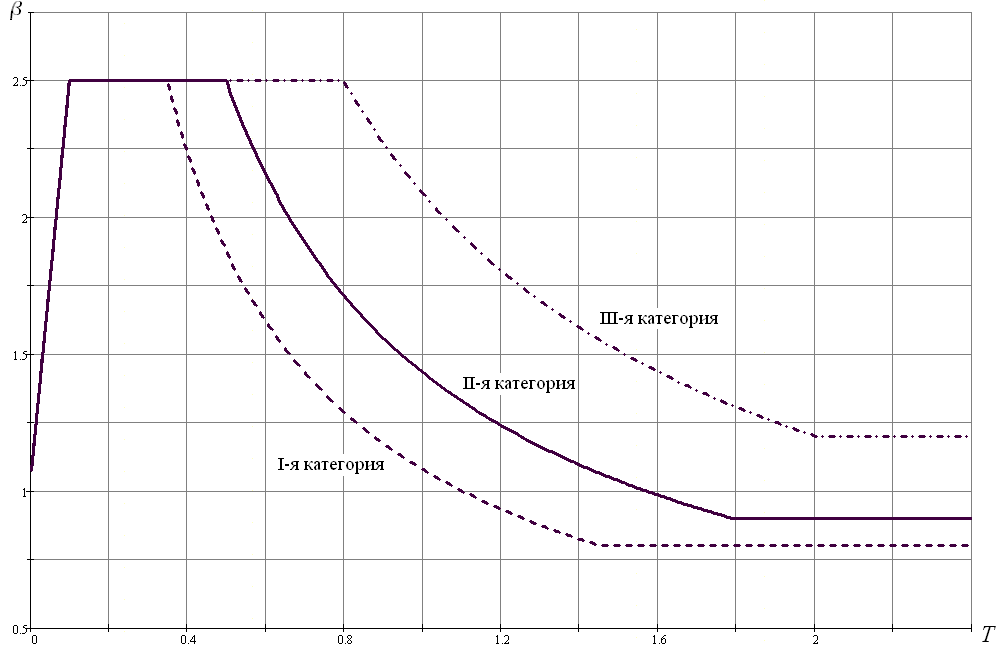
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where n - number of floors of the building (except for floors located below the ground level, basement and attic floors), whereby ;

 – the weight of the building or structure attributed to the point k, determined taking into account design loads on structures;

 – seismicity coefficient, the values of which should be taken equal to 0.1, 0.2, 0.4, 0.6, respectively, for design seismicity 7, 8, 9 and more than 9 degrees;

- dynamics coefficient (uniformed response spectra) corresponding to the *i*th modes, taken according to the graphs below (Fig.2);

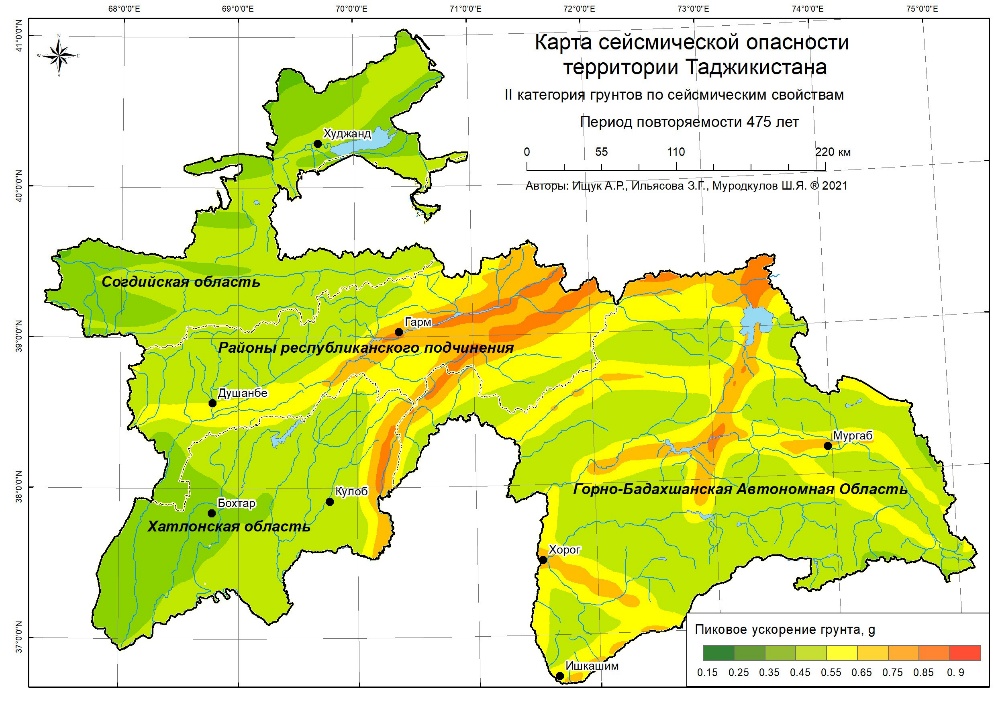


**FIGURE 2.** Dynamic coefficient graph 

 – coefficient that takes into account the ability of the building and structure to dissipate energy;

 – mode coefficient, depending on the shape of deformation of the building or structure during its free vibrations on the *i*th mode and on the location of the load.

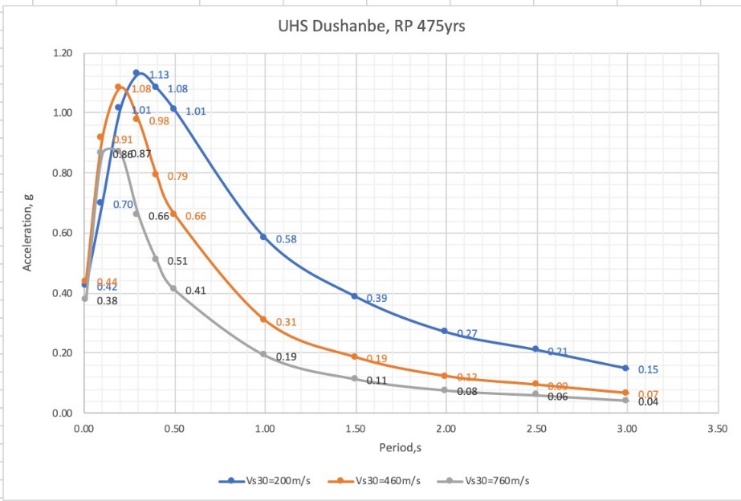
To present, the Institute of Geology, Earthquake Engineering and Seismology of NAST based a special methodology using the R CRISIS soft has developed the set of probabilistic seismic hazard maps for the territory of Tajikistan in units of peak ground acceleration PGA for earthquake return periods of 475, 975, 2475 and 4975 years for three types of soil conditions, characterized by the spreading speed of transverse seismic waves in the upper 30-meter ground layer velocity – Vs,30 (Fig.3) [5].



**FIGURE 3.** Example of probabilistic seismic hazard map in PGA for soils of seismic properties category II for earthquake return period of 475 years

# Analysis of results

One of the results during the maps developing in addition to peak ground accelerations assessment, are also the uniform hazard spectra in g values for three types of soil conditions, which can be fully used in design practice as a given design response spectrum (Fig.4).



**FIGURE 4.** Example of developed response spectra

Analysis of the shape and parameters of the given design response spectra shown in fig.4 indicates that their application in design according to SNiP methodology will be incorrect and associated with errors.

Obviously, for linear spectral calculations, the design seismic load can be determined by the following formula:

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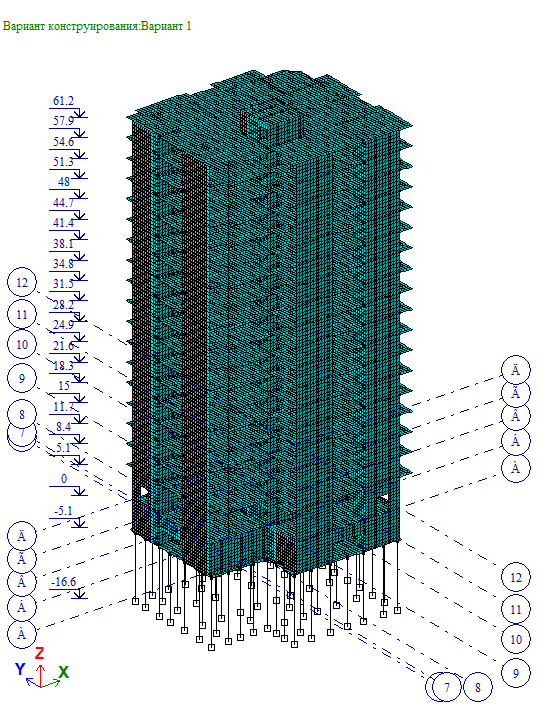
where  – reduction factor depending on the level of seismic impact,  – load safety factor,  – value of the design response spectra in g per period *Ti*.

According to the recommendations of international institutions, the using of formula 4 in structural design at , indicating the prevention of damages in load-bearing structures of buildings, can take place only for service level earthquakes (SLE) with a 50% probability of exceeding the design values during the design life of the building [6–8]. In particular, for buildings and structures with a design life of 50 years, the SLE earthquake return period is 72 years.

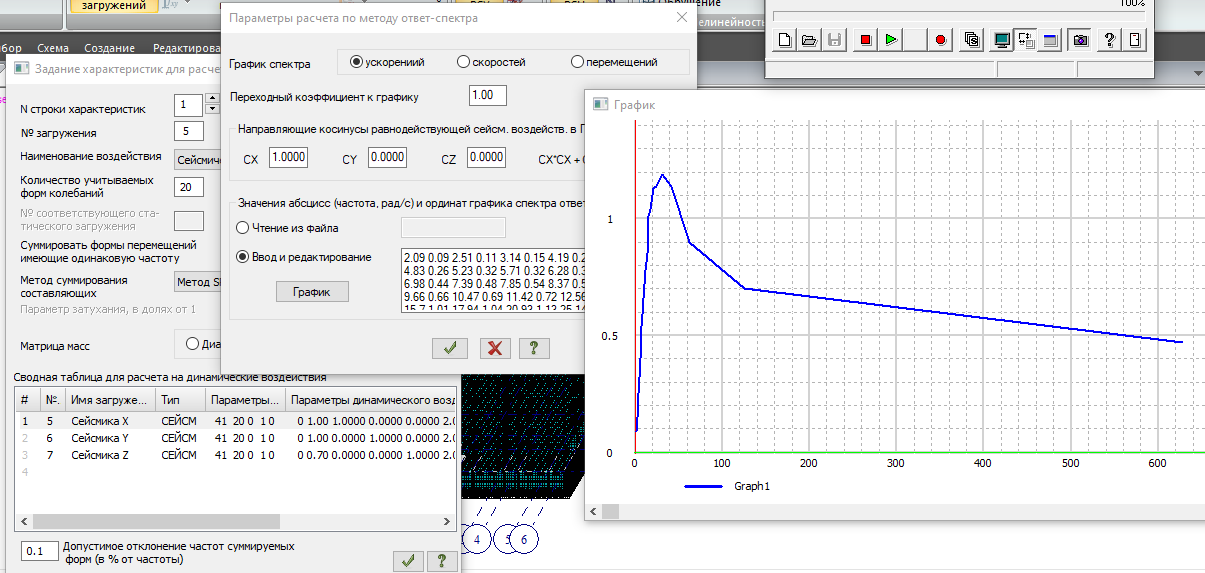
In this case, the design seismic excitation should be specified by the following combinations [9]:

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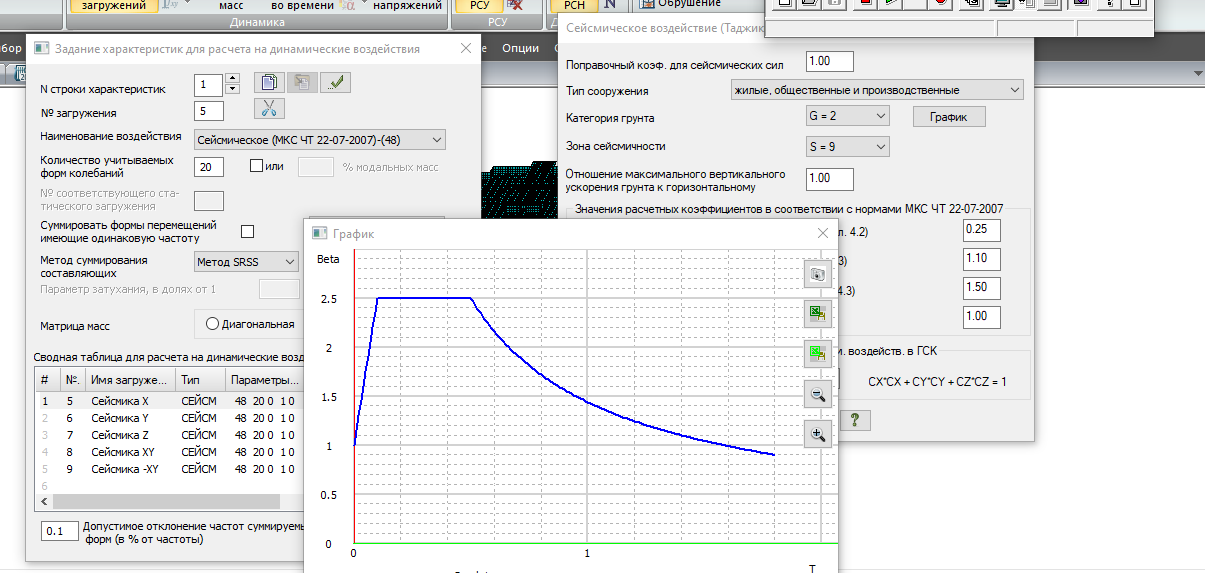
This approach to the application of the results of PSHA for structural analysis was used in the design studies of the stress-strain state of a real 18-storey building has been constructed in Dushanbe and comparative analysis with the results obtained according to the current seismic codes of Tajikistan (Figs. 5-7). In said studies load safety factor was taken to be one – .



**FIGURE 5.** 3-D model of the studied building

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**FIGURE 6.** Design seismic impact in the form of a given design spectrum (the abscissa axis is represented in circular frequencies)

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**FIGURE 7.** Design seismic impact according to current seismic codes SNiP RT 22-07-2018

# Conclusion

The stress-strain state of the building was determined by the design reinforcement of the main load-bearing structures, which, in the author's opinion, is an integral indicator of the stress-strain state of the structures. According to the results of the conducted studies, the design reinforcement values of the load-bearing reinforced concrete structures determined by using the given design response spectra from the probabilistic seismic hazard analysis are up to 1.5-3 times lower in comparing to the results of calculations in accordance with seismic codes.

The results of the conducted research allow us to conclude that it is possible to revise in the future the normative coefficient К3, which takes into account the number of stories of buildings and structures, as well as to introduce into the codes the reduction coefficient Kр, which depends on the level of seismic impact.

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