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Research Article

DEVELOPMENT OF SEISMIC MODELS OF SOIL CONDITIONS FOR SEISMIC MICROZONING OF CITIES IN UZBEKISTAN (IN ENGINEERING TERMS)

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ABSTRACT
The article discusses modern methods for assessing the seismicity of urban areas using seismic soil models. The purpose of the study is to optimally assess the level of seismicity of construction sites based on the engineering and geological conditions of the area and soil parameters and reduce the impact of possible seismic processes. The calculations of the values of peak accelerations of the free surface in the models were carried out using the STRATA program. To solve the tasks of construction and installation works in the city of Namangan, 85 models were developed throughout the city. For 85 seismic and soil models, the responses of soil strata to seismic impacts given on rocky half-spaces are calculated. For each model, peak accelerations and maximum displacement on the free surface, their change with depth, as well as the reaction spectra of the soil layer were obtained. Schemes of seismic microzoning of the city territory in terms of peak accelerations are drawn up.

Keywords: *Engineering-geological conditions, seismicity, seismic wave propagation velocity, soil density, non-linear soil properties, equivalent linear model, STRATA*

INTRODUCTION
The seismicity of construction sites is determined based on seismic microzoning performed as part of engineering and geological surveys, as well as within the framework of the requirements of KMK 2.01.03.-19. Construction and installation work is carried out in order to quantify the impact of local soil conditions (composition and properties of soils, relief features, the presence of dangerous geological phenomena, etc.) on seismicity, indicating changes in intensity in points and/or instrumental parameters of seismic vibrations. In the United States and other Western countries, seismic intensity assessment was carried out from the very beginning using instrumental parameters (PGA, spectral accelerations, etc.) and under the patronage of civil engineers. In the CIS countries, the main output parameter characterizing the seismic impact was initially the macroseismic intensity. The conversion of macroseismic intensity into quantitative parameters such as PGA, spectral accelerations, etc., was carried out in building codes. Macroseismic intensity is also used in Uzbek building codes. In the case of a macroseismic approach to assessing the seismicity of construction sites, there are shortcomings that appear when considering the influence of the groundwater level on the seismic effect. There is a formula for the dependence of the increase in intensity on the groundwater level, but there is no physical justification for this dependence and its type (Zaalishvili, 2000). In addition, the question of how the presence of a fluid component affects the physical and mechanical properties of the soil showed the absence of reasons that could affect the increase in the seismic effect. The same can be seen with respect to the type of dependence of the increment of seismic intensity on the seismic stiffness of the soil (Zaalishvili, 2018). Due to the lack of answers to the above questions, during construction and installation work, many researchers refuse to use the stiffness method for macroseismic assessment of construction sites and switch to the soil conditions modeling method.
Currently, the concept of a model is used in all industries, particularly in science. The modeling approach is now a requirement of the time, as it helps a lot in carrying out large amounts of work. A model is a material or

imaginary object that, in the process of cognition, replaces a real object, while maintaining its essential properties (Aleshin, 2011). The main concept that determines the features of engineering and seismological surveys in the study area is a model of seismic-soil conditions. This concept includes all local features of the geological environment that determine the specifics of seismic effects - their amplitude and spectral composition. The soil layer model includes both physical (elastic wave velocities, density, damping constants, etc.) and geometric (layer thicknesses, shape of boundaries) characteristics.

MATERIALS AND METHODS

The proposed method is the modeling of seismic-ground conditions for assessing the seismicity of construction sites, which studies the real engineering-geological and geophysical indicators of soils, and determines the influence of soil conditions on the parameters of seismic vibrations under real impacts of strong earthquakes.
The algorithm of actions in solving problems related to the development of seismic and soil models is divided into 3 stages. (fig.1)
Stage 1. Collection and systematization of materials.
Stage 2. Data analysis and processing of materials by various programs.
Stage 3. Generalization of results.

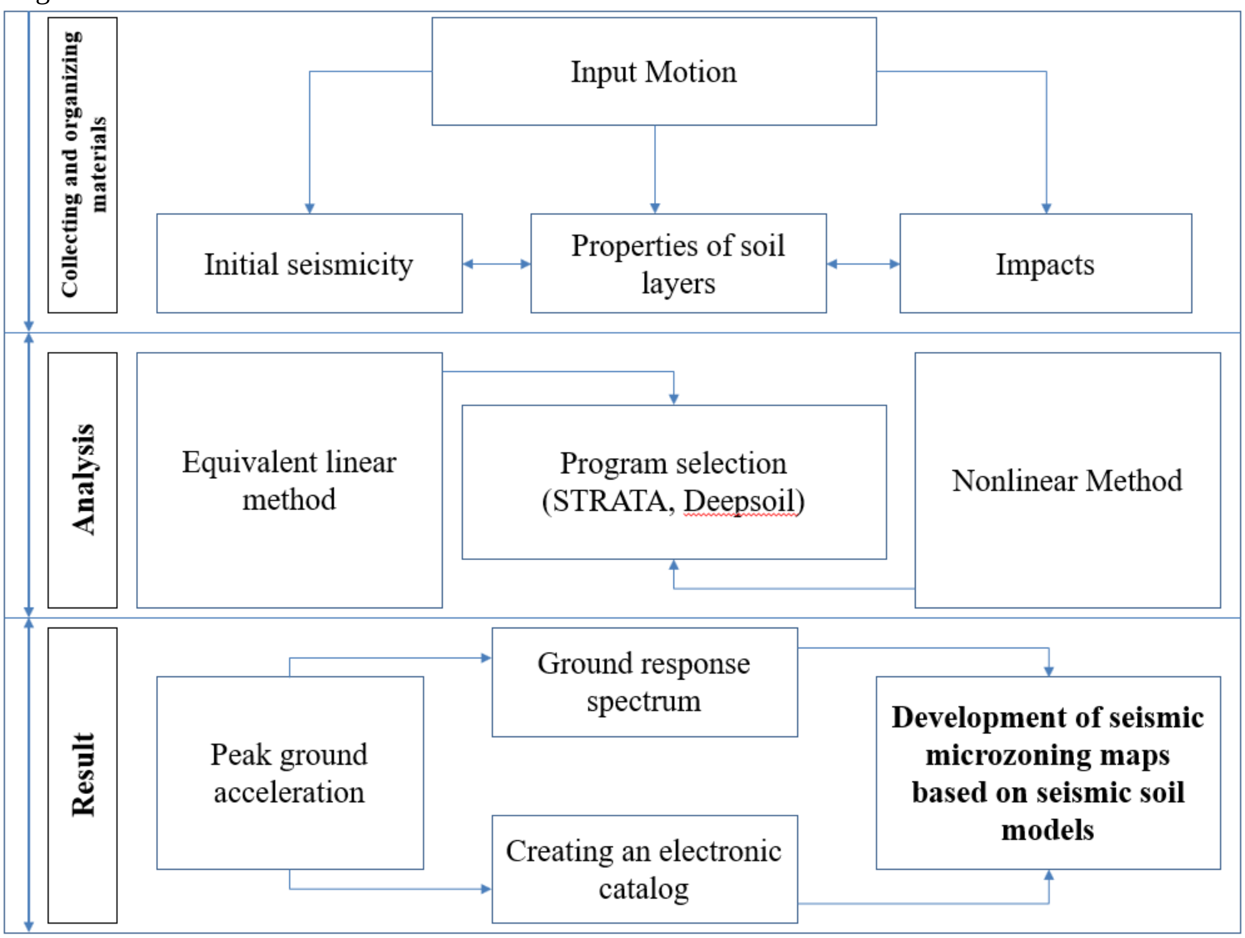

Figure 1: Algorithm of actions for the development of seismic-soil models

Recently, much attention has been paid to the development of methods that allow considering the nonlinear properties of soils [Amasyan and Mikaelyan, 1982]. Calculations have established that the introduction of nonlinear absorptions, as well as the relationship between strains and stresses, can significantly change the frequency composition of the seismic signal [Aleshin, 2015]. To calculate actions on the free surface, it is

necessary to specify an initial motion that is compatible with the target response spectrum on the bedrock.
For this purpose, the computer program "STRATA" was developed [Albert *et al.,* 2019].
The STRATA software program performs an equivalent linear analysis of ground response in the frequency domain using input motions in the time domain or random vibration theory (RVT) methods and allows randomization of ground properties. The STRATA software package implements an equivalent linear model (ELM) of the soil stratum - a model that takes into account the features of the nonlinear behavior of soils [Aki and Richards, 1983]. In ELM, soils are considered as a linear viscoelastic material, and their nonlinear properties are considered by introducing the dependences of the elastic moduli and the absorption coefficient on the magnitude of the deformation. The equivalent linear approximation is to modify the Kelvin-Voigt model (to account for some types of non-linearity). Solving the one-dimensional wave equation for one wave frequency (ω) gives displacement (u) as a function of depth (z) and time (t) [Kramer, 1996]:

$$u(z,t) = A\exp[t(\omega t + k'z)] + B\exp[t(\omega t - k'z)] \quad (1)$$

In equation (1), A and B represent the amplitudes of the up (-z) and down (+z) waves, respectively (Figure 2).
The complex wave number (k*) in equation (1) is related to the shear modulus (G), damping factor (D), and mass density (ρ) of the soil using:

$$k^* = \frac{\omega}{v_S^*} \quad (2)$$

$$v_S^* = \sqrt{\frac{G^*}{\rho}} \quad (3)$$

$$G^* = G(1 - 2D^2 + i2D\sqrt{1 - D^2}) \cong G(1 + i2D) \quad (4)$$

G* and v_S^* are called the complex shear modulus and the complex shear wave velocity, respectively. If the damping factor (D) is small (<10-20%), then the approximation of the complex shear modulus in equation (2-4) is appropriate. In calculations, STRATA uses the full definition of the complex shear modulus, rather than an approximation (Aleshin *et al.,* 2017).

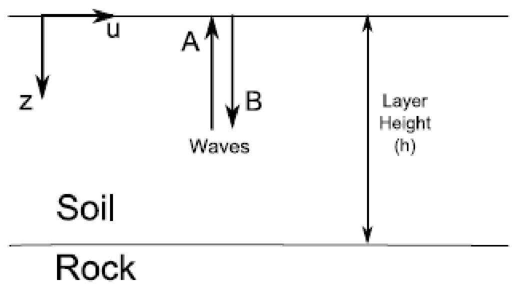

Figure 2: Notation used in the wave equation

The equivalent linear model assumes that shear modulus and damping factor are functions of shear strain. In the STRATA software package, the shear modulus and attenuation coefficient are determined iteratively so that they correspond to the strain levels in each layer.
To calculate seismic actions on the free surface using the STRATA program, it is necessary to set the input actions on the rocky base and build a seismogeological model of the soil stratum.
Models are built on the following assumptions:
– the soil stratum is taken as a viscoelastic medium lying on a viscoelastic half-space;
– the boundaries between the soil layers are horizontal;
– body seismic waves propagate vertically;
– energy absorption is determined by the attenuation coefficient in soils.
To determine the models of seismic and soil conditions on the construction site, the following are used:

Sections of the loose sediment cover down to the rocky basement. Each layer is characterized by power, density, elastic (Vs) and dissipative (αp, αs) characteristics.
The boundaries of a sharp change in the parameters of the geological section, faults, and discontinuities with vertical and lateral mixing of layers, as well as the nature of the absorption of elastic energy in the layers. The variability of the parameters of the seismogeological model can also be included in the calculations.

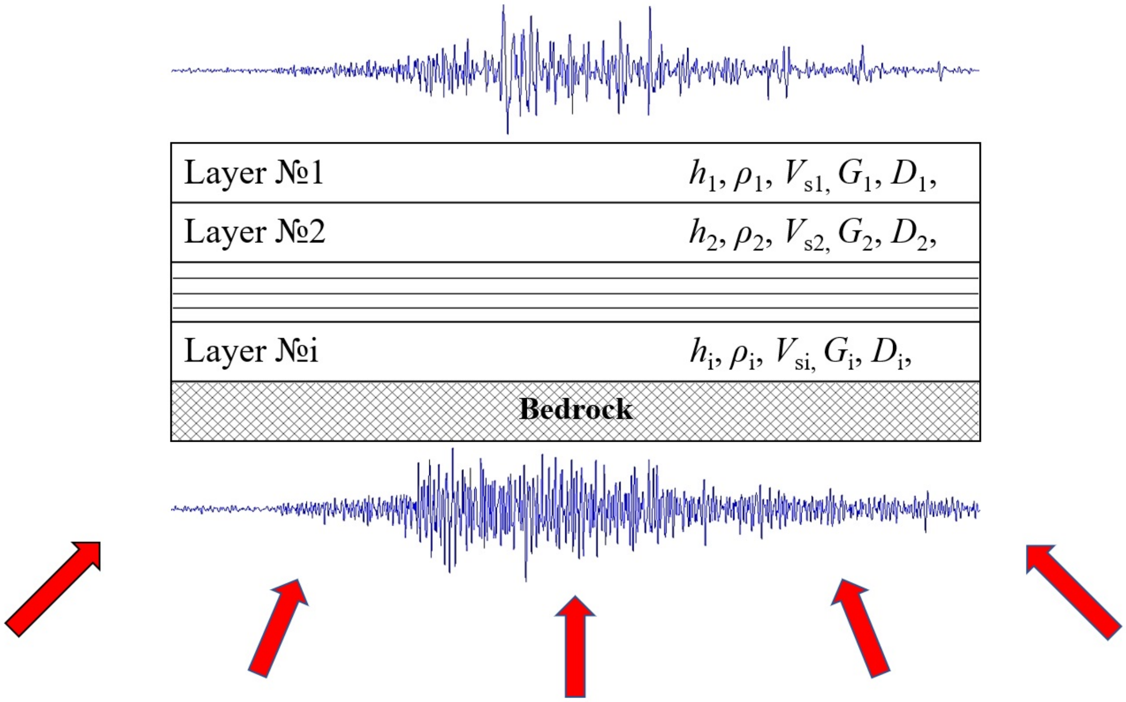

Figure 3: Nomenclature of theoretical wave propagation and initial data of seismic and ground models

In a dynamic system, the properties that determine the response of a medium are mass, stiffness, and damping. In soil under shear seismic load, the mass of the system is characterized by mass density (ρ) and layer height (h), stiffness - by shear modulus (G), and damping - by viscous damping ratio (D). Soil dynamic behavior is difficult to model because it is non-linear, so both the stiffness and damping of the system change with shear deformation.
As an initial impact, real accelerograms of earthquakes were taken, which, in their mechanism (faults and reverses) and in the nature of the propagation of seismic waves, correspond to the seismological conditions of the territory of the Republic of Uzbekistan.
Further, materials were collected that characterize the engineering-geological and seismic properties of soils (based on the materials and results of complex geophysical studies carried out by seismic exploration methods KMPV, MASW, and the physical and mechanical properties of the soil were also studied. [3]

RESULTS AND DISCUSSION
Integrated engineering-geological and geophysical studies were carried out on the territory of the city of Namangan of the Republic of Uzbekistan. The territory of the city of Namangan and its environs are characterized by the distribution of deposits of the Upper Pliocene of the Neogene age in the adyr zone and the Quaternary system in the plain. The Neogene system is represented by the Upper Pliocene deposits of the Kepeliya Formation (N_2^3кр) represented by an interbedded stratum of clays, and sandstones and conglomerates. The Quaternary system is represented by four age complexes of sediments: the Lower Quaternary-Sokh complex ($Q_I$sh); Middle Quaternary-Tashkent Complex (Q_{II}ts); Upper Quaternary - Golodnostepsky complex (Q_{III}gl); Holocene modern-Syrdarya complex (Q_{IV}Sd).

The thickness of the deposits of the Sokh complex is 10-20 m. The deposits of the Sokh complex also include loess-like loams, compacted, yellowish-gray in color, plastered with inclusions of pebbles, gravel and crushed stone. The Middle Quaternary deposits of the Tashkent complex ($Q_{II}ts$) occupy the surface of the IV and V above-floodplain terraces of the Naryn River and its tributaries, as well as the denudation surfaces corresponding to these two phases of denudation. To the south, the Lower Tashkent boulder-pebbles submerge under the Upper Quaternary deposits of the Golodno-steppe complex ($Q_{III}gl$). The maximum thickness of the Lower Tashkent deposits is 80-90 m.[5]

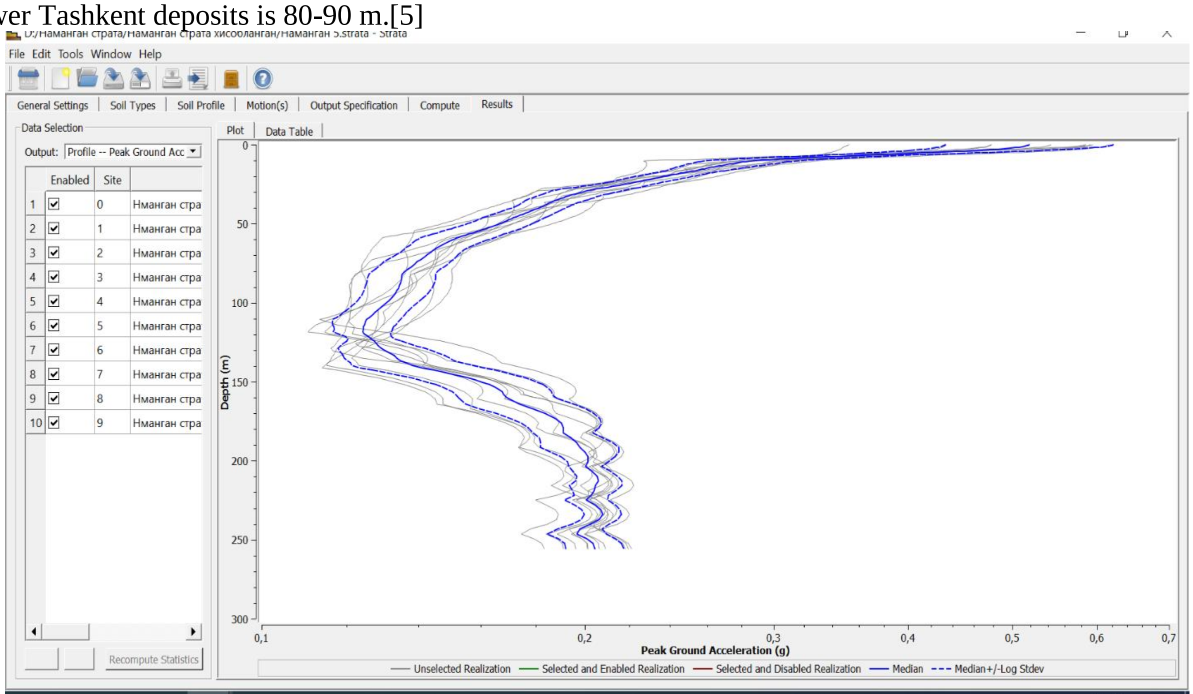

Figure 4: Peak ground acceleration profile of observation point №25

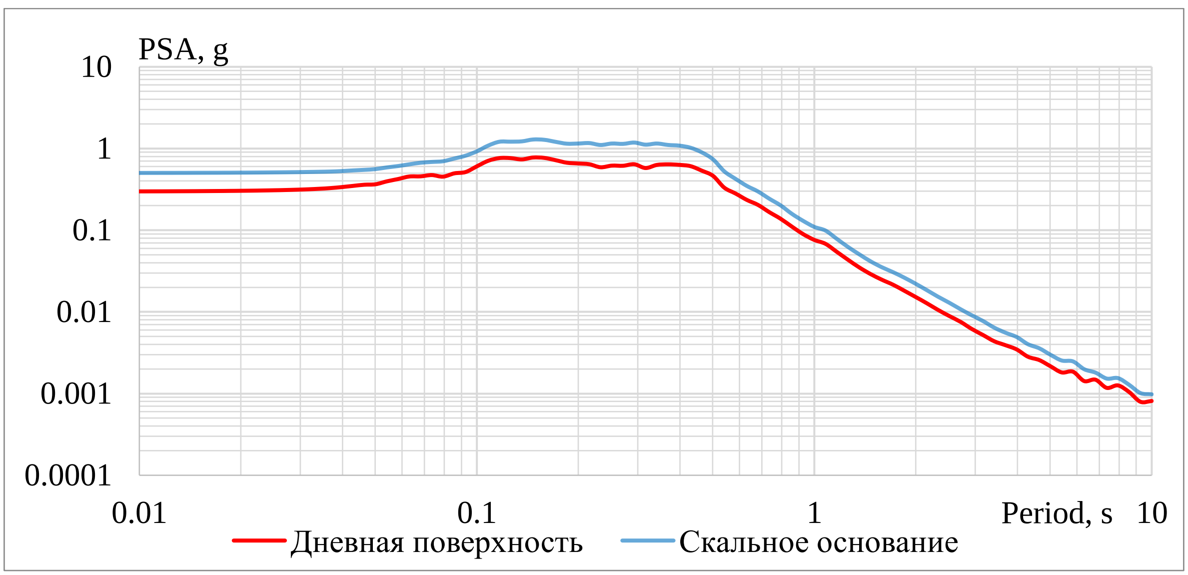

Figure 5: Soil stratum reaction spectrum at different depths for point №25

Soil density varies from 1.54 to 1.80 g/cm^3. According to the results obtained, the Vs30 velocities for the entire site lie in the range of 298-778 m/s. The territory of the study area can be conditionally divided into three sections: relative to the average speed (400-500 m/s) - the central, and northeast and southwestern parts of the area. High values of velocity Vs30 (600-700 m/s) are found in the eastern, and northern and north-south parts of the area. In the southern and southeastern parts of the area, the propagation speeds of transverse waves lie in the range of 300-400 m/s.

Table 1: An example of a seismic and soil model used in the calculations by the STRATA program (point No. 21 in the territory of Namangan)

Lithology	Soil type	Layer power, m	Shear wave speed Vs (m/s)	Ground density ρ (κN/m³)	V_{30}	ρ_{30}	Peak ground acceleration (PGA) Initial exposure at 0.33 g		Estimated seismic intensity of the site, in points
							Linear elastic wave propagation	Equivalent Linear Analysis	
	Sandy-loam	16,77	255	1,71	345	1,83	0,45	0,53	9
	Gravel	13,62	628	2					

Table 2: An example of a seismic and soil model used in the calculations by the STRATA program (point No. 10 in the territory of Namangan)

Lithology	Soil type	Layer power, m	Shear wave speed Vs (m/s)	Ground density ρ (κN/m³)	V_{30}	ρ_{30}	Peak ground acceleration (PGA) Initial exposure at 0.33 g		Estimated seismic intensity of the site, in points
							Linear elastic wave propagation	Equivalent Linear Analysis	
	Sandy-loam	3,80	316	1,91	708	2,12	0,31	0,39	8
	Gravel	21,70	657	2,05					
	Conglomerate	4,50	1152	2,4					

Based on an equivalently linear approach, seismic-soil models have been developed for 85 observation points. It should be noted here that the results of seismic surveys were used in the development of seismogeological models, *i.e.* changes in parameter space Vs30. For each point of the study, such an important indicator of engineering seismology as the spectrum of soil response to seismic effects was built.

The response spectra of the soil stratum allow one to analyze the change in the response of the soil to impacts in various spectral ranges. The smallest change is observed for point 25 (Fig. 4-5). As a result of the simulation, graphs of the change in peak acceleration and the response spectrum of soils with depth were calculated.

The value of the peak acceleration on the day surface of the studied territory for the presented points varies from 0.27g to 0.53g.

The isolines of various peak accelerations were displayed using the triangle method. Having simulated three earthquakes for all 85 points, a map of the seismic zoning of the territory of Namangan city was constructed by the calculation method based on the values of peak accelerations at initial seismicity of 0.338g, respectively. The maps were first built using 85 points using the triangle method. Next, the disputed areas were corrected using the ArcGIS vector graphics editor and other graphics editors.

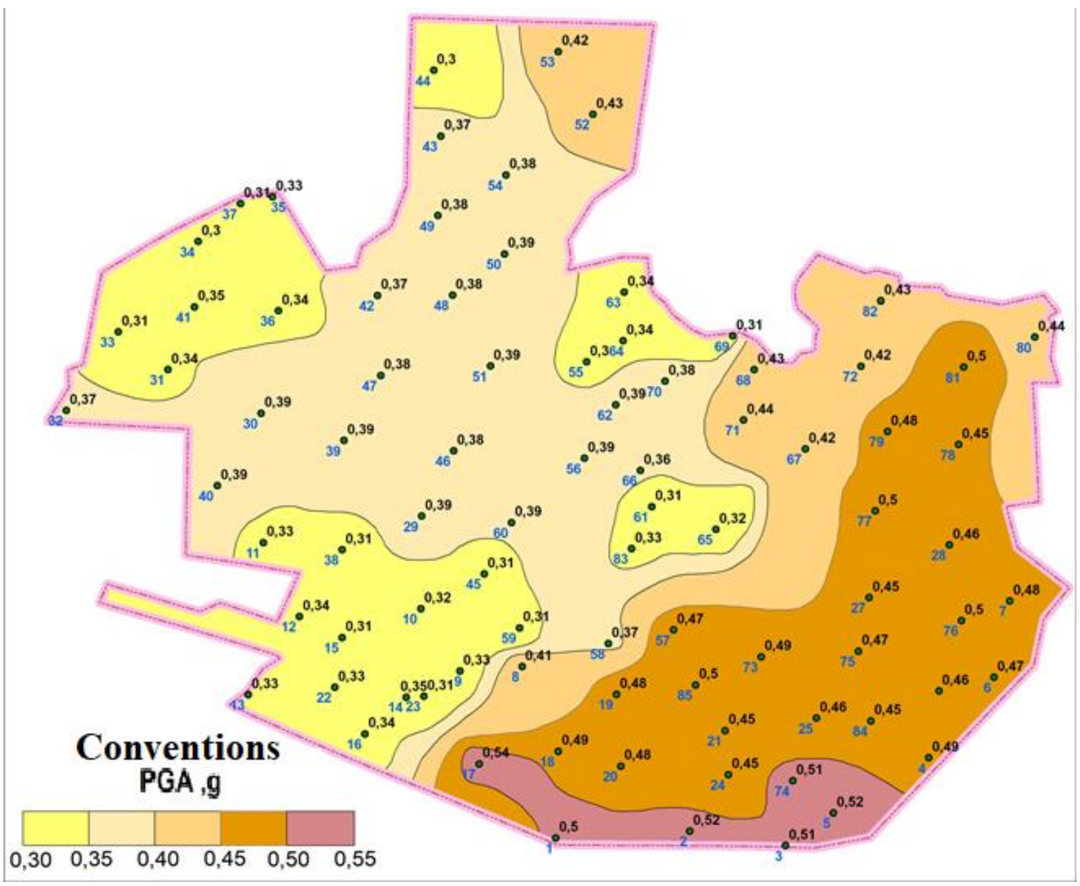

Figure 6: Map of seismic microzoning of the territory of the city of Namangan according to the values of peak acceleration (PGA) on the surface of the model

CONCLUSION

Studying the response of soil strata to seismic vibrations (in peak accelerations PGA) under given seismic effects using the STRATA program helps to dissect territories with different peak accelerations of soil particles, taking into account the seismological, engineering and geological conditions of urban areas. Based on the simulated PGA plots and increments of seismic intensity, the seismicity of construction sites is assessed not only in terms of macroseismic indicators but also in engineering parameters. The compiled models of the city territory can be applied to solve the problems of urban planning.

REFERENCES

Aleshin AS (2011). Macroseismic foundations of seismic microzoning//Problems of engineering seismology.. Issue **38**(4) 15-28.

Aleshin AS, Anikin OP, Pogrebchenko V (2017). Communication of engineering-geological and seismic characteristics of soils: justification and prospects for use. "Seismic technologies-2017" materials of the scientific and practical conference. Center for Seismic Data Analysis of Moscow State University named after M.V. Lomonosov, 231-234.

Bozorov Zh, Mansurov A, Ruzimboev F, Teshaeva R (N.D). On the issue of the influence of loess soils on the seismic intensity of the construction site. 152-156 Art.

Zaalishvili VB (2000). Physical bases of seismic microzoning. M.: OIFZ RAN. 367p.

Karimov VI (1971). Results of preliminary hydrogeological studies on the territory of Namangan to determine the conditions for the use of various types of drainage (report of the Namangan drainage party for 1969-1971) Funds of the NPGGO Uzbekhydrogeology, Tashkent.

Zaalishvili (2018). Methodology for assessing seismic impacts. V.kn.: Setting seismic impacts. Issues of engineering seismology. M.: Nauka, 193. Issue. 34. 155 p.