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DEVELOPMENT OF A CATEGORY OF SEISMOGROUND MODELS BASED ON THE SEISMIC INDICATORS OF SOILS.

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Annotation: This article highlights the development of seismoground models based on seismological and geological-geomorphological research. Seismoground models play a crucial role in assessing the variations of seismic waves in soil layers of different depths and their impact on structures.Using computational methods, the amplitude-frequency characteristics of soil layers and the propagation velocities of seismic waves were determined. During the study, accelerograms of three earthquakes corresponding to real ground conditions were analyzed. Calculations conducted in the "ProShake" software resulted in the identification of the physical-mechanical and dynamic characteristics of soil layers.
Keywords: seismoground models, seismic waves, soil layers, amplitude-frequency characteristics, accelerogram, ProShake software, seismic hazard.

Seismic soil models are being developed that help to take into account seismic waves in different layers of soils and their impact, as well as are important in assessing the seismic risk associated with buildings and structures. Seismic ground models are primarily used to assess the dynamic properties of the earth and their seismic impact.

Calculation methods allow determining the amplitude-frequency characteristics of the soil layer and, accordingly, the characteristics of vibrations on the free surface of the site or at internal points of the medium, modified by the layered medium [1].

To perform calculations using this method, it is necessary to determine the initial seismic impact, given by an accelerogram or reaction spectrum, and construct seismogeological models of the soil layer. Real accelerograms of three earthquakes were obtained, corresponding to the seismological conditions of the study area in terms of their mechanism (descent and rise) and the nature of seismic wave propagation.

In engineering-seismological and geological-geophysical studies, a seismic soil model is compiled. This model describes how the layers of the engineering-geological floor respond to seismic waves. This model includes the lithology, density, transverse wave velocity (Vs), longitudinal wave velocity (Vp), moisture content, and other important properties of soils[1,2].

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In the "ProShake" program, the values of soil lithology, depth, transverse wave velocity Vs (m/s), and dynamic modulus of elasticity y (kPa/m) are entered to obtain cross-sections of transverse wave velocities (Vs) of soil layers.
The lithology of the soil is determined based on the results of engineering-geological data. In seismic studies, data on the speed of seismic wave propagation in the soil are obtained. The dynamic modulus of elasticity is determined using the soil layer density values [2,3]. In seismic prospecting, the product of the formation density 9.81 m/s2 (gravitational acceleration, g) is used to derive the dynamic modulus of elasticity y (kPa/m).
The dynamic modulus of elasticity has the following relationship with the average bulk density of the layer:

$$U=\rho \cdot g$$

Here: ρ - density of the soil layer (g/c=sm3); g - gravitational acceleration (9.81 m/s2).

From seismic exploration data, the speed of transverse wave propagation in soil layers is determined by interpreting seismograms. The average transverse wave velocity (Vs30) is obtained as a result of calculating the values of the transverse wave velocity obtained from each layer in the soil layers up to a depth of 30 meters (engineering-geological layer). It is calculated according to the following formula:

$$V_{S30} = \frac{30}{\frac{h_i}{V_{Si}}}$$

Here: Vs30 - average transverse wave velocity for a soil layer up to a depth of 30 meters; hi - thickness of each soil layer; Vasi - the transverse wave velocity of each soil layer.
The data obtained from engineering-seismological and geological-geophysical studies conducted to study the seismic properties of the soil are used in the formation of a seismic-soil model (Table 1).
Physico-geological parameters of point No. 197 in the city of Tashkent

Lithologi	Depth	Layer thickness	Transverse wave velocity (VSi), m/s	Density (ρ), g/cm3	Dynamic modulus of elasticity (U) kPa/m
Loam and clay	0.00	1.16	396.6	1,77	17,36
Loam and clay	1.16	1.45	397.9	1,77	17,36
Loam and clay	2.60	1.81	221.8	1,67	16,38

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Loam and clay	4.41	2.26	510.7	1,82	17,85
Loam and clay	6.67	2.82	618.1	1,89	18,54
Crushed stone	9.49	3.53	729.2	1,94	19,03
Crushed stone	13.02	4.41	949.3	1,99	19,52
Crushed stone	17.43	5.51	1106.7	2,00	19,62
Crushed stone	22.95	6.89	1052.9	2,00	19,62
Crushed stone	29.84	170.2	1191.2	2,20	21,58
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The value of Vs30 determines the properties of soils to amplify or attenuate seismic waves. The transverse wave velocity of each layer expresses its density and strength. The value of Vs30 is one of the main factors in determining the stability of the soil as a foundation.
A synthetic accelerogram was used as the input accelerogram (Fig. 1).

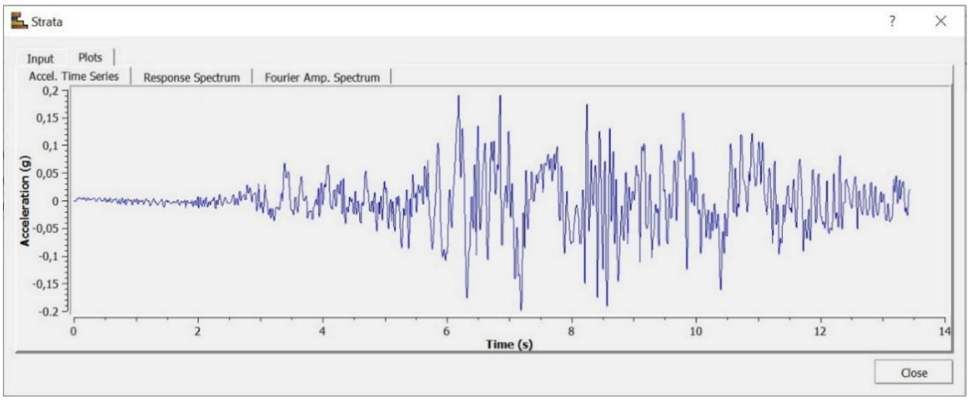

Figure 1. Synthesized accelerogram for the city of Tashkent, PGA-0.274g

The accelerogram was normalized and brought to an acceleration value corresponding to the acceleration of soils of the first category, consisting of dense conglomerates of Neogene age and rocky loess, distributed in the territory of the city of Tashkent at a depth of 70-250 m[4-7].
Data on the geological structure and physical properties of soils are the initial data for modeling the soil reaction to seismic impact. Such modeling is based on the thin-layer method, as well as the finite element method. This modeling allows taking into account the resonant properties of the soil layer and assessing the influence of soil conditions on the amplitude, frequency spectrum, and duration of oscillations [8-10].

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Based on this approach, 728 seismic soil models have been developed in the city of Tashkent. It should be noted here that in the development of seismic-soil models, seismic exploration results were used, i.e., changes in the Vs30 value of soils up to a depth of 30 meters.
For each point of the study, such an important indicator of engineering seismology - the reaction spectrum of soils to seismic influences - was constructed [9,10].
The reaction spectra of the soil layer allow us to analyze the change in the soil's reaction to the action in different spectral ranges, the smallest change was observed at point 197 (Fig. 2-3).
As a result of modeling, graphs of the maximum acceleration of soils and the change in the reaction spectrum with depth were calculated.

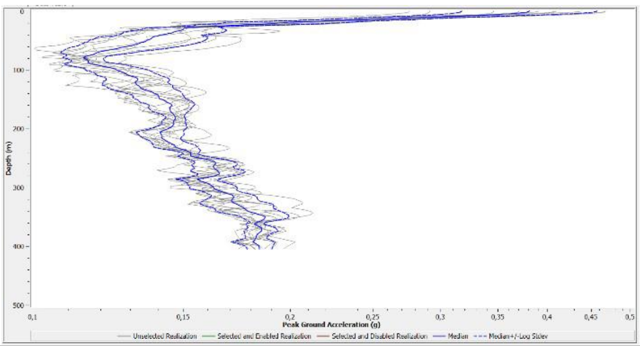

Figure 2. Peak acceleration profile of the observation point soi

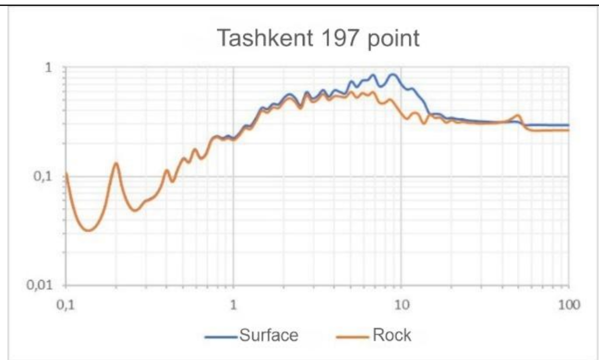

Figure 3. Reaction spectrum of the soil layer at different depths

In this geological column, based on borehole data, the lithological composition, thickness, and depth of the rocks are shown.
In this case, the rocks are distributed at a depth of 30 meters in the following order: bulk soils - 0.0-0.9 m, sandy loam - 0.9-3.3 m, gravel-gravelly - 3.3-30.0 m.
Also, based on the results of seismic exploration research, the rates of passage of transverse waves through soil layers at a depth of 30 meters are presented (Fig. 4).
When comparing the velocities of transverse waves through the soil with the data obtained from drilling wells, it was revealed that the sandy loam layer has a low velocity, and the gravel-pebble layer has a high velocity.
These indicators can be substantiated by the absorption capacity of transverse waves when passing through soils.
Thus, the lower the soil density, the higher the absorption capacity of seismic waves, and conversely, the lower it is in hard rock formations, which in turn determines the velocity value.

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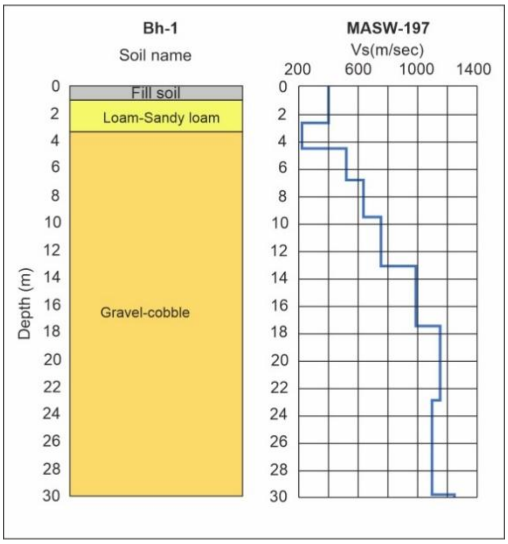

Figure 4. Graph of the change in Vs30 according to the engineering geological column and depth

Seismic-soil models perform the following main functions:
Determining the dynamic properties of soils: studying soil layers and how they affect seismic waves.
Analysis of the seismic stability of structures: assessment of the strength and stability of buildings and structures in relation to seismic movements [11,12].
Development of anti-seismic risk measures: development of advanced technologies and structures to increase the seismic resistance of buildings and structures and reduce seismic vulnerability.
Modeling the propagation of seismic waves: determining the propagation of seismic waves in different soil layers, which is the calculation of their seismic impact force [10-12].
Seismic hazard assessment: assessment of seismic hazards and identification of highly hazardous areas due to tectonic movements of the earth and their forces.
These developed seismic ground models are mainly aimed at assessing the seismicity of the territory of construction sites of various structures, the propagation of seismic wave movements on the earth's surface (Fig. 5).

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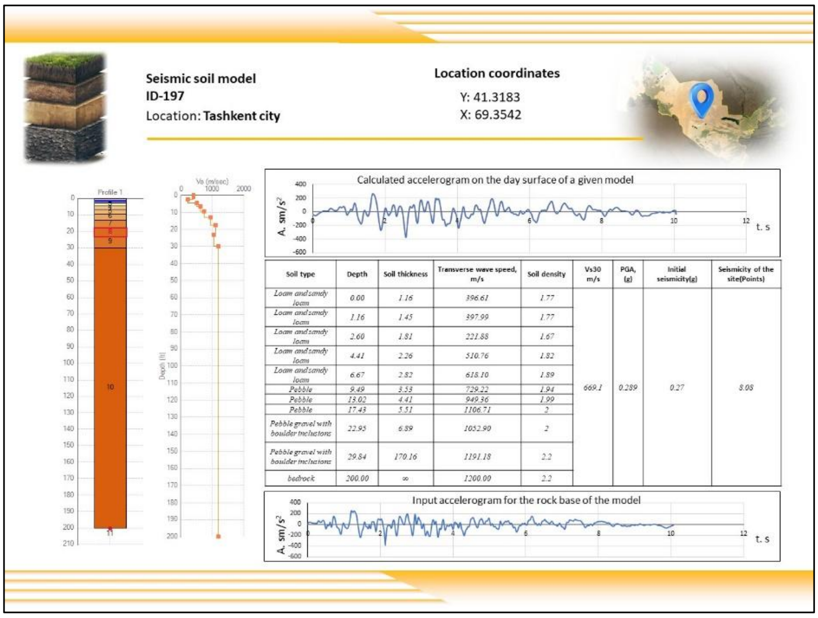

Soil type	Depth	Soil thickness	Transverse wave speed, m/s	Soil density	Vs30 m/s	PGA, (g)	Initial seismicity(g)	Seismicity of the site(Points)
Loam and sandy loam	0.00	1.16	396.61	1.77	669.1	0.289	0.27	8.08
Loam and sandy loam	1.16	1.45	397.99	1.77				
Loam and sandy loam	2.60	1.81	221.88	1.67				
Loam and sandy loam	4.41	2.26	510.76	1.82				
Loam and sandy loam	6.67	2.82	618.10	1.89				
Pebble	9.49	3.53	729.22	1.94				
Pebble	13.02	4.41	949.36	1.99				
Pebble	17.43	5.51	1106.71	2				
Pebble gravel with boulder inclusions	22.95	6.89	1052.90	2				
Pebble gravel with boulder inclusions	29.84	170.16	1191.18	2.2				
bedrock	200.00	∞	1200.00	2.2				

Figure 5. Seismic ground model at various depths.

Based on the data obtained in the soils, a seismic soil model is developed. The seismic soil model is used in assessing the seismic hazard of the territory, determining the dynamic properties of soil layers, and providing engineering recommendations for construction.

Seismic-soil models are used as an important source for making reliable decisions on various seismic conditions and construction projects, as well as ensuring the seismic safety of construction.

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