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Effect of Sand Consolidation In Course of Time on Seismic Properties

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Abstract:
Background*: The growing pace and volume of construction of high-rise buildings and important engineering structures requires the development of new territories, which, according to expert estimates, are often characterized by difficult engineering and geological conditions and deteriorated seismic properties.Cities are expanding, usually settling on land with poor seismic properties.*
Materials and Methods*: The study investigated the effect of consolidation of alluvial sand over time on the amplitude-frequency characteristics of the soil under the construction site.*
Results*: The results of the study of the influence of the factor of consolidation of alluvial sand over time on the amplitude-frequency characteristic of the soil environment under the construction site showed that the soil conditions for construction are consolidated of sands that are alluded to the shore over time and with consolidation will improve in seismic terms. This is evidenced by a decrease in the width of the frequency range of the resonant amplification of seismic vibrations by soils and a shift of resonance frequencies to a higher frequency region.*
Conclusion: *Taking into account the amplification of seismic effects in the low frequency range is important for the earthquake-resistant design of high-rise and extended structures, since they are characterized by low natural vibration frequencies. For objects located on the territory of Ukraine, this is especially important, due to the influence of strong sub crustal earthquakes from the Vrancea zone. Low-frequency vibrations propagate over long distances without significant attenuation, which can lead to dangerous resonance phenomena in structures and buildings.*
Key Word*: Amplification, Seismic oscillations, Seismic properties of soils, Frequency characteristics of soil, Earthquakes.*

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I. Introduction

The growing pace and volume of construction of high-rise buildings and important engineering structures requires the development of new territories, which, according to expert estimates, are often characterized by difficult engineering and geological conditions and deteriorated seismic properties. Cities are expanding, usually developing territories for development, the soils of which belong to the III and IV categories for seismic properties, according to SBS R.1.1-12: 2014 [2]. Very often, such soils are alluvial sands, which tend to change their physical and mechanical properties over time, in particular due to consolidation.

Confirmation that the seismic hazard of the territory is more influenced by soil conditions than the magnitude or energy of the earthquake, was the consequences of the earthquake in Quebec in the Lawrence Valley (Canada) in 1925. Severe damage and destruction were found at a distance of more than 100 km from the source in buildings based on loose deposits of the St. Charles River. At the same time, the steel structures of the granary were bent, the concrete floors were thrown off, the bases of the columns were crushed from the overvoltage of reinforced concrete. At the same time, at a distance of about 800 m from the source of the earthquake in a large hotel built on a rocky slope, residents hardly felt the earthquake. The local intensity on loose sediments was 8 points, and on rocky soils - 3 points on the modified Merkali macroseismic scale (MM). Thus, the difference in the behavior of structures, due to soil conditions, reached 5 points. At the same time, resonance effects were obviously added to the seismic effects caused by the physical and mechanical properties of soils.

II. Material And Methods

It is possible to obtain a predictive assessment of the behavior of the soil during an earthquake using ground response analysis. There are three basic approach to carry out the ground response analysis [9]. One is known as linear ground response analysis; another is called non-linear ground response analysis depending on what type of behavior of the soil material we are considering for an earthquake load. When we are considering the shear stress versus shear strain relationship of the material linear, we call it - linear ground response analysis. When we are considering it as non-linear we call it as non-linear ground response analysis.

Within non-linear there are two cases one is equivalent linear, another is absolutely non-linear.

In an equivalent linear approach, soil behavior is approximated as a Kelvin-Voigt solid. The shear stress-shear strain relationship is expressed as:

$$\tau = G\gamma + \eta \frac{\partial \gamma}{\partial t},$$

where τ- shear stress, G – shear modulus, γ - shear strain and η – viscosity, t - time.

Then the equation of motion for a viscoelastic medium has the next form:

$$\rho \frac{\partial^2 u}{\partial t^2} = G \frac{\partial^2 u}{\partial z^2} + \eta \frac{\partial^3 u}{\partial z^2 \partial t}$$

where ρ - density, u=u (t, z) – horizontal displacement, z - depth below the ground surface.

The algorithm in the original program SHAKE [14] is based on the continuous solution to the wave equation [8; 10], which was adapted for transient motions using the Fast Fourier Transform techniques. To date, this algorithm is used by the programs Proshake [12], EERA [1], DEEPSOIL [6], etc. An equivalent linear procedure is used to account for the nonlinearity of the soil using an iterative procedure to obtain values for shear modulus and damping ratio that are compatible with the strain induced in each sublayer.

In non-linear analysis, the following dynamic equation of motion is solved:

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = -[M]\{I\}\ddot{u}_g(t),$$

where [M] - matrix of mass, [C] – matrix of damping, [K] - matrix of stiffness, $\{\ddot{u}\}$ - acceleration vector, - velocity vector, — displacement vector, {I} - unit vector, $\ddot{u}_g(t)$ - input accelerogram.

The equation is solved numerically at each time step using a time integration method. The mass, stiffness and damping matrices are updated at each time increment to incorporate non-linearity of the soil.

Most currently available nonlinear ground response analysis computer programs characterize the stress-strain behavior of the soil by cyclic stress-strain models:

- Ramberg-Osgood model - CHARSOIL [16];
- Iwan model –N0NLI3 [7];
- Martin-Davidenkov model - MASH [11];
- Hyperbolic model TARA [4];
- Hardin-Drnevich-Cundall-Pyke (HDCP) - TESS1 [13];
- Iwan – Mroz (IM – model) - NERA [1];
- Modification on the hyperbolic model - DeepSoil [5].

When constructing a computational seismic geological model for mathematical modeling of the effect of the soil strata on seismic effects, data on tectonics, lithology, boundary geometry, and physical-mechanical and non-linear soil properties of the site should be taken into account. On the other hand, calculations are limited by the capabilities of computational algorithms. In each case, it is necessary to find the optimal relationship between the complexity of the computational model of the geological environment and the capabilities of computational algorithms for calculating the movement of soil particles in complex models of the environment during earthquakes.

III. Result

The study investigated the effect of consolidation of alluvial sand over time on the amplitude-frequency characteristics of the soil under the construction site.

It is known that the lowest values of the velocities of propagation of longitudinal and transverse waves are observed in freshly washed sands (<0.5 years), which have practically no structural connectivity or in some of them this connectivity is weak. In such soils, the shear wave velocity Vs, as a rule, does not exceed 150 m/s. Over time, alluvial soils are compacted, structural bonds grow and strengthen in them, as a result of which seismic wave velocities increase significantly. This is confirmed by experiments that were carried out earlier at other sites (see Table 1) [2]. The phenomenon of an increase in the speed of elastic waves in such soils is explained by their consolidation and strengthening over time (siliceous bonds are formed between sand particles and clay layers, which depend on the reclamation technology), which was confirmed by the results of soil experiments with static loads in vertical and horizontal planes and sounding [2].

Table no 1: The velocities of body waves in alluvial sands

How long ago sand was washed ashore, *time*	V_p, m/s	V_s, m/s	*E*, MPa
2 months	250	140	10-12
5 months	320	190	25-28
10 years	450	260	30-35
25 years	700	430	

Table 1 shows how the velocity of P and S waves changes in sand consolidated with time.

At the first stage of the study, the available values of the shear wave velocities in the sands, which make up the soil model under the construction site (at 30 Bereznyakovskaya St. in the Dnieper district of Kyiv), were listed for the velocity value for sands that were washed ashore for 10 years and 25 years. The calculated values are shown in Table 2.

Table no 2: Change in shear waves over time in the interval of 10 and 25 years for the construction site on the street Bereznyakovskaya, 30 in the Dnieper district of Kiev

№	Lithological composition	Depth interval H, m	The velocities of shear waves Vs, m/s		
			Research time (2020)	After 10 years	After 25 years
1	Fill soil: fine-grained sand, caked, slightly moist with admixtures of construction waste	0-0,8	180	335	553
2	Alluvium soil: fine-grained sand, slightly moist, medium density and dense	0,8-5,0	260	484	798
3	Fine sand and silty sand, medium density and dense, with lenses of plastic sandy loam	5,0-27,2	240	446	736
4	Glauconite sand, fine, dense, water-saturated with interlayers of plastic sandy loam	27,2-46	350	651	1075
5	Sandstone, siliceous marl	46-66	340	340	340
6	Kaolinite sand is water-saturated	66-86	520	520	520
7	Limestone, marl	86-180	650	650	650
8	Clay	180-240	920	920	920
9	Sand, sandstone, siltstone	240-295	1300	1300	1300
10	Granite, diorite	295 - ∞	2800	2800	2800

Using the calculated velocities, new predictive soil models were built under the construction site at the address: st. Bereznyakovskaya, 30 in the Dnieper district of Kiev, which will reflect the seismic properties of soils in 10 and 25 years. Using the modified parameters of the models as a result of temporal changes (after 10 and 25 years), the frequency characteristics of the soil were calculated. The calculated frequency characteristics are presented in Figure 1. In the calculations, the software product PROSHAKE [12] and the method of equivalent linear modeling of soil response to seismic impacts [3,9] were used, since in most cases it is its application in the conditions of Ukraine that is most justified [14]. The input data were computational models of the soil strata.

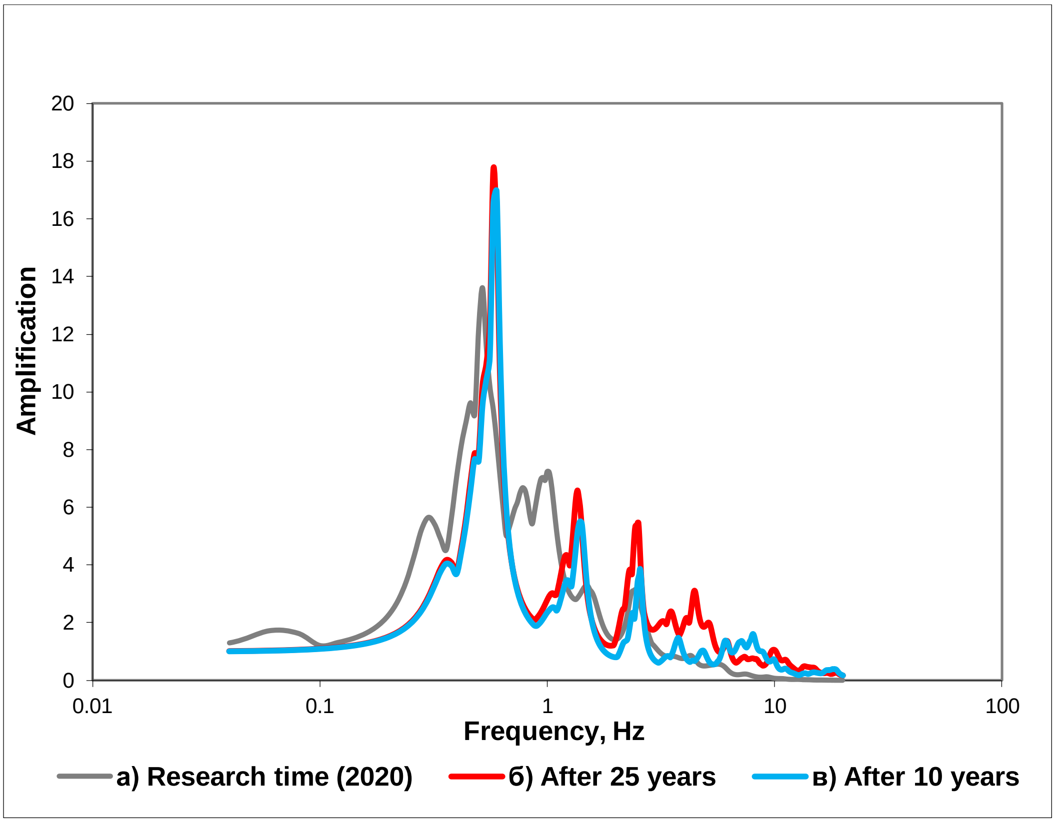

Figure no 2: Frequency characteristics of the soil compiled by sands: a) at the time of research (2020); b) taking into account the consolidation of sands after 25 years; c) taking into account the compaction of sands after 10 years.

Figure 1 shows that the frequency characteristics of soils composed of alluvial sands of different compaction are different in all three cases. In the frequency characteristics of predicted seismic soil models (after 10 and 25 years), compiled by compacted sands, the amplification factors of seismic vibrations increase, but the width of the frequency range of the first maximum decreases significantly. There is also a slight shift of the resonant frequencies to the high-frequency region. Therefore, in general, it can be argued that for the investigated site, the soil conditions for construction will improve seismically over time.

Piled up sands of soil under the construction site on the street. Bereznyakovskaya, 30 in the Dnieper district of Kiev - today, according to Table 5.1 SBS R.1.1-12: 2014 [2], belongs to the soils of the III category in terms of seismic properties.

The ratio of the velocity of longitudinal and transverse waves is an important characteristic of the material (lithological) composition, type and physical condition of the soil. As follows from Table 5.1 of SBS R.1.1-12: 2014, the magnitude of the body wave velocity is an important indicator on which the seismic properties of soils depend. If we assume that the seismic properties of soils are determined by the magnitude of the velocity of volumetric (longitudinal and transverse) waves, then, as can be seen from Table. 2, after 25 years, the soil under the construction site on the street. Bereznyakovskaya, 30 in the Dnieper district of Kiev - can be attributed to the soils of the II category in terms of seismic properties.

Figure 1 also shows that with the deterioration of the seismic properties of soils, the amplification of the vibration amplitude decreases. That is, the maximum vibration amplitude of dense soil will exceed the maximum vibration amplitude of loose soil. While, according to the experience of macroseismic studies, it is known that on loose soils, there is great damage to buildings. This is explained by the fact that under the action of seismic vibrations, the soil can change its properties. Some of the contacts between soil particles break, as a result of which the strength of the soil is noticeably reduced and, accordingly, buildings on such soils can settle, bend, and the like. With sufficiently strong seismic effects, such soils can even be thinned out, that is, the bonds between soil particles are completely lost. These phenomena are described in the nonlinear theory of the propagation of seismic vibrations in models with nonlinear soil properties. In soils of categories III and IV, according to seismic properties, changes in the parameters of the shear modulus and absorption coefficient can be sharper than in soils of I and II categories. A decrease in the amplification factor of vibrations in soils with weak seismic properties, in comparison with soils of category II in terms of seismic properties or rocky soils, at large vibration amplitudes is explained by the advantage of the influence of absorption over the intensification of vibrations.

IV. Conclusion

Conclusions. Taking into account the amplification of seismic effects in the low frequency range is important for the earthquake-resistant design of high-rise and extended structures, since they are characterized by low natural vibration frequencies. For objects located on the territory of Ukraine, this is especially important, due to the influence of strong sub crustal earthquakes from the Vrancea zone. Low-frequency vibrations propagate over long distances without significant attenuation, which can lead to dangerous resonance phenomena in structures and buildings.

The results of the study of the influence of the factor of consolidation of alluvial sand over time on the amplitude-frequency characteristic of the soil environment under the construction site showed that the soil conditions for construction are composed of sands that are alluded to the shore over time and with compaction will improve in seismic terms. This is evidenced by a decrease in the width of the frequency range of the resonant amplification of seismic vibrations by soils and a shift of resonance frequencies to a higher frequency region.

References

[1]. Bardet, J., Ichii, K., Lin, C.: Manual of EERA: A Computer Program for Equivalent-Linear Earthquake Site Response Analysis of Layered Soil Deposits. University of Southern California, Los Angeles (2000)

[2]. Building in seismic regions of Ukraine: SBS V.1.1-12: 2014, (2014). Kyiv: Building Ministry of Ukraine, 84 p. (in Ukrainian)

[3]. Chowdhury I., Dasgupta S.P. (2019) Soil Dynamics and Earthquake Engineering. In: Earthquake Analysis and Design of Industrial Structures and Infra-structures. GeoPlanet: Earth and Planetary Sciences. Springer, Cham. https://doi.org/10.1007/978-3-319-90832-8_3

[4]. Finn, W. D. L., Yogendrakumar, M., Yoshida, N., Yoshida, M.: TARA-3: a program for nonlinear static and dynamic effective stress analysis. Soil dynamics group, Univ. of British Columbia, Vancouver (1986)

[5]. Hashash, Y. M. A., Park, D.: Non-linear one-dimensional seismic ground motion propagation in the Mississippi embayment. Engineering Geology 62(1-3), 185—206 (2001)

[6]. Hashash, Y.M.A., Musgrove, M.I., Harmon, J.A., Okan, I., Groholski, D.R., Phillips, C.A., Park, D.: DEEPSOIL 7.0, user manual. University of Illinois at Urbana-Champaign (2017)

[7]. Joyner, W. B., and Chen, A. T. F.: Calculation of nonlinear ground response in earthquakes. Bulleting of the Seismological Society of America, 65(5) 1315-1336 (1975)

[8]. Kanai, K.: Relation between the Nature of Surface Layer and the Amplitude of Earthquake Motions. Bulletin Tokyo Earthquake Research Institute (1951)

[9]. Kramer, S. L.: Geotechnical Earthquake Engineering. Prentice-Hall, New Jersey. 273 (1996)

[10]. Lysmer, J., Seed, H.B., Schnable, P.B.: Influence of base rock characteristics on ground response. Bull Seismol Soc Am. 61:1213–1232 (1971)

[11]. Martin, P. P., Seed, H. B.: MASH: A computer program for the non-linear analysis of vertically propagating shear waves in horizontally layered deposits. University of California, Earthquake Engineering Research Center, Report No. EERC 78-23, Berkley, California (1978)

[12]. ProShake Ground Response Analysis Program, version 1.1. User's Manual, EduPro Civil Systems, Washington, USA, 1998, 54 p.

[13]. Pyke, R. M., TESS1: A Computer Program or Nonlinear Ground Response Analysis, California: User Manual, TAGA Engineering Software Services, Lafayette (1985)

[14]. Schnabel, P. B., Lysmer, P. B., Seed, H. B.: SHAKE: A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites. In: Report EERC 72-12, Earthquake Engineering Research Center. University of California, Berkeley (1972)

[15]. Semenova Yu., Kendzera A (2019). Calculated accelerograms for the direct dynamic method of determining seismic loads // Conference Proceedings, 18th International Conference on 5. Geoinformatics – Theoretical and Applied Aspects, May 2019, Volume 2019, p.1 – 5 https://doi.org/ 10.3997/2214-4609.201902111

[16]. Streeter, V.L., Wylie, E. B., Richart, Jr., F.E.: CHARSOIL: Soil motion computations by characteristics method. J. Geotech. Eng. Div. 100 (3), 247—263 (1974)

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