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Seismic Soil Response at the base of the Srednedniprovska Hydroelectric Power Plant

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ABSTRACT: The article presents the results of the analysis of the seismic response of various sections of the structure within the territory of the location of the main structures of the Srednedniprovska HPP. For each site, the frequency characteristics of soil models were calculated and the frequency ranges of possible amplification of seismic motions by soils were determined. A brief analysis of the results obtained is presented. It is shown that within the same territory, areas with different geological structure differ significantly in filtering properties in relation to seismic motions.

KEYWORDS: Earthquake, Inpainting, Seismic microzoning, Spectral characteristics of the soil.

I. INTRODUCTION

The nature and distribution of earthquake damage is largely determined by the response of local soil conditions to seismic impact. The destructive effect is determined by the spectral composition and intensity of seismic motions. Under strong seismic impacts, the behaviour of soils becomes nonlinear and the problem of assessing the response of the soil becomes much more complicated. Under such conditions, the reaction of the soil depends both on the composition, physical parameters, thickness and water saturation of the soil layers, and on the intensity of the earthquake and the frequency composition of oscillations in its source and on the crystalline foundation under the site.

The degree of damage to an object during an earthquake depends not only on the level of seismic effects, but also on the quality of seismic design and construction. Ensuring the required quality is possible only if the quantitative parameters of the seismic hazard of the site are correctly predicted, carried out using a set of works on seismic microzoning [1,8,9,10]. The soil mass at the base of a building or structure behaves like a filter: at some frequencies it transmits motions almost unchanged, while at others it amplifies or attenuates them. The purpose of seismic microzoning of construction sites is to predict the reaction of soils during possible earthquakes to prevent the destruction of buildings and structures during earthquakes [1, 8, 9, 10]. Despite a large number of works in this area, predicting the behaviour of soils under strong seismic impacts remains one of the most pressing problems of seismology.

The most important parameters of seismic soil motions for engineering calculations of seismic design and construction are: amplitude peak parameters of ground motions (peak accelerations, peak velocities and peak soil displacement), motion duration and frequency composition. The frequency composition of seismic motions has a significant impact on the response of a structure to seismic motions. The most dangerous phenomena are when the frequency composition of soil motions and the natural frequencies of the structure are close to each other. Thus, earthquake protection requires reliable data on the behaviour of the soil under seismic actions.

II. METHODOLOGY

The paper considers the results of modelling the spectral characteristics of the soil layer at the basis of the location of the main structures of the Srednedniprovska HPP. Srednedniprovska HPP is located within the north-eastern slope of the Ukrainian Shield. The territory on which the HPP facilities are built are subject to seismic impact mainly from earthquakes that occur in the Carpathians, Crimea and the platform part of Ukraine. The dominant influence is the Carpathian earthquakes occurring at the contact of the Southern and Eastern Carpathians (Vrancea mountains). Crimean earthquakes and earthquakes of the platform part of Ukraine, to a lesser extent, but can be perceptible. During the seismic microzoning, 3 engineering and geological sites were identified within the territory of the territory for the location of the main structures of the Srednedniprovska HPP.

For engineering-geological sites No. 1, No. 2 and No. 3, averaged models of the geological environment were built. To assess the influence of the sedimentary strata, one-dimensional (horizontally layered models of the environment) were used, which is quite acceptable in conditions near the horizontal occurrence of the main geological elements of the



sedimentary strata. Models of the geological territory for the location of the main structures of the Srednedneprovskayahydroelectric power station for engineering-geological sites No. 1, No. 2 and No. 3 were built as horizontally layered and vertically inhomogeneous. The parameters of the averaged model of the geological environment for the engineering-geological site No. 1 of the territory where the main structures of the Srednedneprovskaya HPP are located are given in Table 1.

Table 1. An averaged model of the geological environment of the engineering-geological site No. 1 Srednedneprovskaya HPP (right-bank dam)

| № | Lithological composition | Depth interval H, m | Density ρ , g/cm ³ | The velocities of body waves V, m/s | |
|---|--|---------------------|------------------------------------|-------------------------------------|----------------------|
| | | | | V _p , m/s | V _s , m/s |
| 1 | Sands washed into the right bank dam | 0 – 16 | 1,62 | 450 – 500 | 300 – 350 |
| 2 | Alluvial fine-grained and medium-grained sands with interlayers of sandy loam and loam | 16 – 32 | 1,66 | 1200 – 1300 | 350 – 400 |
| 3 | Precambrian gneiss, granite gneisses and granites, cracked, weathered | 32 – 40 | 2,2 | 1800 – 2000 | 800 – 1200 |
| 4 | Dense gneisses | 40 – ∞ | 2,6 | 2500 – 3500 | 1400 – 1600 |

The parameters of the averaged model of the geological environment for the engineering-geological site No. 2, allocated within the territory of the Srednedneprovskaya HPP, are given in Table 2.

Table 2. An averaged model of the geological environment of the engineering-geological site No. 2 Srednedneprovskaya HPP (Hydroelectric power plant building, spillway dam)

| № | Lithological composition | Depth interval H, m | Density ρ , g/cm ³ | The velocities of body waves V, m/s | |
|---|--|---------------------|------------------------------------|-------------------------------------|----------------------|
| | | | | V _p , m/s | V _s , m/s |
| 1 | Granite-gneisses, Precambrian, undivided, strong | 0 – 37 | 2,6 | 2500 – 3500 | 1400 – 1600 |

The parameters of the averaged model of the geological environment for the engineering-geological site No. 3 of the territory where the main structures of the Srednedneprovskoe HPP are located are shown in Table 3.

Table 3. An averaged model of the geological environment of the engineering-geological site No. 3 Srednedneprovskaya HPP (Hydroelectric power plant building, spillway dam)

| № п/п | Lithological composition | Depth interval H, m | Density ρ , g/cm ³ | The velocities of body waves V, m/s | |
|-------|---|---------------------|------------------------------------|-------------------------------------|----------------------|
| | | | | V _p , m/s | V _s , m/s |
| 1 | Mixed-grained alluvial sands in the body of the dam | 0 – 14 | 1,62 | 350 – 450 | 300 – 350 |
| 2 | Quartz sand, fine and silty, with freshwater shell detritus | 14 – 36 | 1,6 | 1200 – 1300 | 350 – 400 |



| | | | | | |
|---|---|---------|------|-------------|-------------|
| 3 | Quartz sandstone, weakly cemented glauconite | 36 – 42 | 1,88 | 1400 – 1500 | 800 – 1000 |
| 4 | Dark green clay, glauconite, sandy with sand interlayers | 42 – 68 | 1,92 | 1200 – 1600 | 1000 – 1200 |
| 5 | Precambrian gneisses, granite-gneisses and granites, fractured, weathered | 68 – 80 | 2,2 | 1800 – 2000 | 800 – 1200 |
| 6 | Dense gneisses | 80 – ∞ | 2,6 | 2500 – 3500 | 1400 – 1600 |

Calculations of the amplitude-frequency characteristic (AFC) of models of the soil strata of the territory of the location of the main structures of the Srednedniprovskaaya HPP were carried out using the ProShake software package [5], developed for one-dimensional modelling of the response of the upper part of the geological medium section to seismic effects. AFCs are calculated for three models of the soil environment of the engineering-geological site No. 1 (right-bank dam), No. 2 (hydroelectric power station building, spillway dam) and No. 3 (left-bank dam). The initial data for constructing the AFC were taken from tables 1-3 and the created database of the deformation characteristics of soils (the dependence of the shear modulus and the absorption coefficient on the magnitude of the shear deformation) based on materials [3, 4, 6, 7, etc.].

When constructing the frequency response of models of the geological environment of engineering-geological sites No. 1, No. 2 and No. 3 of the territory of the location of the main structures of the Srednedniprovskaaya HPP, the method of equivalent linear modelling of the reaction of the soil layer to seismic effects was used [2]. The behaviour of each layer of the soil model in the calculations was specified by the Kelvin - Voigt model (viscoelastic). Each layer of the soil model was characterized by such parameters as: layer thickness, P and S wave velocities, density, nonlinear dependences of shear modulus and absorption coefficient on shear deformation. The use of the dependences of the shear modulus and the absorption coefficient on the shear deformation in the calculations makes it possible to take into account the nonlinear behaviour of soils during an earthquake.

III. EXPERIMENTAL RESULTS

In fig. 2 shows the amplitude-frequency characteristics of models of soil strata of engineering-geological site No. 1, No. 2 and No. 3 of the territory of the location of the main structures of the Srednedniprovskaaya HPP

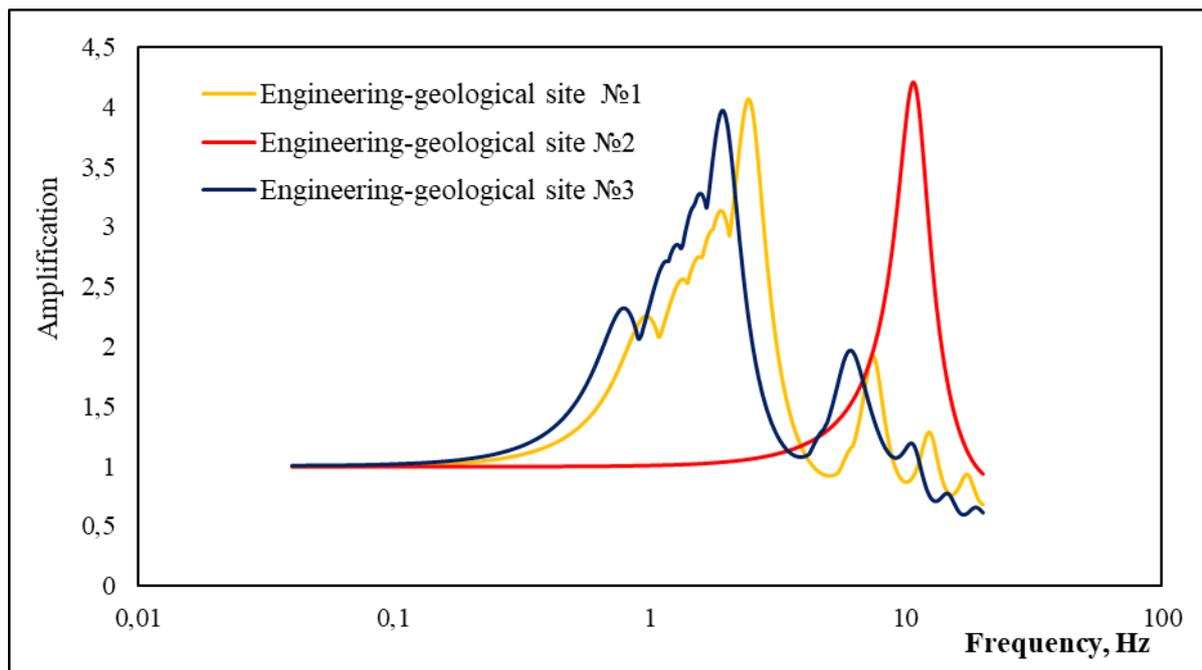


Fig. 2 amplitude-frequency characteristics of models of soil strata of engineering-geological sites No. 1, No. 2 and No. 3 of the territory of the location of the main structures of the Srednedniprovskaaya HPP



From Fig. 2 it can be seen that the frequency characteristics of the soil of the engineering-geological site No. 1 (right-bank dam) of the territory of the location of the main structures of the SREDNEDNEPROVSKY HPP is characterized by a frequency range of resonant amplification of motions by local soil conditions from 0.82 to 3.12 Hz with a seismic motion amplification factor of 4.06.

The frequency characteristics of the soil of the engineering-geological site No. 2 (the building of the hydroelectric power station, the spillway dam) of the territory of the main structures of the Sredneprovskoye hydroelectric power station is characterized by the frequency range of resonant amplification of motions by local soil conditions from 7.72 to 13.58 Hz with a seismic motion amplification factor of 4.2. The frequency response of the model of the environment of the engineering-geological site No. 2 is characterized by the frequency range of the resonant amplification of seismic motions within sufficiently high frequencies, which is associated with the release of granite-gneiss on the free surface within this site.

The frequency response of the soil of the environment of the engineering-geological site No. 3 (left-bank dam) of the territory of the main structures of the Srednedneprovskaya HPP is characterized by the frequency range of resonant amplification of motions by local soil conditions from 0.72 to 2.42 Hz with a seismic amplification factor of 3.97.

Thus, the amplitude-frequency characteristics of the soil massifs of the three sections of the main structures of the Srednedneprovskaya HPP are somewhat different. Each soil stratum exhibits its filtering properties and, thus, it is possible that the amplification of seismic motions by soils occurs in different frequency ranges. These factors must be taken into account in order to avoid possible resonance effects.

IV. CONCLUSION

The paper presents the results of modeling the filtering properties of sections of various structures within the territory of the location of the main structures of the Sredneprovskaya HPP. For each site, the frequency characteristics of soil strata models were calculated and the frequency ranges of possible amplification of seismic motions by soils were determined. A brief analysis of the results obtained is presented. It is shown that within the same territory, areas with different geological structure differ significantly in filtering properties in relation to seismic motions. The frequency range of possible amplification of seismic motions is different for each engineering-geological site. Thus, in order to determine the seismic vulnerability of the main structures within the territory of the Srednedneprovskoe hydroelectric power station, it is necessary to take into account the natural frequencies of the structure and the frequency range of possible amplification of seismic motions by soils in the areas of its location. The frequency characteristics of soil complexes were used to generate sets of calculated accelerograms for simulating seismic effects from local earthquakes and earthquakes in the Vrancea zone on the main structures of the Sredneprovskoe HPP.

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