

# The research of dynamic impacts on the hydraulic structure foundation base, transformed in the process of accident recovery

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**Abstract.** The article presents the results of a comprehensive research of the dynamic impacts on a modified base. The modified base was obtained as a result of compensatory injection at the experimental site for the accident recovery at the hydraulic engineering structure. The complex study of the dynamic impacts includes special laboratory tests to determine the soil parameters, the finite element analysis of the experimental site, taking into account the dynamic properties, the selection of the necessary equipment for field experiments based on the numerical solution results, a full-scale experiment with the measurement of the foundation sediments of the experimental site.

## 1 Introduction

The emergency hydrotechnical facility is located in the Moscow region. The stage of leveling the structure is to be performed by the method of compensatory injection. The need to study the technology [1-4] for performing work at the construction site is caused by the fact that in the world practice of construction production there is no experience of raising the building and structures by a value of about 1.0-1.5 m.

## 2 Main Part

The purpose of the research was to determine the parameters of the dynamic effects from the operation of the equipment of the structure on its base, transmitted through its foundation slab. These parameters are determined for different modes of operation of the main equipment of the structure.

To achieve this goal, it is necessary to solve the following tasks:

1. Collection and processing of archival data on the study of the dynamic effects of the equipment operation.
2. Installation of seismic sensors in the area of the base plate of the structure and conducting direct measurements of the dynamic effects on it.

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3. Evaluation of the results of the study of dynamic loads and the selection of a list of adverse dynamic effects.

4. Development of an algorithm for transferring the results of measurements of dynamic effects to the site of experimental work and selection of equipment for modeling dynamic loads.

5. Performing laboratory studies of the dynamic effect on modified soils

6. Development of a calculation model/models for determining the nature of the dynamic effects on the modified base.

7. Selection of equipment for creating dynamic loads on the pilot model.

The stage of leveling the structure is to be performed by the method of compensatory injection. To determine the nature of the dynamic effects on the modified base, a section of experimental work was built.

Experimental area of experimental work to determine the nature of the dynamic effects on the modified base is a frame of 9 racks, based on the previously formed model of the foundation slab. Above the pillars a grillage with stiffeners is performed. On the grillage in its upper part, a platform (pedestal) is arranged to accommodate the mechanism for transferring dynamic loads to the base plate model.

The model of the foundation slab was formed in the course of the work on the pilot site. Under the model of the foundation slab, injection was performed, and it was raised above its initial position in the course of experimental work.

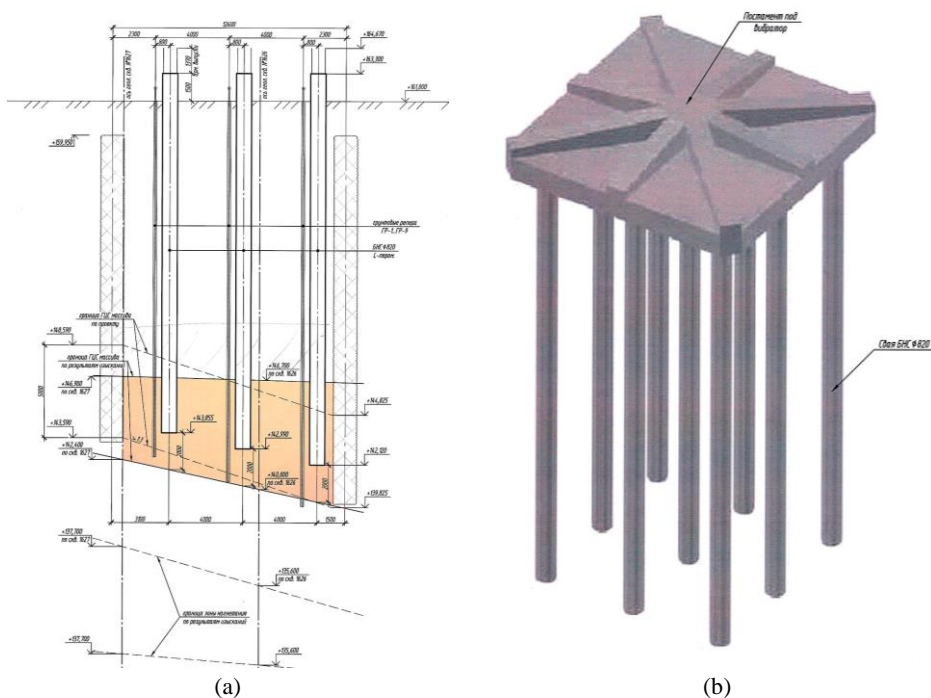
Racks are made of reinforced bored piles with a diameter of 820 mm.

Grillage is made of monolithic reinforced concrete.

The main and auxiliary devices and transmission systems on the basis of dynamic loads are located on the pedestal under the vibrator and near the place of production.

Prior to the commencement of work, equipment must be installed and verified to determine the movement of the foundation plate model during the research.

The schematic diagram of the experimental section is shown in Figures 1 and 2.



**Fig. 1.** The schematic diagram of the experimental section

For dynamic studies [5] of the foundation plate model, it is required to create a source of dynamic impact, the technical characteristics of which will allow achieving the required amplitude-frequency parameters of the foundation base, which are necessary for modeling the dynamic effect created by the turbine of the hydroelectric unit. The required dynamic parameters of the foundation base are presented in Table 1.

**Table 1.** Formatting sections, subsections and subsubsections.

No.	Soil parameter	Value
1	Dynamic load type	Sinusoidal,
2	Amplitude of foundation oscillation, $\mu\text{m}$	12,0
3	Frequency of dynamic load, Hz	2,5

To carry out numerical simulation in the REC «Geotechnics», the NRU MSUCE carried out special laboratory tests to determine the dynamic parameters of the foundation soils.

It is known that the interaction between the peak (and mean) values of the shear stresses and the magnitude of the shear strains plays an important role in modeling the interaction of the foundation soils with the projected structures of the pumped storage power plant complex under vibrational influences. On the magnitude of the dynamic deformations of the shift depends on the choice of this or that model of soil base work. Evaluation of dynamic shear deformations is the main objective of these special soil tests [6].

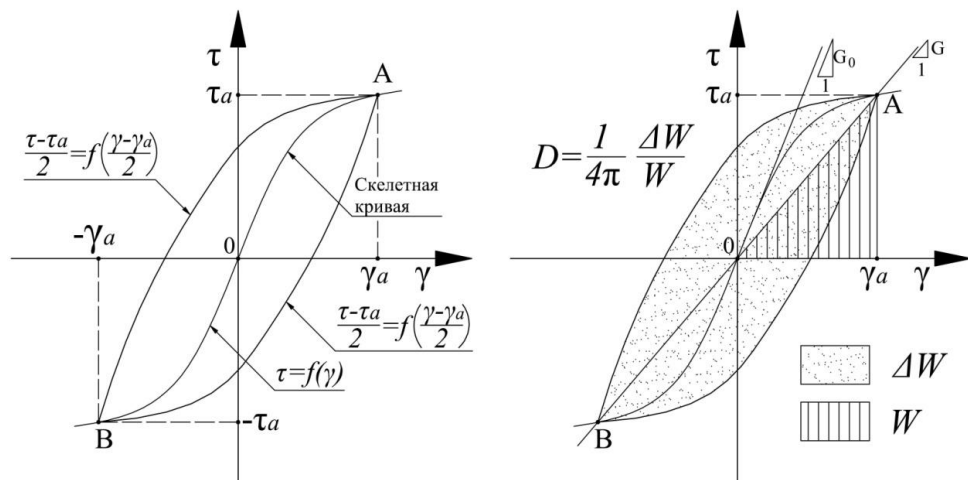
The irreversible loss of energy (dissipation) in the deformation of the base soils is characterized by the magnitude of the attenuation (or damping) coefficient. In this case, the values of the shear modulus depend on the level of shear strains. The evaluation of these dependencies is included in the tasks of these special soil tests. For use in numerical calculations of geotechnical software complexes, the value of the damping coefficient is recalculated in the Rayleigh coefficients [7].

Special laboratory studies were carried out under conditions of dynamic triaxial compression of dispersed soil samples, taking into account the complete water saturation. The test mode in accordance with the requirements of GOST 56353 is adopted consolidated-drained, which repeats the conditions for filtration and dispersion of pore pressure in a real soil massif of the base. A total of 18 tests were performed. Classification of soils and separation of engineering-geological elements is made in accordance with the results of engineering survey performed at the construction site.



**Fig. 2.** The dynamic triaxial test machine and the soil sample

Determination of the values of the dynamic strain modulus  $E$ , the damping coefficient of the soils  $D$ , and the coefficient of vibration creep is carried out in accordance with the provisions of GOST 56353, ASTM D3999 from the graphs of strain loops constructed in the coordinates  $\tau$ - $\varepsilon$  or  $\tau$ - $\gamma$  [8]. The values of the soil parameters obtained as a result of the tests are given in Table 2.



**Fig. 3.** Hysteresis loop of shear strain under cyclic loading of the sample

**Table 2.** Soil parameters after laboratory tests

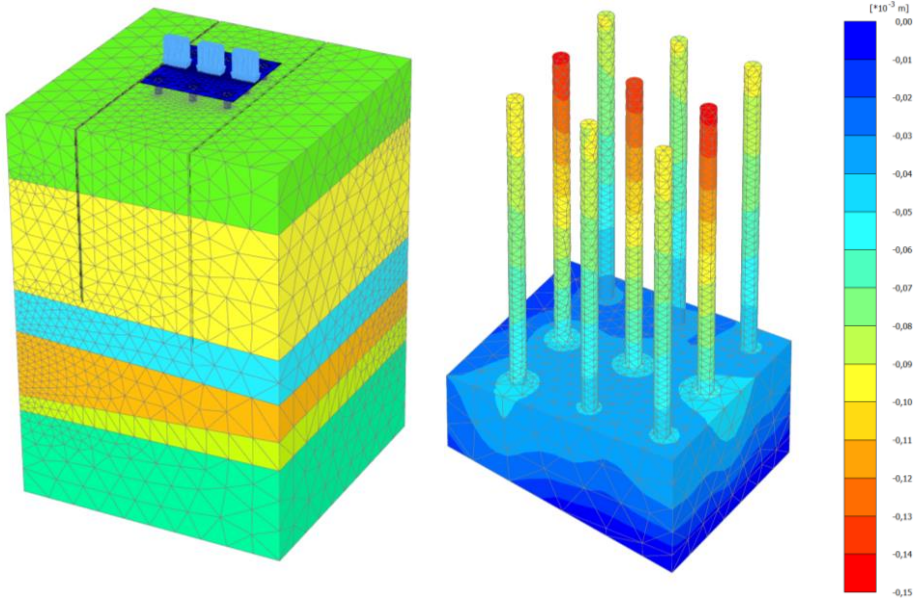
Soil name	$p^{ref}$ , kPa	Deformation modulus $E_s^{ref}$ , кПа	Dampin coefficient $D$ , %	Rayleigh coefficient		Coefficient of vibration creep $K$
				$\alpha$	$\beta$	
1	3	4	5	6	7	8
Zone I	466	638 444	12,64	0,916	9,196	0,98
Zone II	401	421 130	7,93	0,575	5,771	0,99
Zone III-1	472	484 062	17,70	1,284	12,884	0,98
Zone III-2	689	379 031	5,97	0,433	4,343	1,00

The results of special laboratory tests were subsequently used to calculate the SSC of the base on the test section by the finite element method. PLAXIS 3D 2017.01 was used to perform the calculations; it was tested during the construction of a large number of construction projects in Europe and the world, as well as in the design of a large number of erected structures, both pile and natural in the Russian Federation.

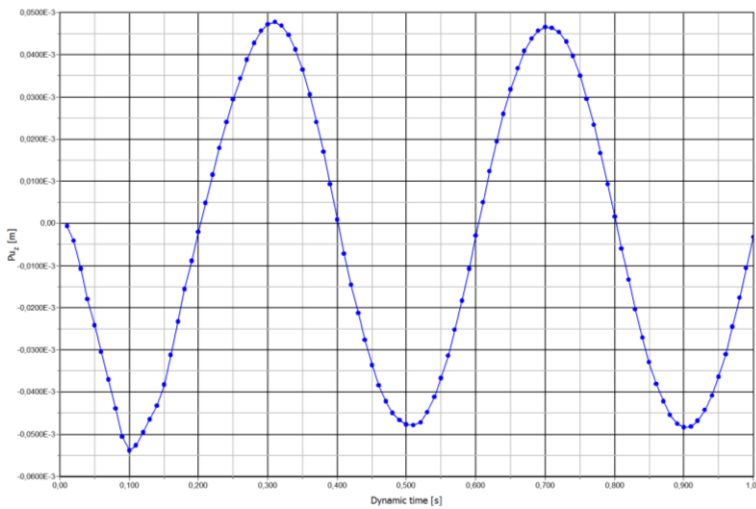
The structural part of the design model includes the construction of a pile foundation and a distribution plate. The load on the distribution plate was set in accordance with the previously performed studies of dynamic loads on the foundation slab of the structure.

The design scheme of the proposed structure is shown in Fig. 4. In Fig. 4 and 5 presents the results of calculating the SSC of the system under consideration - the shadings of vertical displacements (sediment) of the base, which includes the reinforced layer and piles, and the plate grid and the graphs of the dependence of displacements on time in the process of dynamic impact.

The calculation of the system showed that the maximum draft of the heel of the central pile from dynamic loads was 53  $\mu\text{m}$ .



**Fig. 4.** Model scheme and calculation results- shadings of maximum vertical deformations during vibration



**Fig. 5.** Results of FEM-modelling- oscillation amplitude on the central pile bottom

### 3 Conclusion

Based on the results of the calculations, the minimum value of the exciter force of the vibrator was obtained to provide the necessary displacements at the end of the piles of the experimental section. According to the parameters, the necessary equipment was chosen for carrying out field experiments on the experimental site.

This work was financially supported by the Ministry of Education and Science (state task #1.4984.2017/6.7). All tests were carried out using research equipment of The Head Regional Shared Research Facilities of the Moscow State University of Civil Engineering.

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