Numerical analysis of static strength for different damages of hydraulic structures when changing stressed and strained state

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Abstract. The results of finite element state simulation of stressed and strained changes under different damages of hydraulic structures are presented. As a result of the experiment, a solid-state model of bearing elements was built. Stressed and strained state of reinforced concrete bearing elements under different load combinations is considered. Intensive threshold of danger to form longitudinal cracks and defects in reinforced concrete elements is determined.

1. Introduction
Computation was carried out by a software complex SCAD office V.21, operation of which is based on the method of finite elements and superelements. Stressed and strained state of reinforced concrete bearing elements under bending, torsion, compression and tension and their different combination, as well, is considered. Coding of source information was being fulfilled in terms of the increment method taking into account fragmental representation of bearing elements as objects of a simple geometric form made of B 45 reinforced concrete. In statement of numerical computation, the task was set to determine an adequacy of a solid state model in stressed and strained state. The number of elements and that of assembly units were 143673 and 32742, correspondingly.

2. Materials and methods
Comparisons of diagrams for water receiving sump movements by the vertical far and wide of bearing elements revealed insignificant inside changes. The diagram of movements by the horizontal is the most interesting (figure 1). It shows change in element location because of imposed loads as well as uncritical side shifts. These results [1] testify to availability of their significant safety margin.
Figure 1. Diagram of movements by horizontal across water receiving sump

Movements by the horizontal along bearing elements show insignificant shifts of support areas of the horizontal reinforced concrete elements (figure 2).

Figure 2. Diagram of movements by horizontal along length of water receiving sump

In figure 3, a diagram of movements of water receiving sump by the vertical is presented where a weak point of the reconstructed reinforced concrete water receiving sump is clearly seen. In the conjugation area of horizontal and vertical elements when operating a structure and changing technical parameters, longitudinal cracks can occur. To avoid this problem, it is necessary to strengthen the detected weak point of the reinforced concrete structure because its technical characteristics are at a dangerous threshold of operation. It is also necessary to pay attention to strengthening a reinforcing cage of the water receiving sump [2].

Diagrams of total movements emphasize (figure 4) insignificant rigidity of side horizontal elements also needed in reinforcement, according to the result of comparison for the diagrams of equivalent stress on von Mises, the highest stresses occur by the vertical of bearing elements, exactly in the lower part of the structure. This testifies to occurrence of critical stresses in the structure base, imposing both water load and weight of the whole structure [3].

Diagrams of equivalent stress on von Mises by the horizontal far and wide bearing elements also show the highest stresses arising in the area of the structure support on the base caused with the strains
of bearing elements; stresses are also in the horizontal reinforced elements.

**Figure 3.** Diagram of movements by vertical of water receiving sump

Computations of stressed and strained state for main canals were being carried out on the model of their typical element-reinforced concrete lining considered as a thin-walled envelope [4] taking into account its support on the ground base.

The entire theoretical substantiation of the mathematical model is characterized on the base of experimental studies to assess the structure reliability under different combinations of destroying impacts [5, 6]. There studies were carried out on the base of mathematical modelling to establish danger degree and permissible dimensions of sections, existing and possible failures of projects; for example, reinforced concrete lining is considered as a thin-walled envelope, where conditions of its support on the ground base is taken into account.

**Figure 4.** Diagram of total movements of water receiving sump

When designing a solid-state model as a reinforced concrete lining of the main canal (figure 5) without any faults, the task was set to establish identity to a real construction [7]. Location and typical parameters of faults for stressed and strained state of the reinforced concrete lining of the main canal were taken according to the data received by the authors in the course of inspections on location.
Figure 5. Diagram of absolute movements of main canal lining as a result of bedrock seal failure

It is evident that settlement and loss of reinforced concrete lining stability because of ground seal failure and void forming from water filtration [8] are the most dangerous, the results of which are lining failure and slide from the canal slope. Numerical solutions as diagrams of stresses and movements of construction elements under defects in the bedrock are given in figure 6.

Figure 6. Diagram of stress intensity for main canal lining by horizontal axis

Realization of this result was preceded with numerical experiments [10, 11] to assess stressed and strained state of lining because of seal failure of the ground base differentially – for settlement and movement [12].

3. Conclusion

Simulation of stressed and strained state carried out confirmed availability of significant safety margin in bearing reinforced concrete elements.

Analysis of the data received showed that the values of absolute movements satisfied the accepted standards of hydraulic structure designing. Comparisons of the diagrams for equivalent stress on von Mises and movements showed that the highest stresses had arisen at junction in the points of element joining. There results testify to arising critical stresses in support areas twice as large as in other areas that under heat increasing can result in destruction of the elements considered and loss of bearing capacity of the whole structure.
Empirical relations between the change of stress and strain state of the simulated elements and intensity level rising are received; as a result of the digital experiments conducted, an intensive danger threshold of water rising was determined.

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