The seasonal regulation basin dam basis deformation forecast

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Abstract. The algorithm and its implementation in numerical modeling of the seasonal regulation basin (SRB) dam base deformation, where the Mohr-Coulomb theory is adopted to describe the behavior of engineering geological elements is presented.

Introduction
The various types production intensification, the sustainable development of agriculture requires an ever-increasing fresh water amount [1, 2]. In the economically most developed European part of the Russian Federation and especially in the south, the shortage of this resource is becoming more acute [3]. A means of promoting the water accumulation and regulation are SRB [4, 5]. Their use is an economically viable action, and in some cases the only solution to the issue of obtaining fresh water [6]. However, this approach contributes to the “linking” of the SRB in more and more complex engineering and geological conditions, which in turn requires the mandatory specification of approaches to the adopted constructive-technological solutions design justification. Manual structures counting used in the recent past, does not meet the modern requirements and cannot ensure the decisions unambiguity, in view of the need to take into account an increasing number of influence factors [7]. The SRB base location geotechnical conditions complexity, deformation of the base is one of the most problematic tasks requiring detailed analysis and clarification [8]. Currently, calculations of the stress-strain state (VAT) of hydraulic structures are mainly carried out using software systems implementing the finite element method (FEM). This is due to the structures’ complex configuration presence both in the underground part of the structure and in its above-ground part with complex relief, geological and hydrogeological conditions, the presence of seismic, etc.

Materials and methods
The initial data are taken in a real object.

Engineering-geological surveys in the area of low-pressure hydraulic structures marked three engineering-geological elements corresponding to the selected geological and lithological layers [9]. Physical and mechanical properties of soils are shown in Table 1.

| № EGE | E, [mPa] | µ | Y, [kN/m³] | H, [m] | C | φ |
|-------|---------|---|----------|--------|---|---|
| 1     | 9       | 0.37 | 18.1     | 1.2    | 36 | 36 |
| 2     | 12      | 0.36 | 19.2     | 2.5    | 36 | 36 |
| 3     | 13      | 0.3  | 20.3     | 4      | 36 | 36 |

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The soil mathematical model choice
For the engineering geological elements behavior mathematical description, the Mohr-Coulomb theory, which describes the behavior of soils in accordance with the diagram presented in Figure 1, was adopted [10].

![Figure 1. Mohr-Coulomb mode diagram 1](image1)

Adopted design and technological solutions.
Hydraulic structures are made of monolithic reinforced concrete. The class of concrete used is B25, the compression characteristics is $R_b = 14,500 \text{ kN/m}^2$, and the tensile strength is $R_{bt} = 1050 \text{ kN/m}^2$, the reinforced concrete specific gravity is 25 kN/m$^3$, the deformation modulus $E = 3 \times 107 \text{ kN/m}^2$. Figure 2 shows the geometric characteristics of the object under study [11].

![Figure 2. Geometric characteristics of the object under study](image2)

Geotechnical calculation of the seasonal regulation basin was carried out in the Midas GTX NX 2016 software package [12]. The design model is presented in Figure 3.
A model calculation is conducted taking into account a temporal factor. The calculation stages are presented in Table 2.

### Table 2. Calculation Stages

| №  | Stage  | Description                                                                 |
|----|--------|-----------------------------------------------------------------------------|
| 1  | 1 stage| At the first stage, the calculation and reset of the computational model soil mass displacements take place. |
| 2  | 2 stage| At the second stage, the dam is erected in a time span of 180 days (results are output every 60 days) |
| 3  | 3 stage| At the third stage, the pool is filled into 1/4 parts within 3 hours (results are output every hour) |
| 4  | 4 stage| At the fourth stage, the pool is filled to 2/4 parts within 3 hours (results are output every hour) |
| 5  | 5 stage| At the fifth stage, the pool is filled into 3/4 parts within 3 hours (results are output every hour) |
| 6  | 6 stage| At the sixth stage, the remaining pool volume is filled within 3 hours (results are output every hour) |

The deformation results obtained from the calculation of the third stage are presented in Figure 4.

### Table 3. Pivot table data

| Stage | 1 | 2 | 3 | 4 | 5 | 6 |
|-------|---|---|---|---|---|---|
| S, [mm]| 0 | +4.5 | -8.6 | +4.5 | -9.9 | +4.6 | -12.7 | +4.8 | -17.1 | +5.1 | -21.9 |
Note: S – defines the deformation size; <+-> positive / negative deformation.

The dam base deformation diagram according to the sixth stage of the calculation and the general deformation diagram are presented in Figure 5.

Summary
Analyzing the obtained results, it can be stated that part of the hydraulic structure base is in a plastic state. The deformations magnitudes are within the acceptable limits, however, based on the model describing the engineering-geological element, according to the Mohr-Coulomb theory, it is necessary to take into account the plastic deformations further development possibilities.

Based on the above-mentioned, it is necessary to conclude that, according to the Mohr-Coulomb theory, the prediction of base deformation, within the framework of the presented task, is very approximate, as a result of which it is necessary to apply models that more accurately take into account the plastic deformations development.

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