STUDY OF THE STABILITY AND SAFETY OF THE DAM ON LAKE BOYUK-SHOR IN BAKU

Fakhreddin Gabibov[1], Vugar Aliyev[2], Emil Gafarov[3], Aytan Akhmedova[3], Sabina Magerramova[3]

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[1]Azerbaijan Scientific Research Institute of Construction and Architecture
farchad@yandex.ru
[2]AMIR Technical Services LLC, Azerbaijan
prof.vugar.aliyev@gmail.com
[3]Azerbaijan University of Architecture and Civil Engineering
emilqafarov@inbox.ru
aytenaxmedova@mail.ru
sabinamaharramova@mail.ru

Abstract

The embankment dam on Lake Boyuk-Shor is designed for a highway and divides the lake into two parts. Engineering and geological studies have revealed a complex structure of the soil base of the dam and high seismicity. Studies of the stability of the dam slopes under the PLAXIS 2D program have shown their reliable stability. Studies of the sediment of the body of the dam and its soil base according to the PLAXIS 2D program have shown that the sediment of both the dam and its soil base is acceptable for this class of structures.

Keywords: dam, stability, soil foundation, expensive, sediment, lake, slope.

I. Introduction

Lake Boyuk-Shor is one of the largest lakes in Azerbaijan. It is located on the Apsheron Peninsula on the territory of the Binagadi, Sabunchi and Narimanov districts of Baku. The lake has a relict origin [1]. Figure 1 shows an aerial photo of Lake Boyuk-Shor.

In 1866, the first oil storage tank in Azerbaijan was built near the lake. In 1929, oil industry waste flowed into the lake through the Keshl Canal. Since the 70s of the last century, household and industrial waste has been thrown into the lake. In 2011-2015, the Baku Olympic Stadium was built on the eastern shore of the lake.

According to international experts, Lake Boyuk-Shor is considered one of the most polluted lakes. In 2014, in connection with the construction of the Olympic stadium, the lake was cleaned as part of a project to restore and improve the ecological condition of the lakes of the Apsheron Peninsula. The project of ecological restoration of the lake consisted of two stages. The first was carried out in 2014-2015, during which the restoration of an area of 300 hectares was carried out, separation and isolation using a dam of the northern part of the lake contaminated with oil. The second stage of restoration and improvement of the state of the OSNR began in 2015 and lasted until 2020. In December 2018, a new Balakhany-Binagadi road was opened, which runs along the dam and has a length of 1570 m.

The construction of multi-purpose bulk dams is a complex engineering process, the basics of which are described in the monographs K.Terzghi [2], J.L.Sherard, R.J.Woodword, S.F.Gizienski, W.A.Clevenger [3], G.V.Jeleznyakov, Y.A.Ibad-zade, P.L.Ivanov and others [4], A.L.Goldin, L.N.Rasskazov [5], W.F.Van Impe, R.D.Verastegui Flores [6] and others. Figure 2 shows a photo of the dam construction process on Lake Boyuk-Shor.

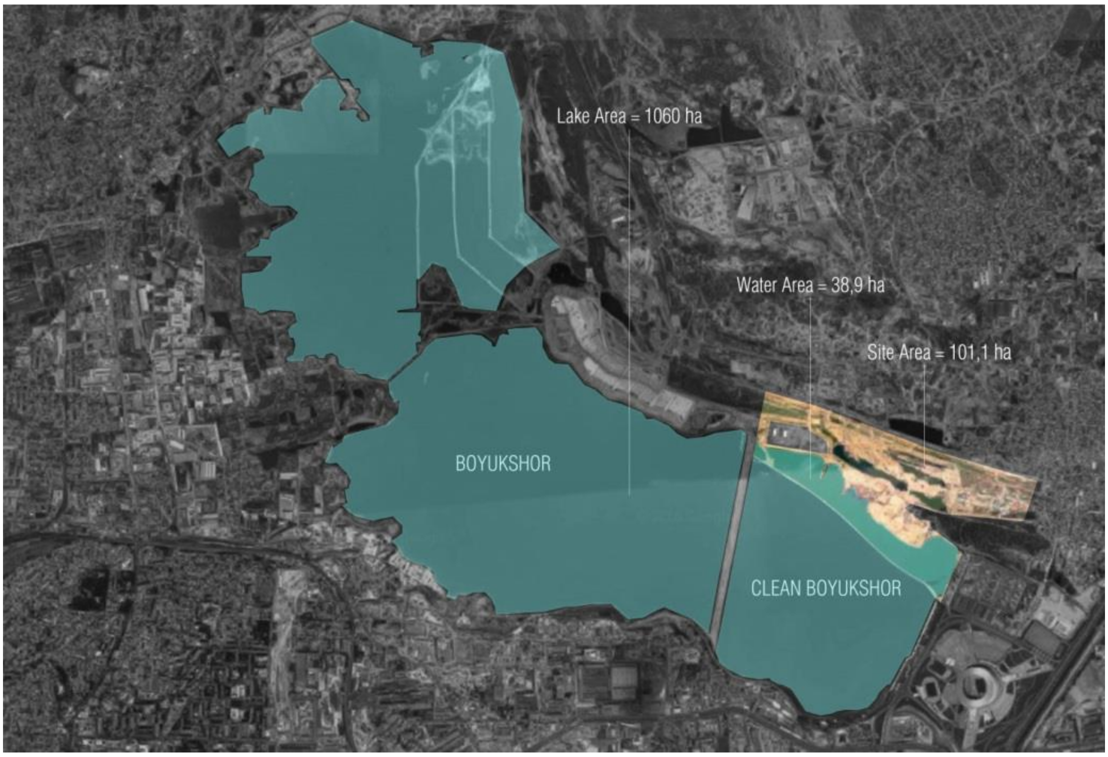

Figure 1: *Aerial photo of Lake Boyuk-Shor*

Figure 2: *Photo of the dam construction process on Lake Boyuk-Shor*

II. Selection of design sections and determination of design parameters of the dam

Along the projected route of the road located on the dam, 16 engineering and geological wells were drilled every 20 m. Based on the information received, two cross-sections of the dam with the foundation soils were selected, which differ from each other. In the selected section 1-1, the soil base is represented by the following layers: refractory clay – 5.35 m; plastic sandy loam – 1.5 m; semi–solid loam – 2.45 m; weak limestone - 0.55 m; dusty, moist sand – 5.0. In section 2-2, the soil base is represented by the following layers: semi–solid loam - 1.3 m; dusty, moist sand – 8.5 m; semi–solid loam - 4.5 m.

The physical and mechanical characteristics of the soils of the dam base are as follows. Clay is refractory: density – γ = 1.92 g/cm^3; angle of internal friction – φ = 13º; adhesion force - C = 27 kPa; modulus of deformation – E = 14 MPa; porosity – e = 0.877. Semi-solid loam: density – γ = 2.06 g/cm^3; angle of internal friction – φ = 21 °; adhesion force - C = 21 kPa; modulus of deformation – E = 24.5 MPa; porosity – e = 0.60. Sandy loam plastic: density – γ = 2.05 g/cm^3; internal friction angle – φ = 22 °; adhesion force - C = 9 kPa; modulus of deformation – E = 21 MPa; porosity – e = 0.588. The sand is dusty, moist: density – γ = 2.01 g/cm^3; internal friction angle – φ = 27 °; adhesion force - C = 3 kPa; modulus of deformation – E = 18 MPa; porosity – e = 0.658.

The physical and mechanical characteristics of the dam soils are as follows. Dam body: density – γ = 2.4 g/cm^3; internal friction angle – φ = 34º; adhesion force - C = 0 kPa; deformation modulus – E = 100 MPa. Dam prisms: density – γ = 2.4 g/cm^3; internal friction angle – φ = 36º; adhesion force - C = 0 kPa; modulus of deformation – E = 100 MPa. Dam loading prisms: density – γ = 2.4 g/cm^3; internal friction angle – φ = 40º; adhesion force - C = 2 kPa; deformation modulus – E = 100 MPa.

Two highways run along the crest of the dam. A traffic load acts on the dam from this road. According to the NK-100 standard, two loads from 12.5 tons wheels act on each side of the road.

III. Determination of the stability of dam slopes

The stability coefficients of the Ks dam slopes were calculated using mathematical modeling of the stress-strain state of the soil massif by the finite element method using the PLAXIS 2D computer program in a two-dimensional formulation of the problem. The seismic impact was modeled in a quasi-static formulation. The seismic force Q_s was determined as a fraction of the weight of the soil mass P:

$$Q_s = \mu P \tag{1}$$

where μ is the coefficient of dynamic seismicity (for seismicity 8 points μ = 0.05.

According to the building codes, the following limiting coefficients of stability of the dam slopes were selected: for a normal combination of loads – 1.3; for a special combination of loads (taking into account seismics) – 1.1. The calculation results showed the following. According to the calculated cross section 1-1: with a normal combination of loads K_s = 2.05; with a special combination of loads K_s = 1.616. According to the calculated cross section 2-2: with a normal combination of loads K_s = 2.085; with a special combination of loads K_s = 1.74.

Stability coefficients were calculated for the right slope of the dam. Stability calculations were not carried out for the left slope, since the problem is axisymmetric and the calculation results coincide with the results of calculations of the stability of the right slope.

The least stability of the dam slopes is observed with a special combination of loads. Figures 3 and 4 show the results of calculations of the stability of the right slopes. As can be seen in both calculated sections, the sliding lines pass from the place of application of the transport load, enters and crosses the upper layers of the soil base and comes to the surface at the very bottom of the slope. The stability of the dam slopes in all cases is provided with a margin.

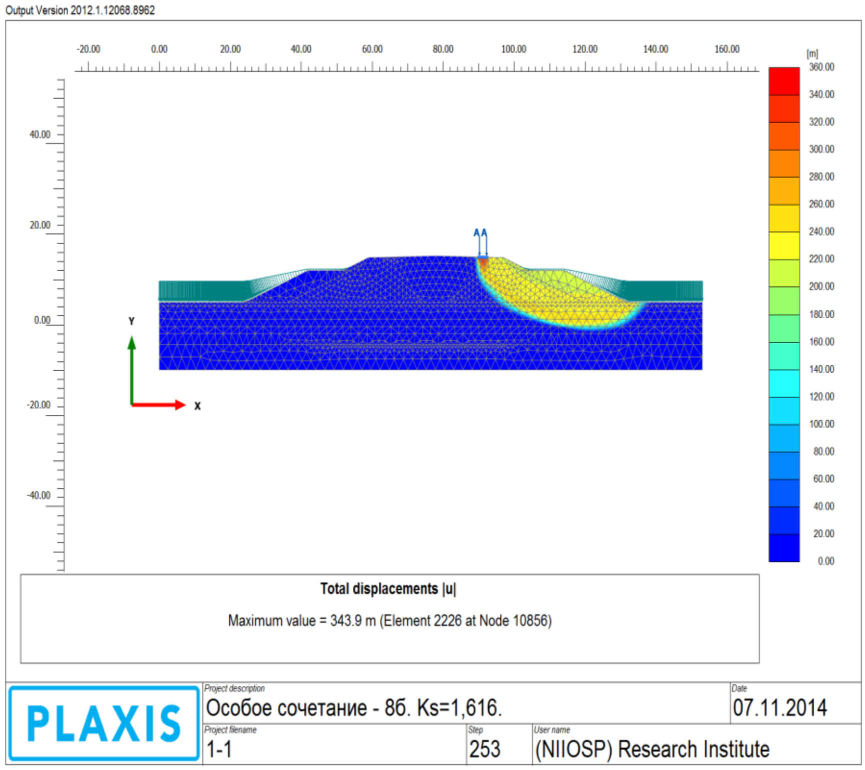

Figure 3: *The result of calculating the stability of the dam slope (section 1-1) under seismicity conditions*

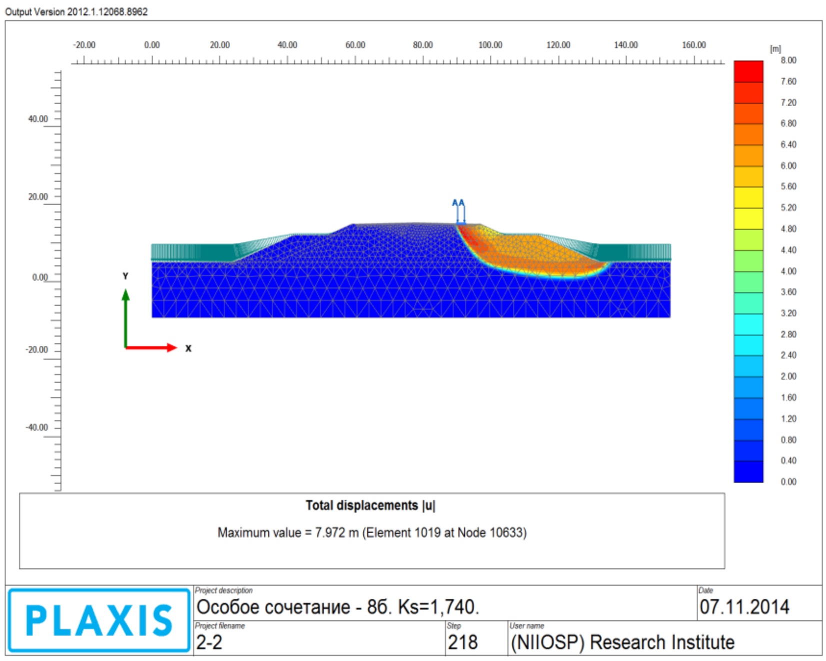

Figure 4: *The result of calculating the stability of the dam slope (section 2-2) under seismicity conditions*

IV. Determination of dam sediment

The calculation of the sediment of the dam itself and its soil base was carried out using the computer geotechnical program PLAXIS 2D. Two types of calculations were performed: determination of the sediment of the body of the dam; determination of the sediment of the soil base of the dam. To be able to perform calculations and assign the height of the calculated area, the compressible thickness H was determined. The compressible thickness of the soil base was determined according to the requirements of building codes by the formula:

$$\sigma_{zp} = 0.5\ \sigma_{zq} \qquad (2)$$

where σ_{zp} are vertical stresses in the soil from an external load; σ_{zq} are vertical stresses from the soil's own weight, taking into account the weighing action of water.

Compressible thickness of the soil base is determined for a dam with a width of B = 107 m with a load on the soil $\sigma_{zp,0}$ = 17.2 t/m^2.Compressible thickness H = 32.1 m. Further, the resulting compressible thickness (calculated area) was set in the program, according to the calculation results of which the sediment of the dam was obtained. Figure 5 shows the isolines of vertical displacements in the array at the level of the dam crest along the 1-1 section (U_y = 25.5 cm). The movement of the soil base at the level of the bottom of the dam is 23.2 cm. Thus, the sediment of the dam body is ΔU_y = 2.3 cm. Figure 6 shows the isolines of vertical displacements in the massif at the level of the dam crest along the section 2-2 (U_y = 22.5 cm). The movement of the soil base at the level of the bottom of the dam is 20.3 cm. Thus, the sediment of the dam body is ΔU_y = 2.2 cm.

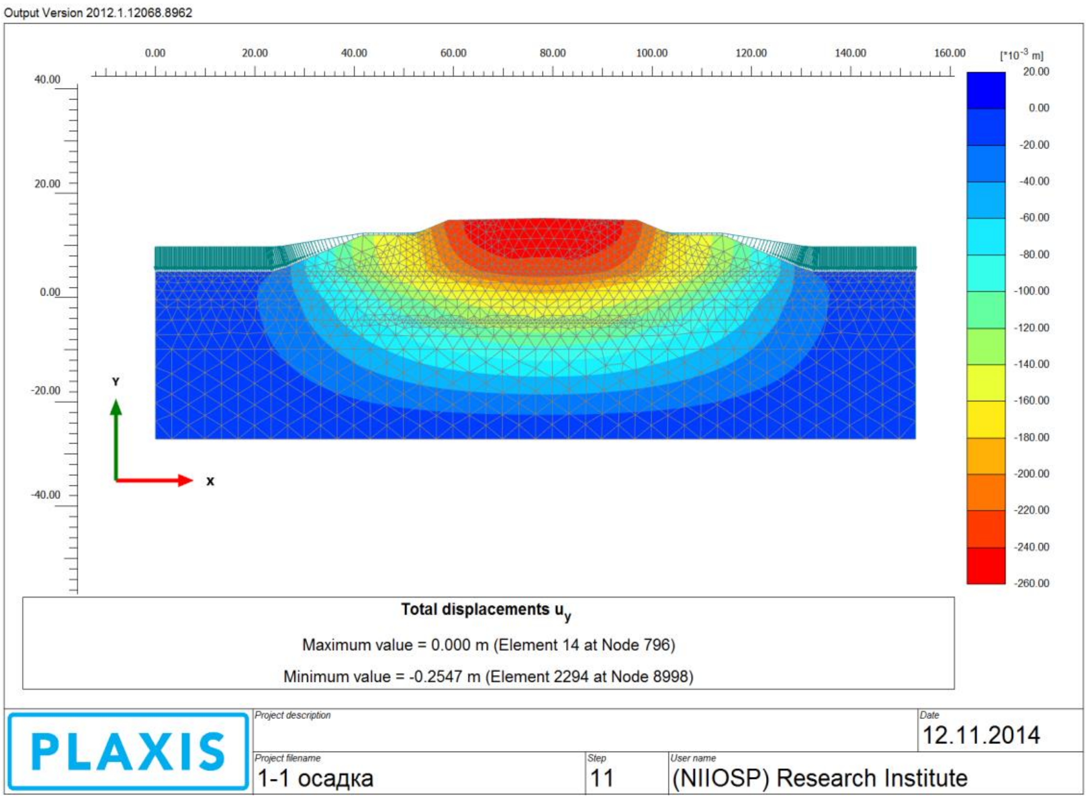

Figure 5: *Isolines of vertical movements during landing in the dam array and its base (section 1-1)*

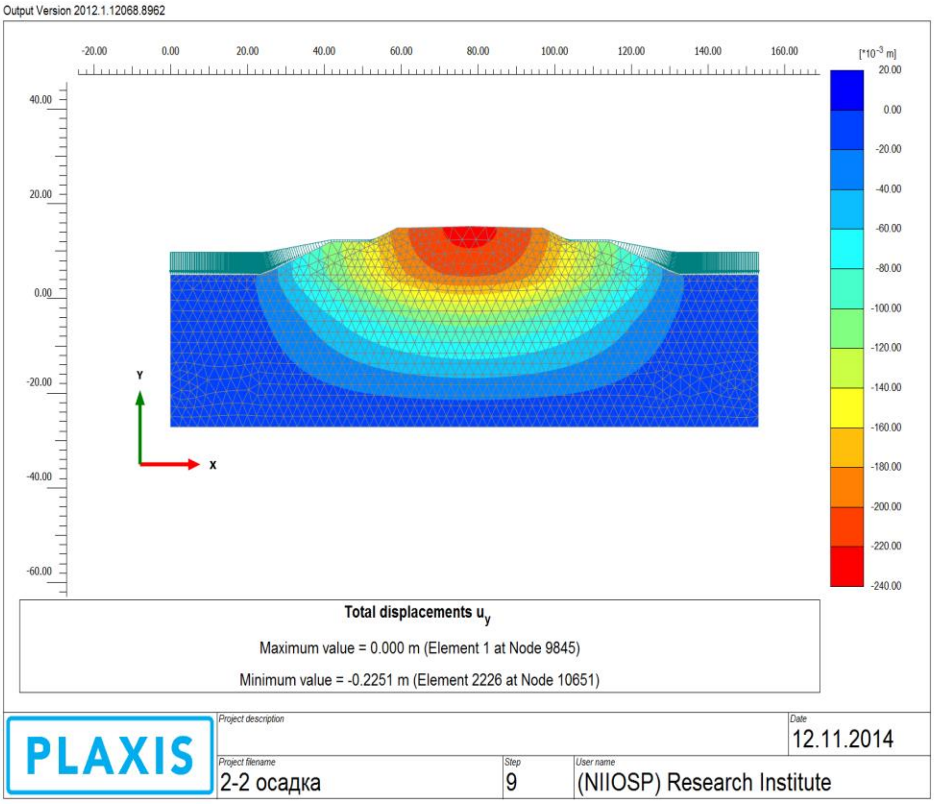

Figure 6: *Isolines of vertical movements during landing in the dam array and its base (section 2-2)*

V. Conclusions

1. The bulk dam on Lake Boyuk-Shor is designed to solve engineering, environmental and transport problems;
2. The dam is located in difficult engineering-geological and seismic conditions;
3. Studies have shown that the stability of the dam slopes is provided in any conditions with a margin;
4. The sedimentation of the dam and its soil base is permissible for this class of structures.

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