ISSN 2181-8622

Manufacturing technology problems

Scientific and Technical Journal Namangan Institute of Engineering and Technology

Volume 8
Issue 2
2023

STRESS-STRAIN STATE OF SOIL DAMS UNDER THE ACTION OF STATIC LOADS

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Abstract:

Objective. The objective of this article is to develop a methodology for the static calculation of earth dams under the action of water pressure in the reservoir, taking into account various physical and mechanical characteristics of soils, and the design features of the Pachkamar, Gissarak, and Sokh earth dams in a two-dimensional statement.

Methods. The developed model and calculation algorithm for studying the stress and strain state of earth dams based on a variational approach using the d'Alembert principle are presented. Numerical calculations in the article are conducted using the finite element method.

Results. As a result of the study, it was revealed that the stress and strain state of the above-mentioned earth dams significantly depends on the physical and mechanical parameters of soils and the commensurability of geometric dimensions, as well as on the coefficient of slopes of the dam retaining prisms.

Conclusions. As a result of the study, it was revealed that the movement of points in the body of the dam under the action of body forces is approximately symmetrical about the vertical axis of the dam core. The largest values of displacement were observed in the core and crest zones of the dam. The level of water filling in the reservoir has a significant impact on the stress and strain state of the dam.

Keywords: earth dam, plane statement, structure, stress-strain state, variational problem.

Introduction. In earth dams, under the influence of body forces and hydrostatic water pressure (static loads), a complex interaction occurs between the parts of the structure. In some cases, under the influence of these factors, tensile stresses appear in the body of the dam and its impervious devices, which can lead to the formation of cracks in them and a violation of the strength characteristics of dams as a whole.

Research task. The stress state and deformation of earth dams is a complex problem in the theory of continuum mechanics, and it is necessary to take into account the properties of materials, the design of the structure, construction time, operation, the variety of acting loads, etc. The solution of such a problem is currently difficult due to the lack of sufficiently substantiated data on the rheological properties of soils, the difficulty of simultaneously taking into account the influence of all possible factors in the numerical implementation of the solution, etc.

At the same time, the solution of particular problems with the adoption of certain assumptions and prerequisites can be most fully and accurately obtained using numerical methods, for example, the finite element method (FEM) or the finite difference method (Красников Н.Д, 1981; Зарецкий Ю.К., Ломбардо В.Н., 1983; Мирсаидов М.М., 2010; Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023; Mirsaidov M.M., 2019).

To date, there are a number of scientific papers that are devoted to the study of the stress state and deformation of earth dams using various models of structures.

The static stress state of various soil dams is considered in (Mirsaidov M.M., 2019; Маткаримов П., Жураев Д., Уразмухамедова З., 2022 г.; Matkarimov P.J., Juraev D.P., Usmonkhuzhaev S.I., 2022), which take into account the structures of the structure, the rheological properties of the soil, the interaction of structures with reservoir water, and other features of structures.

In (Kong X., Liu J., Zou D., 2016), the SSS of soil dams under dynamic and static effects is studied by the finite element method, taking into account the elastic-plastic deformation of the soil of the dam, and these number results are comparable to the number results of field measurements of the Wenchuan earthquake.

The paper (Alonso E.E., Cardosa R., 2010) analyzes in detail the use of non-traditional materials (earth and stone mixtures) to ensure the stability of the slopes of earth dams.

The paper (Белостоцкий А.М., Акимов П.А., Нгуен Тай Нанг Льюнг, 2017) considers a method for numerical simulation of the motion of the spatial system "Foundations - dam - reservoir" under the influence of various influences. The stress-strain states of arched concrete dams are estimated, and their natural frequencies are determined and the corresponding vibration modes are constructed. The studies used the universal program ANSYS Mechanical.

The work (Kozinetc G.L., Kozinetc P.V., 2022) provides a detailed review of the method for calculating the dynamic characteristics of structures and the results of assessing the response of structures to time-varying excitations and earthquake accelerograms. The results obtained made it possible to estimate the maximum value of horizontal accelerations.

In (Arbian A., et al., 2020), to assess the reliability of the spillway structure of the Chendero dam (Malaysia), the results of experimental spectral analysis and operational forms of deviation were used. Along with the experimental study, numerical simulation was carried out using the ANSУS software package.

In (Ravindra V., 2022), several natural frequencies of the design of the Indirasagar dam, located in the state of Andhra Pradesh, are determined taking into account only the dead weight of the dam and pressure (hydrostatic) water using the ANSУS software.

The paper (Ahmet A., 2021) presents the results of an experimental vibration study to determine the structural behavior of the Deriner arch dam. And also in the work by the numerical method (FEM) the natural frequencies and vibration modes of the dam are determined.

As the review shows, studies of the stress state and deformation of earth dams, taking into account design features and real work, have not been sufficiently studied, therefore, research in this direction is of great scientific interest. Based on the foregoing, this work is devoted to the development of a methodology for calculating the SSS of the Gissarak, Sokh and Pachkamar soil dams in Central Asia in a flat setting, taking into account the design features, material properties and the degree of filling of the reservoir. As a computing device, the finite element method is used in the work.

Methods. An earth dam of complex geometry is considered, occupying a volume $V = V_1+V_2+V_3$ (V_1, V_3 - volume of upper and lower prism, V_2 - core volume) (Fig. 1). Dam foundations Σ_u are rigidly clamped, and the surface of the lower slope and ridge are free from stress. The dam is under its own weight $\vec{f}$ and to the surface Σ_1 water pressure (hydrostatic) $\vec{p}$.

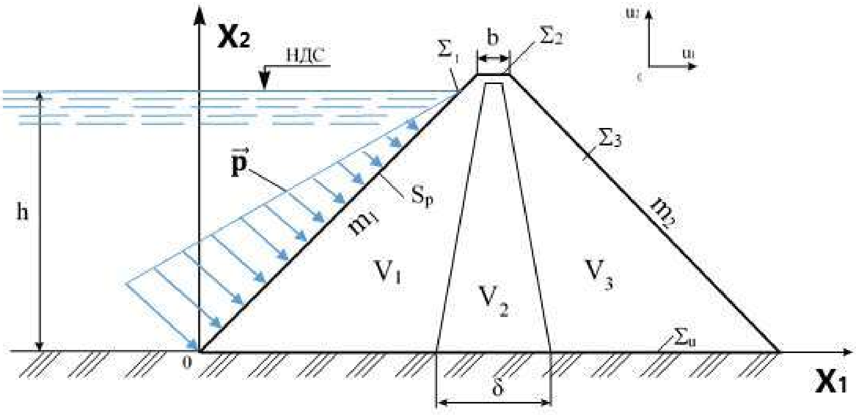


Figure. 1. Calculation scheme of an earth dam

To solve the given problem, we used the principle of possible displacements. According to this principle, the sum of all acting active forces is zero (Мирсаидов М.М., 2010; Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023; Mirsaidov M.M., 2019; Маткаримов П., Жураев Д., Уразмухамедова З., 2022 г.; Matkarimov P.J., Juraev D.P., Usmonkhuzhaev S.I., 2022):

$$\delta A = -\int_{V_1} \sigma_{ij} \cdot \delta\varepsilon_{ij} dV - \int_{V_2} \sigma_{ij} \cdot \delta\varepsilon_{ij} dV - \int_{V_3} \sigma_{ij} \cdot \delta\varepsilon_{ij} dV + \\ + \int_{V} \vec{f} \cdot \delta\vec{u}\, dV + \int_{\Sigma_1} \vec{p} \cdot \delta\vec{u}\, d\Sigma = 0, \quad i,j=1,2 \tag{1}$$

The physical properties of the body are described by the Hooke relations (Александров А.В., Потапов В.Д., 1990),

$$\left.\begin{aligned} \sigma_{11} &= \lambda\theta + 2\mu\varepsilon_{11} \\ \sigma_{22} &= \lambda\theta + 2\mu\varepsilon_{22} \\ \sigma_{12} &= \mu\varepsilon_{12}. \end{aligned}\right\} \tag{2}$$

$$\lambda = \frac{E\nu}{(1+\nu)(1-2\nu)}, \quad \mu = \frac{E}{2(1+\nu)}.$$

and Cauchy relations

$$\varepsilon_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right), \tag{3}$$

as well as the boundary condition

$$\vec{x} \in \sum u: \quad \vec{u} = 0 \tag{4}$$

In calculations, the value of hydrostatic water pressure on the upper slope of the dam is determined by the formula

$$p = \rho_0 g(h - x_2) \tag{5}$$

Here $\vec{u}$, σ_{ij}, ε_{ij}, - displacement vectors, stress and strain tensors; ρ - density of material; ρ_o - density of water, (h –x_2) – reservoir filling level (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

To solve the variational problem (1) - (3) for a region of a non-canonical complex shape, the most convenient is the finite element method (FEM), which allows taking into account both the geometry features and the properties of the construction material. Here, the area occupied by the body is divided into sub-areas with different physical and mechanical characteristics, then the sub-areas are automatically divided into triangular finite elements of the first order with 6 degrees of freedom. As a result, a discrete continuum model is created.

Using a feature of the finite element method allows us to reduce the considered variational problem (1)-(4) to a system of non-homogeneous high-order algebraic equations, i.e.:

$$[K]\{u\} = \{P\} \tag{6}$$

Here: $[K]$ - stiffness matrix for the considered body (Fig. 1); $\{P\}$ - components of external forces acting on the nodes of the finite element; $\{u\}$ - the desired components of the displacement vectors in the nodes of the finite element (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

When solving the above tasks, we used the calculation program developed by us on a PC. In this case, the number of unknowns in equations (6) reached 6200.

Results and Discussion. The paper investigates the stress-strain state of soil dams in a two-dimensional setting, under the action of hydrostatic water pressure and its own weight. In calculations of the effect of water on the stress-strain state of dams, the gradual filling of the reservoir was considered.

With the help of the above mathematical model and method, the SSS and the strength of these dams under water in the course of the river, self-weight of the structure are studied, the design features of the dams in question and acceptance account the mechanical and physical characteristics of soils.

The research work was carried out in erath dams located in the territory of Uzbekistan. Information about these earth am is given below:

1) Gissarak dam high H=138.5 m was built in the Kashkadarya region of Uzbekistan, with slope coefficients of earth dam m_h=2.2, m_m=1.9. Prisms are established from the rock mass. Physical and mechanical parameters of soil - E=3600 MPa, specifical gravity - γ=1.9 kF/m^3, Poisson's ratio - ν=0.3. Core is established from loam. Physical and mechanical parameters of loam - E=2400 MPa, soil specific gravity - γ=1.7 тс/м^3, Poisson's ratio - ν=0.35 and adhesion coefficient C= 20 kPa. Transition zone of sandy-gravelly soil. Dam crest with width b=16m and length L=660m; (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

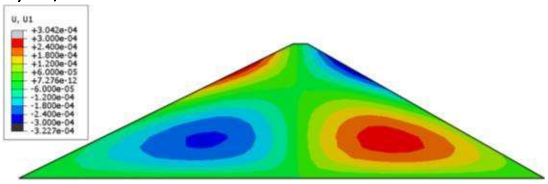
2) Sokh dam high H=87.3 m is located in the Fergana region, slope coefficients are m_b=2.5, $m_н$=2.2. Both prisms - from pebbles with physical and mechanical parameters - E=3550 MPa, Poisson's ratio - v=0.35 and specifical gravity - γ=2.1 kF/m^3. The core is established from loam. Mechanical and physical parameters of loam soil - E=2400 MPa, Poisson's ratio - v=0.35, specific gravity of the soil - γ =1.75 kF/m^3 and Dam crest with width b=10 m and length L=487.3; (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

3) **Pachkamarskaya dam high** H=70 m was built in Kashkadarya region, with slope coefficients m_b=$m_н$=2.25. Thrust prisms - from pebbles and sand with mechanical and physical parameters - E=3600 MPa, soil specific gravity - γ=2.25 kF/m^3, Poisson's ratio - v=0.3. The core is

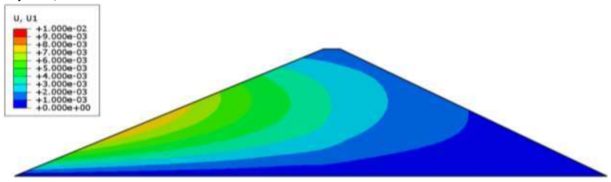
established from loam with physical and mechanical parameters - E=2400 MPa, specific gravity - γ=1.78 kF/m^3, Poisson's ratio - ν=0.35. (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

The results of numerical studies are the components of displacement vectors u, v, deformations ε_x, ε_y, γ_{xy} and stresses σ_x, σ_y, τ_{xy} for all points of construction. Below is the construction of isolines of the displacement components and stresses in the cross sections of the dam.

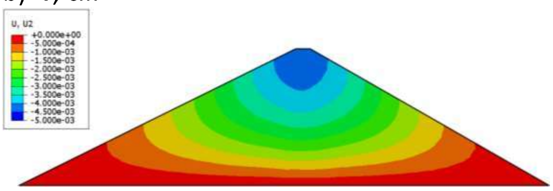
a) u, см



v) u, см



b) v, см



g) v, см

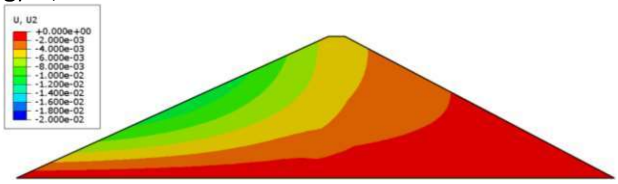


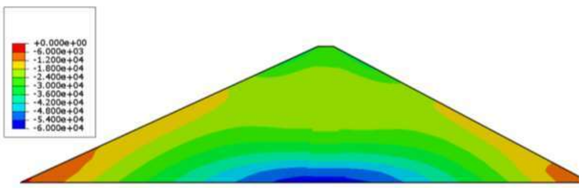
Fig. 2. Field of equal levels of displacements (u and v) of the Hissarak dam with empty (a, b) and full filling of the reservoir (c, d)

The analysis of the obtained results (Fig. 2 a and b) shows that the value of displacements in the body of the dam has an approximately symmetrical character with respect to the vertical axis of the dam. In the center of the dam, horizontal displacements are equal to zero, and their value increases towards the upper and lower prisms. This is explained by the rapid implementation of calculations taking into account the dam's own weight. The displacement at the upper points of the dam is greater than at the lower points (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

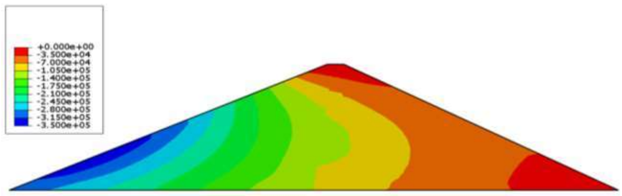
The values of the displacements in the Gissarak dam (Fig. 2. c and d)depend on the level of water affecting the dam. Similar results were found in the study of the stress-strain state of the Pachkamar and Sokh dams (Mirsaidov M.M., Vatin N., Sultanov T.Z. and Juraev D.P, 2023).

Figure 3 shows lines of equal levels of horizontal σ_{11} (a), vertical σ_{22} (б) and tangents σ_{12} stresses of the Gissarak dam under the action of body forces and pressure (hydrostatic) of water at empty and full filling of the reservoir.

a) σ_{11}, МПа



g) σ_{11}, МПа



b) σ_{22}, МПа

d) σ_{22}, МПа

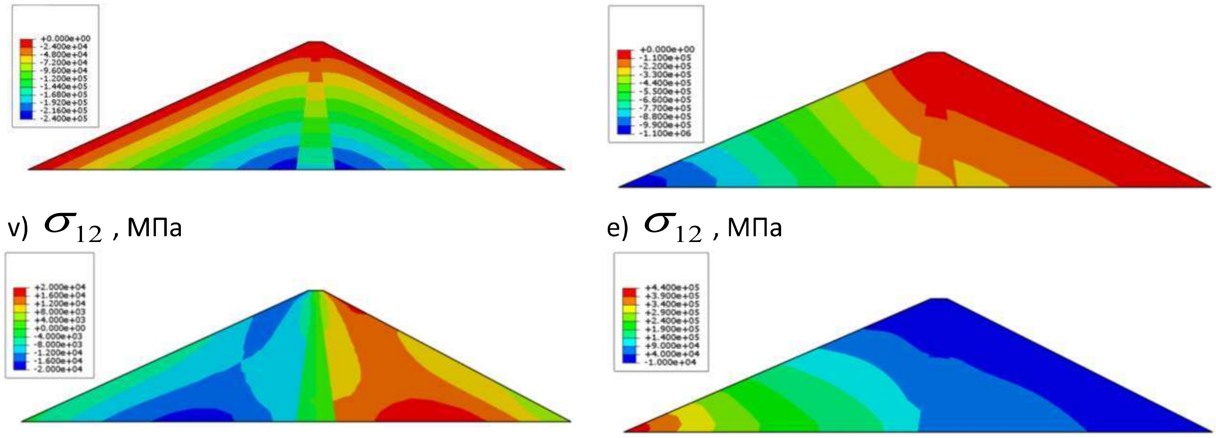


Figure 3. Field of equal horizontal levels σ_{11} (a, g), vertical σ_{22} (b, d) and tangents σ_{12} (b, e) Stresses for the Hissarak Dam
at empty (a, b, c) and full (d, e, f) filling of the reservoir

The obtained results show that in areas close to the contour, the stresses of the dam are practically zero, which is explained by the absence of load on the surface of the crest and slopes. The SSS as a whole is almost symmetrical about the vertical axis of the dam. And lines of zero level of tangential stresses - σ_{12} pass along the central axis of symmetry of the dam. With distance from this axis, σ_{12} increase, reaching a maximum at the bottom of the slopes. At the same time, the influence of the design features of the core leads to the appearance of an arch effect and a significant change in the SSS of the dam. The above phenomena are explained by the fact that due to differences in the deformability of the materials of the loamy core, thrust prisms and the transition zone of the dam. As a result of this type of deformation, the solidity of the dam can be broken with the probable formation of through transverse cracks inside and longitudinal cracks on the crest of the core (Тейтельбаум А.И., Мельник В.Г., Саввина В.А., 1975).

A comparison of the obtained results shows that when the reservoir is completely filled, the influence of the hydrostatic water pressure completely changes the nature of the stress distribution σ_{11}, σ_{22} And σ_{12} in the body of the dam and their symmetrical character is completely lost. In this case, the value of stresses σ_{11} increases by 1.5-2 times, and the value of vertical stresses σ_{22} increases up to 1.5 times in areas close to the slope of the upper prism.

Conclusions.

1. A mathematical model based on the variational Lagrange equation has been developed to calculate the stress-strain state of soil dams in a two-dimensional formulation. With the use of the numerical method (FEM), the problem posed was reduced to a high order nonhomogeneous algebraic problem.

2. Using the developed algorithm and calculation program, the SSS of dams made of soils under the action of body forces and pressure (hydrostatic) of water was studied.

3. It was revealed that:

- displacements of the dam under the action of body forces are approximately symmetrical with respect to the vertical axis of the dam core. At points located in the upper levels of the structure, the displacement values are greater than at the points of the lower level. On the crest and the zone of the core of the dam, the highest displacement values are observed;

- when studying the stress-strain state of dams made of soils, it is necessary to take into account design features, i.e. the deformable properties of the core, since this significantly affects the prediction of the stress-strain state of the structure and makes it possible to assess its strength;

- the level of water filling in the reservoir has a significant impact on the stress-strain state of the dam body, while the maximum effect is observed when the reservoir is completely filled.

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UDC: 004.4; 621.315.1

MICROCONTROLLER-BASED REMOTE MONITORING OF OVERHEAD POWER LINES

KHAYRULLAEV ALISHER

PhD student of Tashkent University of Information Technologies named after Muhammad al-Khwarazmi

Abctract:

Objective. Due to the technical failure of the line, illegal connections, temperature rise in the cable occurring in the section between the electricity distribution point and the consumer meter of the overhead power lines, a number of difficulties arise in monitoring the energy consumption in the line. There are a number of ways to solve these problems, among which remote monitoring using modern IoT wireless sensors and microcontroller control devices gives effective results. Because this method is the basis of the SG (smart grid), which is widely used in the future. The main goal of this article is to design a monitoring device used in remote monitoring of the condition of low-voltage overhead power lines, classify the structure and characteristics of the sensors used in it, and do a comparative analysis of the modules used in the construction of the data transmission network.

Methods. It is not possible to adequately monitor the condition of 0.4-6 kV transmission lines using ASCAE (automated system for control and accounting electricity). These methods can calculate the amount of energy coming out of the distribution transformer and the amount of power passed through the consumer meter. Therefore, this paper proposed a remote monitoring method based on microcontroller control for real-time monitoring of the status of low-voltage overhead power lines.

Results. As a result of the research, a remote monitoring device was designed, capable of transmitting the results obtained from voltage, current and temperature sensors in real time from two wireless transmission modules. This device transmits data to the concentrator using ZigBee, and it transmits data to the monitoring center through the GSM module. In addition, the microcontroller control unit in the device takes into account the geographic location of the object and the synchronized time.

Conclusion. The system, which is organized using a remote monitoring device, prevents technical failures that may occur in low-voltage overhead power transmission lines, the current parameters of the line (voltage, current, cable temperature, wind speed, phase) and unexpected to the line (the unregistered-illegal connection) provides opportunities to send real-time information about downloads.

Keywords: energy, wireless sensors, voltage, current, temperature, ZigBee, ESP32, IoT, smart grid, power, monitoring system.

Introduction. Application of modern methods of corporate management, advanced information and communication technologies and automated systems of management, accounting and control into the energy sector, on this basis, increase management efficiency and reduce production costs plays an important role in ensuring the transparency of energy sector organizations and financial activities. Especially in recent times, special attention has been paid to studies aimed at regular monitoring of the condition (freezing of the cable, disconnection, temperature rise,

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PRIMARY PROCESSING OF COTTON, TEXTILE AND LIGHT INDUSTRY

GROWING, STORAGE, PROCESSING AND AGRICULTURAL PRODUCTS AND FOOD TECHNOLOGIES