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ANALYSIS OF SOIL PROPERTIES BASED ON THE RESULTS OF THE TRIAXIAL TEST

***Abstract**: The article presents the average values of soil properties during the triaxial test. The calculation was carried out using a special software product, which allowed us to trace the change in the properties of loaded soil as a function of the degree of sample deformation.*

***Key words**: triaxial test, soil, properties, deformation of the sample.*

***Language**: English*

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1. Introduction

The triaxial test allows you to determine the properties of materials under study, including soils [1-3]. The method involves simultaneously loading the sample in the longitudinal and transverse directions using special equipment [4-6]. During testing, the sample undergoes shear deformation. By adjusting the applied force (increasing and decreasing the intensity), several load-unload cycles are performed on the sample, and the material's behavior under these conditions is observed [7-10]. Experimental observations of the sample's stress and strain allow us to create a reference database of material properties for further application in real geological engineering projects [11-12].

The practical value of the research is to provide the most complete description of the stress and strain state of the soil during loading and unloading tests.

2. Materials and methods

The state of loaded soil during the triaxial test was described by the dependencies of material properties on the change in the sample's overall dimensions. The sample was a cylinder with a diameter of 100 mm and a height of 100 mm. The actual values of physical (density – 2400 kg/m^3), mechanical (Poisson's ratio – 0.2), and other properties (initial void ratio – 0.8, cohesion – 1 kPa, dilatation angle – 10 degrees, angle of internal friction – 30 degrees) were assigned to the electronic model of the soil sample. The relationship between the sample stress and the steady-state creep rate was assumed to be 0.5. The sample was subjected to a load of up to 100 kPa.

3. Results and discussion

This section presents the average values of the changes in the properties of soil under consideration during the triaxial test. The values were obtained under conditions of the sample deformation with displacement of soil layers up to 4.5 mm.

1. *Elastoplastic compression modulus*. It is a soil characteristic that allows you to determine its compression resistance in the linear (elastic) deformation region. The value of the elastoplastic compression modulus does not change over the entire shear range of the soil sample and is equal to 20 MPa.

2. *Current void volume fraction*. An indicator that describes the proportion of the structure occupied by empty space between particles. The current void volume fraction of soil increases with low shear deformation intensity and decreases with increasing shear deformation intensity. The average value of the parameter is 0.4494.

3. *Stiffness for primary loading*. A parameter that determines the resistance of soil to deformations caused by stress during initial loading. A decrease in the parameter was observed over the entire shear deformation range of the sample (linear dependence). The average value of this parameter is 25 MPa.

4. *Stiffness for unloading and reloading*. A parameter that determines the resistance of soil to deformations caused by stress during unloading and reloading. This parameter is changed in a similar way to the previous parameter. The average value of stiffness for unloading and reloading is 75 MPa.

5. *Void ratio*. The parameter represents the ratio of the volume of voids in the soil to the volume of solid particles. When the sample is deformed, the ratio decreases nonlinearly. The average value of the coefficient is 0.8161.

6. *Yield function*. A characteristic of soil that describes its ability to deform and change shape under external loads. The parameter changes according to increasing and decreasing functions over the entire shear deformation range of the sample. Positive (maximum value of 10×10^{-11} MPa) and negative (maximum value of -10×10^{-11} MPa) values of the parameter are observed, which determine the type of deformation – tension or compression.

7. *Specific volume*. A physical quantity defined as the ratio of the volume occupied by a substance to its mass. The specific volume of soil tends to increase with small shear deformations and decrease with maximum deformation values. The average value of the parameter is 1.8161.

8. *Shear modulus for unloading and reloading*. The property of a material to resist changes in shape when a force is applied parallel to its surface under unloading and loading conditions. The shear modulus decreases with repeated deformation of the sample. The average value of the parameter is 31.25 MPa.

9. *Swelling to compression ratio*. The ratio determines whether the soil is expansive or non-expansive. During testing, the parameter value is constant (2.1) over the entire shear deformation range of the soil sample.

10. *Coefficient of earth pressure at rest*. It is calculated as the ratio of lateral pressure to vertical pressure. The coefficient value is equal to 0.5 for different shear deformation intensities of the sample, which indicates a predominant transverse load.

11. *Current relative density*. The indicator determines how tightly the soil sample is packed compared to its maximum achievable density. The minimum value of the coefficient is determined at 50% of the maximum deformation of the soil sample, and the maximum value is determined at a shear deformation of 4.5 mm. The average value of the coefficient is 0.5506.

12. *Isotropic hardening modulus*. A property in which the yield surfaces change in the same way in all principal stress axes. During such hardening, the yield surface increases symmetrically relative to the

hydrostatic axis. At different shear deformation intensities, the soil sample exhibits a constant value of this parameter (approximately 38.2 MPa).

13. *Ultimate deviatoric stress*. A property that characterizes the ultimate tangential stress at which horizontal displacement occurs in the soil sample without increasing the tangential stress or equal to 20% of the sample diameter at a given normal stress. As the deformation of the soil sample increases, the stress decreases sharply in the 1-2 mm shear range. The average value of this parameter is 0.2035 MPa.

14. *Elastic swelling modulus*. The parameter is characterized by the coefficient of proportionality between the vertical pressure on the soil and the relative vertical elastic deformation of the soil that occurs during swelling (an increase in the soil volume due to moisture absorption). The resistance of soil to elastic deformation is constant and equal to 41.8 MPa throughout the entire shear deformation range of the sample.

15. *Asymptotic value of shear strength*. The parameter is represented by the maximum tangential stress that the soil can withstand without breaking or excessive deformation. The dependence is similar to the change in the ultimate shear stress of the soil under given loads. The average value of the parameter is 0.2261 MPa.

16. *Plastic potential*. A function used in plasticity theory to describe the direction of plastic deformation in soil. The average value of the plastic potential for the accepted soil type is 0.0667 MPa. A higher intensity of the soil shear deformation leads to a decrease in the value of the plastic potential.

17. *Deviatoric stress*. A part of the stress tensor that represents the difference between the actual stress state and average stresses. Deviatoric stress is related to distortion or change in the shape of a material, rather than its volume. The stress decreases as the shear deformation intensity of the soil sample increases. The calculated average deviatoric stress value was 0.2032 MPa.

18. *Consolidation pressure*. A soil characteristic that determines the rate of soil deformation under constant stress due to water filtration. The soil consolidation pressure increases in proportion to the soil deformation. The average value of the parameter is 0.5937 MPa.

19. *Mobilized dilatancy angle*. The parameter takes into account the influence of both equivalent plastic deformation and confining pressure to describe the nonlinear volumetric deformation of rocks. A decrease in the parameter value to 50% of the calculated deformation of the sample was noted. Then, an increase in the parameter value to 0.18 is observed.

20. *Mobilized friction angle*. The parameter represents the coefficient of natural soil pressure and the relationship between it and the angle of internal friction in one-dimensional compression of normally consolidated soils. The change in this parameter during deformation is similar to the change in the mobilized dilatancy angle. The average value of the mobilized friction angle is 0.5233.

21. *Critical state friction angle*. The parameter represents the constant ratio of voids and the constant friction angle at high values of soil deformation. The soil property during testing is constant and equal to 0.363.

4. Conclusion

In conclusion, we would like to note that the obtained properties characterize a complete picture of the state of stress-strain soil in various aspects of geotechnical work. Based on the testing results, the dependencies of elastic and residual deformations, hardness, stiffness and other soil properties on the intensity of loading and unloading of the sample is traced. Naturally, the presented research results will be relevant for loaded soil under normal climatic conditions (temperature 25°C, pressure 101.325 kPa, and humidity 60%).

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