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COMPARATIVE ANALYSIS OF THE METHODS FOR THE CALCULATIONS OF THE STABILITY OF SOIL SLOPES

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The article discusses various methods for calculating the coefficient of slope stability on three options of soil slopes. The results of the calculations in the software systems PLAXIS and FSS-PSU are provided. The conclusion is made concerning the discrepancy of the obtained results.

Introduction. In construction practice, it is often necessary to assess the stability of slopes to prevent their collapse. A proper assessment concerning the stability of slopes, allows us to predict the formation of landslide processes in advance, provide arrangements to strengthen the slopes, and avoid undesirable consequences.

Currently, various software systems are increasingly used to calculate the soil slopes. The use of software systems allows us to reduce the complexity of calculations and improve their accuracy, due to more complex design models of soil behavior. However, even the most advanced software systems can produce results that are inconsistent with the actual data from field tests and observations. In this case, the discrepancy between test and calculation data can sometimes reach tens of percent or more. The reason for the discrepancy between the calculation results and the experimental data may depend on both, the initial data, and the accepted computational model of the soil.

Software systems for such calculations have been widespread recently, which are based on the finite element method. One of such software systems is PLAXIS, which allows us to carry out a wide range of calculations in the field of geotechnics. Its peculiarity is the presence of various soil models, which allows describing its work with various degrees of adequacy.

When creating a geometric model in PLAXIS design complex, the soil mass is divided into 15-node triangular iso-parametric finite elements. Displacements are determined at 15 nodes, whereas stresses are at 12 points. When modeling the work of the soil under a load, the elastic-plastic model of Mohr-Coulomb is used, which includes 5 initial parameters: deformation modulus E, Poisson's ratio ν, internal friction angle φ, specific cohesion c, dilatancy angle ψ (not considered) [1].

In assessing the overall stability of a slope, the coefficient of overall stability is used, which can be determined as the ratio of the factual soil shear strength to the shear strength in the limit state. If the Mohr – Coulomb strength condition is taken as the condition for the limit equilibrium, then the overall stability coefficient is determined by the following formula (1):

$$\xi = \frac{c + \sigma_n \cdot \tan\varphi}{c_r + \sigma_n \cdot \tan\varphi_r} \quad (1)$$

where c and φ – strength characteristics of soils at the base;

σ_n – factual axial stress;

c_r and φ_r – values of the strength characteristics of the soils in the limit state.

To assess the overall stability in PLAXIS, the Phi-c-rediction method is implemented (the values of φ and c are respectively reduced before the soil is destroyed). The stability is determined by the coefficient $\sum M_{sf}$ (2):

$$\sum M_{sf} = \frac{c}{c_r} = \frac{\tan\varphi}{\tan\varphi_r} \quad (2)$$

The graph-analytical method of the circular-cylindrical sliding surfaces, implemented in the FSS-PSU complex, developed at Polotsk State University, is also widely used in practice. The software is an objectively associative system which allows to organize the storage and manipulation of complex structured data. It allows to calculate the stability using the method of circular-cylindrical surfaces for any soil bases. In this case, the search for the most dangerous sliding surfaces is performed by an iterative method using a special algorithm [2].

When adopting a circular-cylindrical sliding surface, the circular-cylindrical sliding surface method is used.

The principle of such calculation, is that we set the sliding surface with a center point O, and to find the stability coefficient, we determine the ratio of the sum of the holding moments to the sum of the shear moments (3):

$$\eta = \frac{M_h}{M_{sh}} \quad (3)$$

The circular-cylindrical sliding surface method is very popular, and is used for calculating the bearing capacity of foundations, as well as to assess the stability of slopes.

The greatest difficulty in this method is the search for the most dangerous slip surface, for which the safety factor is a minimum [3].

To compare, in the PLAXIS and FSS-PSU software systems, a slope 13m high with a setting angle of $\alpha =$ 60, was considered. Three options of the geological structure of the slope were considered:

1st option – varved clay;
2nd option – fine sand;
3rd option – in the lower part of the slope there is varved clay, whereas on top there is fine sand.

For these types of soils, the physical-mechanical characteristics provided in table 1, were taken.

Table 1. – Physical-mechanical characteristics of the soils

Soil name	Specific weight $\gamma, kN/m^3$	Specific cohesion C, kPa	Internal friction angle $\varphi,°$	Deformation modulus E, MPa	Poisson's ratio ν
Fine sand	15	1,5	31	20	0,30
Varved clay	20	19,12	7,91	18	0,35

The calculated finite element scheme of the slope in the PLAXIS software system, is shown in figure 1, whereas in figure 2, the design diagram of the slope from the FSS-PSU is provided. The calculation results are presented in table 2.

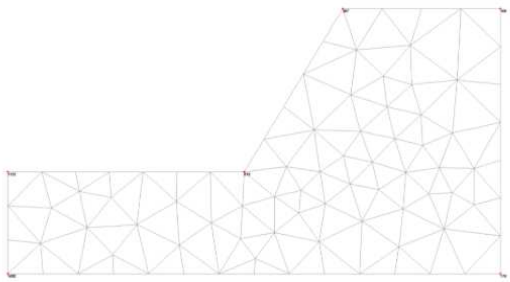

Figure 1. – Calculated finite element slope scheme

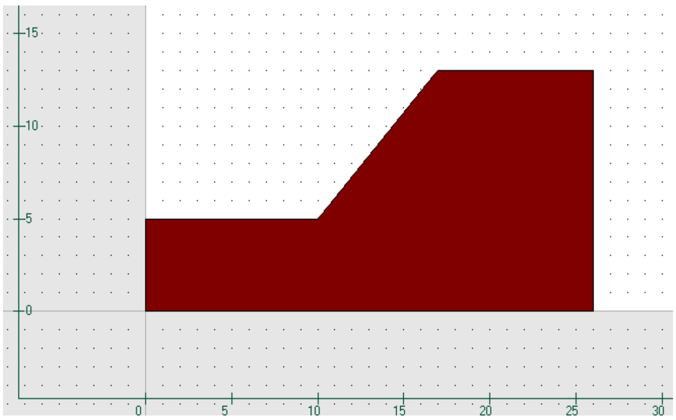

Figure 2. – The design scheme of the slope of the software system FSS-PSU

The results of determining the stability coefficient of the slope are shown in table 2.

Table 2. – The calculation results of the slope stability

Slope sliding options	Stability coefficient in PLAXIS	Stability coefficient in FSS-PSU	Discrepancy in %
1st option (varved clay)	0,966	0,880	8,9
2nd option (fine sand)	0,797	0,700	12,2
3rd option (in the lower part of the slope there is varved clay, whereas on top, there is fine sand.)	0,940	0,870	7,4

By analyzing the obtained results, we can conclude that different approaches to the evaluation of the slope stability, implemented in the PLAXIS and FSS-PSU software systems, provide acceptable -for the construction- convergence in the calculation results. Thus, the maximum discrepancy was obtained for the slope, composed of fine sand, which is 12.2%. This proves the possibility of using various design models to assess the stability of slopes.

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