INFLUENCE OF SOIL PROPERTIES ANISOTROPY ON THE BEARING CAPACITY OF THE FOUNDATION GROUND

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INTRODUCTION

Sophisticated engineering and geological conditions of the Moldova territory, coupled with an active neotectonic activity led to the formation in the overburden thickness, of numerous weakness areas observed even within the watershed areas.

Unfortunately, the construction practice in Moldova essentially lacks detailed data on the impact of the weakened zones on the bearing capacity of the foundation ground. The present work is aimed to learn the nature of Sarmatian clays' strength that form the slopes of the republic and to identify the role of weakness zones within the evaluation of the bearing capacity of the ground under the foundations.

1. STATE OF PROBLEM AND SETTING THE RESEARCH TASKS

The possibility of weakness zones formation in clay soils has been repeatedly confirmed by scientists in various countries. In particular, in the Dnepropetrovsk Institute of Railway Transport Engineering (DIRTE), formation of such areas was recorded after simulation on centrifugal machine and in the process of field observations on the development of landslide deformation in hidden-plastic clays of Odessa.

At the same time, in Moldova, detailed research in this field are practically not carried out. The results of some performed studies are displayed in [1, 2].

It was determined that the formation of weakness zones and inclined sliding surfaces in Sarmatian clays, is facilitated by active tectonic activity, seismic-gravitational and landslides processes. Impact of existing weakness zones on strength, are fixed during soil tests in the laboratory and confirmed by field observations and the results of landslide models tests.

On the territory of the central and northern part of Moldova, due to the peculiarities of modern terrain relief development, on the slopes in the overburden thickness, which was studied at a depth of about 25 meters, a weakened zone was formed. Often, it is characterized by high humidity.

According to field and laboratory studies on all the studied areas, this clearly traced zone at depths of 6-12 m, separates the upper part of the soil thickness, represented strongly weathered rocks with frequent inclined sliding surfaces, from their underlying rocks with a greater degree of preservation of the initial layer, up to the clearly pronounced horizontal stratification. Sliding surfaces found in them, are confined to a certain depth. Strength and rheological properties of weakened zone soils determine the nature and speed of deformation: in the solid clays, the process of sliding surface formation ends with a brittle cleavage (catastrophic slip); in plastics clays - a long-term development of creep processes is observed, often at a very low speed.

The goal of the performed studies is to investigate the possibility of creep zones formation under foundations of houses planned for construction on the old landslide slope in the town Durlesti.

From geomorphological point of view, the area refers to watershed of Durlesti valley's stream. The distinction of the geological structure of the area is the presence of soil with disturbed structure.

The performed researchers found that up to a depth of 4m lie greenish clays, broken by cracks, with many sliding and weakening surfaces.

Considering the adopted laying depth of the foundations, they will be in the active zone under the influence of stresses that appear under the foundation.

It should be recognized that the evaluation of the clay soils strength is still considered one of the unsolved problems of soil mechanics. Recent works of several authors are based on studies of the last century, which were made by recognized authorities: Vyalov S.S., Goldstein M.N., Maslov N.N., Tsytovich N.A., Turov A.Y. et al.

In particular, through experiments with clay soils, there was determined that the sliding surface from the shear sample has a complex form, gradually merging and forming a joint surface, which leads to the macroscopic destruction of the sample. The development of the sliding surfaces is affected by structural defects. The greatest weakening is caused by cracks, tilted at an acute angle to the resultant sliding surface.

Based on all the above, according to the present study, the following tasks were defined:

– to study the rheology parameters of Sarmatian clays forming the slope;

– to determine the possibility of creep zone formation under the foundation;

– to assess the bearing capacity of the foundation ground, taking into account the possible presence in the soil thickness of weakness zones.

2. THE FORMULAS USED FOR CALCULATIONS

The problems were solved on the basis of the provisions of the physical-technical creep theory of prof. Maslov N.N. [3].

The shear strength of foundation ground ($S_{\sigma w}$) described by the known trinomial expression:

$$S_{\sigma w} = \sigma_n tg\phi_w + \Sigma_w + C_c = \sigma_n tg\phi_w + C_w \quad (1)$$

The possibility of formation and the appearance of creep zones in clay soils of building's foundation, was conditioned by criterion:

$$\sigma_n tg\phi_w + \Sigma_w + C_c > \tau > \sigma_n tg\phi_w + C_c \quad (2)$$

In the above expressions:

φ_w – true angle of internal friction, which depends on the density and moisture of soil; Σ_w – cohesion of hydro-colloidal nature of reversible character; C_c – irreversible structural cohesion; C_w – total cohesion.

Thus, it was assumed that the development of creep zones is possible only if shearing stresses that operate anywhere in these zones, are exceeding creep threshold, i.e. it's provided that $\tau > \tau_{lim}$, wherein:

$$\tau_{lim} = \sigma_n tg\phi_w + C_c \quad (3)$$

Rheological condition at a certain point of construction foundation ground with the coordinates z, x (in a flat task condition) was determined by the value of the safety factor of creep (K_{creep}) by the expression:

$$K_{creep} = \tau_{lim} / \tau \quad (4)$$

It is clear, that the phenomenon of creep is possible on condition:

$$K_{creep} \leq 1$$

Shear stresses were found via main stresses σ_1 and σ_2. Safety factor of creep was determined by the expression:

$$K_{creep} = \frac{\left[(\sigma_1 + \sigma_2) + 2\gamma_w (z + h_f + h_c) + (\sigma_1 - \sigma_2) cos2\left(45° + {\phi_w}/{2}\right) \right] tg\phi_w + 2C_c}{(\sigma_1 - \sigma_2) sin2\left(45° + {\phi_w}/{2}\right)} \quad (5)$$

where σ_1 and σ_2 – main stresses in the analysed point; z – the depth of the analysed point; γ_w – density of soil; h_f – the building foundation laying depth; h_c – the fictive building foundation laying depth.

Here:

$$h_c = \frac{C_c}{\gamma_w \cdot tg\phi_w} \quad (6)$$

3. THE STUDY RESULTS OF THE SARMATIAN CLAYS RHEOLOGICAL PARAMETERS

The rheological characteristics (structural cohesion, the threshold creep) were determined in the laboratory by testing samples by direct shear method. There were tested 18 samples. Besides of the natural structure tests, there were performed tests by the method of "*prepared surface shift*" and "*prepared moistened surface shift*".

As it was proved by the results of experiments, the majority of tested samples with natural state, have a solid consistence and possess significant structural cohesion. At the same time, samples with the presence of weakening micro-zones and sliding surfaces were detected. This was stated both visually and by the value of critical shear strain. Thus, when testing a selected sample taken from a depth of 6m, there was determined the minimum shear force. Herewith, the resulted shear equation

$S = 0{,}23\sigma+50$, kPa coincided with the equation obtained for the prepared surface $S = 0{,}25\sigma+50$, kPa.

Performed study of strength and rheological parameters permitted determining of the value used during the rheological analysis. At the same time, the following characteristics were accepted:
1) $\varphi = 16°$, $C_c = 44$ kPa – at the moment of research;
2) $\varphi = 16°$, $C_c = 20$ kPa – taking into account the time factor.

4. EVALUATION OF THE BEARING CAPACITY OF FOUNDATION GROUND

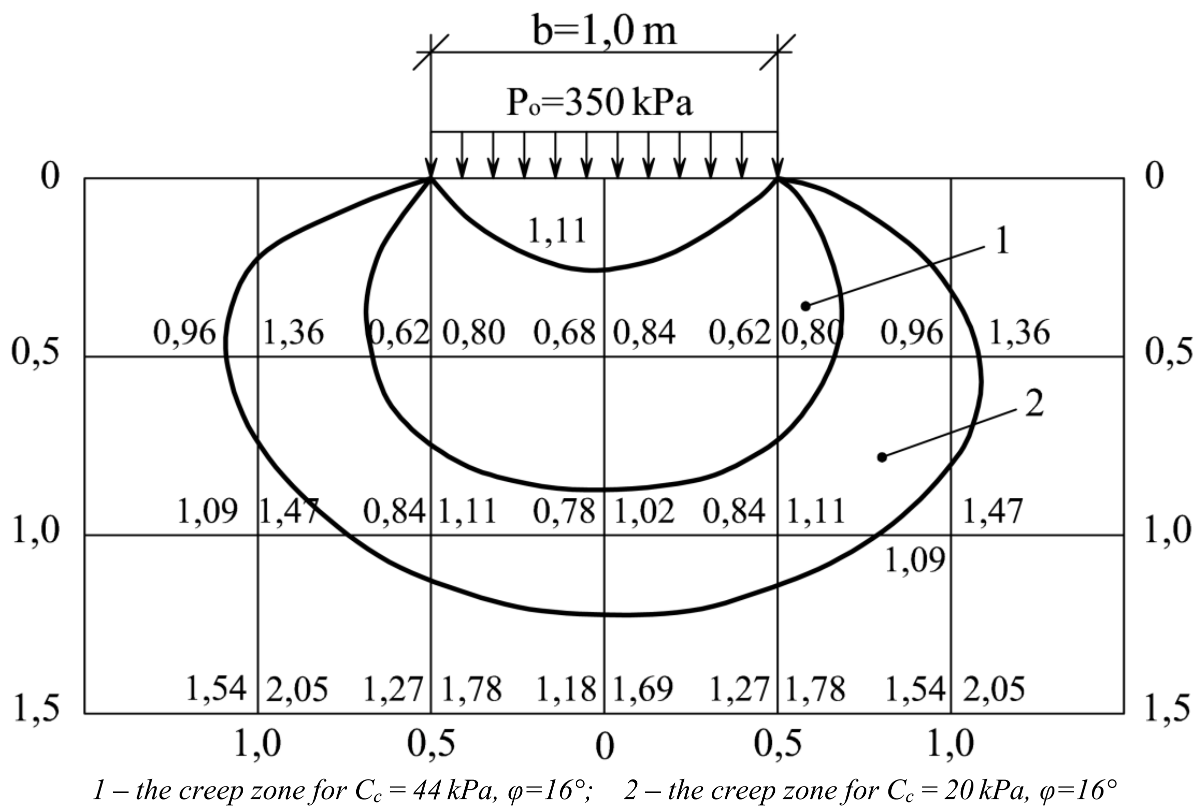
On the basis of the determined values K_{creep}, the lines of it's equal values under the foundation were designed (Fig. 1).

The performed calculations proved that for the foundation width b = 1 m assigned on the basis of the requirements of existing technical rules [4], under the foundations at a depth of about 1 meter creep zone is formed (*$K_{creep} < 1$*), that determines the possibility of persistent in time foundation settlement. Taking into consideration that the overall cohesion in the ground can be reduced to lower values, than those determined in the laboratory, it is suggested to presume the possibility of a downgrade of the stress-strain state under the foundation. So, even at $C_c = 20$ kPa creep zones develop to a depth of 1,3 m at a width of more than 1 m.

Thus, there might appear a situation, when applied to soils that possess hard structural cohesion, with natural weakened zones being present, the accomplishment of conditions P ≤ R and $S \le S_u$ might not be sufficient. The performed calculations have proved that only increasing of the foundation width to the value of $b = 1{,}4$ m (with accepted strength characteristics of soil $\varphi = 16°$, $C_w = 44$ kPa), dangerous creep zones are absent.

5. CONCLUSIONS

When estimating the bearing capacity of foundation ground, composed by landslide Sarmatian clays, two types of anisotropy should be taken into account. The first type is associated with lithogenetic property variability of soils, that compose the slope. The second depends on the formation of the anisotropic properties, when sliding surfaces and weakness zones appear.



1 – the creep zone for $C_c = 44$ kPa, $\varphi=16°$; 2 – the creep zone for $C_c = 20$ kPa, $\varphi=16°$

Figure 1. The lines for equal values of safety factor of creep.

References

1. *Timofeyeva T.A., Polcanov V.N.* *On the long term stability of natural and cutting slopes in Moldova//TRONDHEIM; A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1996. – p. 1387-1390.*
2. *Timofeyeva T.A., Polkanov V.N.* *Evaluation of the strength of Neogene clays of Moldova, taking into account the weakening zones for forecasting slope stability: Abstracts of the regional meeting. Dushanbe, May 30 - June 3, 1990, Dushanbe, 1990. - P. 24-26.*
3. *Maslov N.N.* *Physical-technical theory of clayed soil's creep developed in building practice (in Russians). Moscow, Stroiizdat, 1984 –176p.*
4. *SNiP 2.02.01-83. Foundation ground of buildings and structures. Gosstroj USSR. Moscow. Strojizdat, 1984 – 39 p.*

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