Sediments foundation bases under long-term regime loading

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ABSTRACT

It is proposed engineering method for calculating the settlements of foundation bases at long-term nonlinear deformations soils, which is based on the method of layering with the spatial summation of the stress-strain state of the soil mass, regime of loading and duration of loading. Volume strain in time presented according to the theory of the hereditary creep as the sum of deformations of volume and the shape considering the interference.

Keywords: clay soil, settlement, long-term nonlinear deformations, creep, regime of loading

1. INTRODUCTION

In the real world of construction and design, the load on the foundation soil is applied in stages during the construction of the building or structure. At this stage the active loading stages alternate with long excerpt of the sample under the load.

Based on the fact that in the grounds composed of clay soils the stress-strain state depends on the previous history of loading, the account features of deformation of clay soils under long-term loading regime allows for to study the real properties of the soil more precisely, and the way to approach this theoretical predictions to the actual behavior of soils grounds. In this connection, the experimental study of the stress-strain state of clay soils under the regime long-term triaxial is an urgent task.

2 LABORATORY TESTING OF SOIL

Tests were conducted in the triaxial apparatus under the regime of triaxial long static loading, a feature of which was the alternation of stages step application deviatoric loading and prolonged excerpt of the sample under load: in the first stage sample was subjected to the full compression, then the sample at constant lateral pressure was subjected to stepwise regime of deviatoric loading (Fig. 1).

According to the test results intensity dependence of the tangential stresses \( \tau \), volumetric strain \( \varepsilon \), the intensity of shear strain \( \gamma \) in time, the passport of soil and the passport of creep soil were determined. The joint analysis of these graphs shows that medium stress and loading time increasing impact on deformations change in volume and changes in the shape deformation (positive dilatancy) during compaction of soil within the tested volume (Mirsayapov & Koroleva 2011b).

Fig. 1. The regime's combined long-term static loading.

Experimental studies of clay soil in long-term triaxial compression (Mirsayapov & Koroleva 2011a) have defined the mechanism of tested specimen's failure. The process can be described in a following way: while pressure is applied, consolidated areas in a form of pyramids are formed, pyramids occur in specimen’s upper and lower surface and at specimen’s sides (Fig. 2a). Geometrical sizes of pyramids mentioned, depends on loading conditions.

To define physical-mechanical properties, soil
samples were taken from relevant areas. As a result of analysis of failure process and areas with different densities, authors made a following suggestion: triaxial compression leads to formation of areas of different deflected state. As a result of gradual increment of load, consolidated pyramids of different shapes and sizes in specimen’s upper and lower surfaces and at specimen’s sides are formed. Size and shape of pyramids depends on loading conditions (Fig. 2).

Figure 2. a) – consolidated areas of different density of a specimen in triaxial tests: 1-vertical consolidated pyramids; 2 – consolidated pyramids at specimen’s sides; 3 – uniformed deflected state area; 4- area of dilatancy; b) – deformed state of clay between pyramids formed; c) – deflected state of volume element in space in random moment of time at preultimative condition (stresses and tensions are not shown); d) – deflected state of volume element in space at ultimate condition (stresses and tensions are not shown).

Specimen’s deformation caused by this pyramid’s movement, where pyramids are considered as solid bodies. Above mentioned improvements of physical-mechanical properties in consolidated areas (increment of density up to 11%; φ – 88%; c – 138%) were observed. Negative processes related to reduction of physical-mechanical properties are located in areas between pyramids (area 4, Fig. 2a) (density reduction up to 43%; φ – 45%; c – 67%). At the same time Mohr’s circles drawn based on results of series of tests show reduction of internal tension angle φ up to 16% and cohesive force c – 6 % in an integral volume. Visual investigation of shearing surface after specimen’s failure shows that soil at this area is subjected to both detachment and shearing (Fig. 2a and Fig. 2b).

Analyzes the results obtained it can be said that with increasing of average stress and the time of the load there is a development of strain and deformation volume changes during compaction of soil within a tested volume (Fig. 3 and Fig. 4).

The results obtained were used in the development of the engineering method for calculating of the sediment foundation bases, which is based on the method of layering with the spatial summation of the stress-strain state of the soil mass and changes in the rheological properties and stress-strain state during long-term operation of the building.

Fig. 3. Graph of the volume strain during regime long-term static loading.

Fig. 4. Shear stresses τi intensity and of shear strain γi intensity dependency diagram.

3 CALCULATION SEDIMENTS OF SOILS FOUNDATION BASES

The height of the compressible strata $H_s$ defined by SP 22.13330.2011 "SNIP 2.02.01-83 * Foundations of buildings and structures" (Fig. 5):

$$H_s = Z; \quad \sigma_{zp} = 0.5\sigma_{zg},$$

where $H_s$ – height of the compressible strata received at the depth $Z$;

$\sigma_{zp}$ – vertical normal stress at the depth $Z$ of the additional load $P$ on the base along the axis of the structure;

$\sigma_{zg}$ – Vertical normal stress of its own weight of the
foundation soil at depth \( Z \).

Values for stress diagrams additional vertical axis of the foundation (square stamp) at depths \( Z \) can be determined by conventional regulatory technique. Values of horizontal stress components along the central axes can be determined from the theory of elasticity solutions. It should be noted that the central axis of the vertical and horizontal stresses are principal (Fig. 6).

\[
\sigma = \frac{\sigma_x + \sigma_y + \sigma_z}{3},
\]

\[
\sigma_i = \frac{1}{\sqrt{2}} \sqrt{\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\sigma_z - \sigma_x\right)^2 + 6 \left(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2\right)}
\]

From the values of medium stress and the stress intensity determine increment of the strain tensor:

\[
\varepsilon \equiv \varepsilon_1 + \varepsilon_2 + \varepsilon_3,
\]

\[
\varepsilon_i = \frac{2}{3} \left(\varepsilon_1 - \varepsilon_3\right)
\]

In other cases we use the condition of coaxiality tensor increments of stress and strain:

\[
\frac{\Delta \varepsilon_x - \varepsilon_y}{\Delta \sigma_x - \sigma_y} = \frac{\Delta (\varepsilon_y - \varepsilon_z)}{\Delta (\sigma_y - \sigma_z)} = \frac{\Delta (\varepsilon_z - \varepsilon_x)}{\Delta (\sigma_z - \sigma_x)} = \Delta \varepsilon / \Delta \sigma = \chi
\]

Determination of the conditional modules characterizing transition from natural state of the base to the state after the local loading application:

\[
K_V = \frac{\Delta \sigma}{\Delta \varepsilon_V},
\]

\[
G_V = \frac{\Delta \sigma_i}{3 \Delta \varepsilon_i}
\]

Modules (6) and (7) can be represented by Hooke's law parameters in increments of stress and strain for load step.

Then the increment of axial strain:

\[
\Delta \varepsilon_z = \frac{\Delta \sigma_z - \Delta \sigma_i}{G_V(t) - K_V(t)} = \frac{3K_V(t) - G_V(t)}{3K_V(t) - G_V(t)}
\]

Then consider the effect of duration and load conditions. To do this, modules \( K_V(t) \) and \( G_V(t) \) represented as:
4 CONCLUSIONS

Develop an improved method for calculating the settlement of the foundation’s bases, which is based on layering summation method based on features related to spatial stress-strain state and long-term nonlinear deformation of clayey soils. Volumetric soil deformation in time is described by the theory of hereditary creep deformation as the sum of changes in volume and changes in the shape deformations considering their mutual influence. An improved method for calculating the sediment with high accuracy to estimate settlement of the foundation’s bases under long-term loading is proposed.

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