Initial stress condition of saturated soil grounds

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ABSTRACT: Authors have developed a method of estimating pressure induced under natural ground. A stress measuring device having gauges of stress and pore water pressure has been designed. The results of measurement of stresses in saturated natural soil are analyzed. The estimation of an initial stress for saturated soil is given. A technique to estimate initial stress condition for saturated ground of natural deposition is developed. The reductions in the excess pore water pressure and stress depend mainly on the type of ground conditions. In sandy soils, the process relaxation with time is very intense and a stable value reaches within an hour, and its further fall with time are insignificant. For loam soil relaxation in pore water pressure is less intense and it also takes much longer, than in sandy soil. The attenuation factors confirm the above assumption and accordingly for loam: pore water pressure - 0.50; and stress - 0.49, and for sand: pore water pressure - 0.76 and stress - 0.40 and for soil: pore water pressure - 0.63 and stress - 0.39. The values of attenuation factors suggest loam have a degree of creep, when sandy soil do not have that property. From this research, the quantitative values of pore water pressure factor for various soils are established, which characterizes structure of saturated ground.

1 INTRODUCTION

Soil element in saturated ground is under influence of an own weight. In the geomechanics the self weight of saturated natural ground in a rest condition is defined as the stress coming from self weight of the ground as shown below.

$$\sigma_x = \gamma_i^{/} h_i; \;\; \sigma_y = \sigma_z = \xi_0\, \sigma_x; \; \tau_{xy} = \tau_{yz} = \sigma_{xz} = 0 \qquad (1)$$

where $\gamma_i^{/} = (\gamma_s - \gamma_w)/(1 - n)$ - unit weight of a ground, in view of weighing action of water,
n – soil porosity;
γ_s – unit weight of particles of soil;
γ_w – unit weight of water;

$\xi_0 = \frac{\mu_0}{(1-\mu_0)}$ - factor of lateral stress of a ground in a condition of rest, μ_0 - poisson's ratio;

Thus, saturated ground foundation which is subjected to self weight, requires its estimation, which serves as a source of the necessary information. (Campanella et al. 1982, Uhov 2002)
The estimation of initial stress deformation condition of saturated ground can be made at any point within the soil profile of a ground by considering the external influence and measurement of its response as stress from this influence. (Jamilkowski. et al. 1985, Zhakulin 2011)

2 TECHNIQUE OF AN ESTIMATION OF INITIAL STRESS-DEFORMATION CONDITION

2.1 Essence of a method of research

Installation of the device having measuring probes, in a natural saturated ground is generally done by a method of cave-in. The process of cave-in consists of shearing apart a ground and replacing it with measuring probe. As a result of it, at the contact "point of ground" there is stress concentration at contract point on cave-in, integral of which reflects natural stress working in the given point, and additional stress caused by external influence due to structure of the ground. Thus, total stress developed at contact-point of devices can be written as:

$$P_w^{tot} (\sigma^{tot}) = \gamma_w h (\gamma' h) + \Delta P_w (\Delta\sigma) \quad (2)$$

At cave-in of a saturated natural ground and for given thickness of a plate, deformation and the reaction measured is constant, which depends on the ground type and its mode of relaxation. At the initial moment of such tests, the reaction in ground is maximum, and after a period of time pore water pressure, and total stress decrease. The rate of relaxation of total stress and pore water pressure reduction is determined by properties of a ground. Thus relaxation of only additional stress ($\Delta\sigma$) and pore water pressure (ΔP_w), occurs due to external influence of shear deformation of a ground. The natural stress ($\gamma' h$) and hydrostatic pressure- $\gamma_w h_i$ remain constant in the given point. The device is kept at the given depth until the stable stress and pore water pressure are obtained. Thus depending on physical properties of a ground and additional the ultimate stress relaxation is $\sigma_{tot} > \sigma$. Pore pressure in consolidated ground at the given depths is equal to hydrostatic pressure.
And in not consolidated saturated ground, it may written as:

$$P_w^{tot} > \gamma_w h_i \; ; \; \sigma^{tot} > \gamma' h_i \quad (3)$$

where γ' - submerged unit weight of water. A method to examine release of pore water pressure in a saturated natural ground thus is proposed using cave-in device having measuring probe. A cave-in device causes shearing of a saturated ground. Dissipation of an additional stress and pore water pressure are measured at the interface of soil and the device.

2.2 Formulation of model

The estimation of an initial effective stress in a saturated ground can be done from:

$$\sigma ' = \sigma - P_w = \gamma' h - P_w \quad (4)$$

Initial parameter for pore water pressure is:

$$\beta = \frac{P_{w,to}}{\sigma_{m,to}} \qquad (5)$$

where $P_{w,to}$ -pore pressure and $\sigma_{w,to}$ -stress at t=0.
To examine the nature of relaxation of pore water pressure and the stress a new parameter is defined -value of attenuation factor K_3 - depends on probing speed, pore water pressure and stress:

$$K_3 = \frac{P_{w,t}(\sigma_t)}{P_{w,to}(\sigma_{to})} \qquad (6)$$

where $P_{w,t}$ and σ_t - pore pressure and stress at time t; $P_{w,to}$ and σ_{to} - pore pressure and stress at time t_0.
Figure 1 shows a typical characteristics of relaxation of stress and pore water pressure with time in a saturated ground.

2.3 Design feature of the device

To measure the initial stress - deformation condition of saturated ground, device having gauges for stress and pore water pressure measurement is developed. The device has pointed thin plate of thickness 12 mm, width 120 mm, length 220 mm and length of the projected part 50 mm. Tip angle is 160°. The device has three jacks: two for measurement of stress gauges and pore water pressure, third jack is on opposite side, which is used for connection of wires to the measuring equipment. Electrical gauges have diameters of 35 mm, thickness of 6 mm and pore water pressure gauge has a porous stone.

3 ANALYSIS OF RESULTS OF RESEARCH

By examining the nature of relaxation of stress and pore water pressure on the given depths of saturated ground foundation of natural addition the following diagrams are constructed:
-relaxation of pore water pressure and stress with time. (Figure 1); and
-distribution of pore water pressure and stress with depth. (Figure 2).

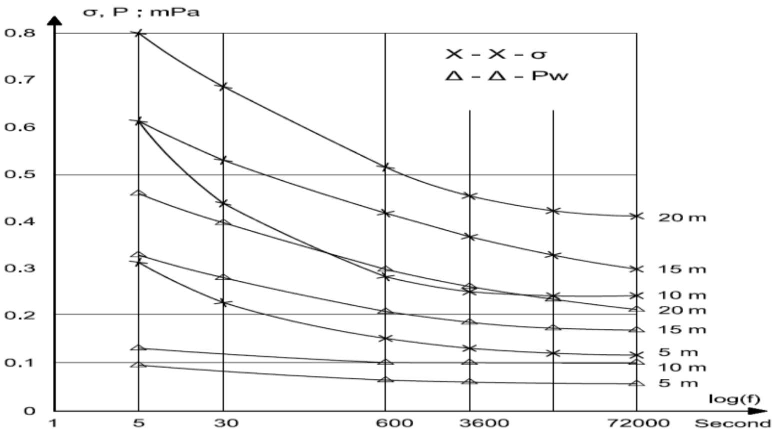

Figure 1. Relaxation of pore water pressure and stress with time.

In figure 1 the relations for relaxation of pore water pressure and stress from t=0 to 72000 seconds at depths of 5, 10, 15 and 20 meters are summarized. From the relaxation diagrams it follows, that the process of cave-in of the device entails occurrence of excess pore water pressure and additional stress, which with time starts decreasing. Also, excess pore water pressure and additional stress increases with depth of cave-in is naturally increased. Most intense relaxation process occurs in the first 30 minutes after inserting the measuring device.

The measurement was made at a depth of 5 meters below the ground surface, where soil consists of saturated silt. Initial excess pore pressure was - 0.051 MPa and in 20 hours, it reduced to - 0.050 MPa. Thus the initial excess pore water pressure is 90% higher than the final value. Relaxation of additional stress is different in nature, than pore water pressure. Value of initial stress is 2.5 times larger than the final. Factor of attenuation of stress is 0.39, and pore water pressure is 0.625. Following this, measurement was made at a depth of 10 meters, where soil is saturated sand. Its initial excess pore was 0.13 MPa, in 30 minutes 0.1 MPa, and even after 20 hours it did not change from 0.1 MPa. The character of relaxation of additional stress has sharp features, having high initial values of 0.6 MPa, which within one hour completely reaches the final measured value. Factors of attenuation of stress is 0.40 and pore water pressure is 0.76. Similarly, initial pore water pressure factors at depth of 5 meters is 0.29 and at 10 meters it is 0.21.

Subsequent measurements were carried out at depths of 15 and 20 meters, where was saturated. At t=0 the excess pore pressure at depth of 15 meters is 0.32 MPa and at 20 meters is 0.45 MPa, in 30 minutes which reduced to 0.20 MPa and 0.28 MPa, and in 20 hours it decreased to 0.16 MPa and 0.22 MPa. The value of initial excess pore pressure is 2 times higher than final at both depths. Relaxation of additional stress has similar character. Factors of attenuation pore water pressure is 0.49 at these depths and stress is 0.48 - 0.50. Initial pore water pressure factor changes within the limits of 0.52 - 0.54. The size of initial additional stress and pore water pressure depends also on kind and density of soil. For soil, initial excess pore pressure and stress exceeds 2 - 3 times final parameter, whereas for additional stress it is 1 - 2 times the final parameter. Also follows, that the characters relaxation of stress and pore water pressure are similar. Also the characters of relaxation of stress and pore water pressure are similar. For sandy soil character of stress and pore water varies depending on its nature and intensity.

Parameter of initial pore water pressure for sand is 0.20, for silt is 0.29 and for loam is 0.52 - 0.54. For sandy soil pore pressure is less, which is reasonable.

In Figure 2 the distributions of pore water pressure and stress with depth after 20 hours of inserting the measuring device in saturated ground are shown. From the analysis of the diagrams it follows that, the process of pore water pressure relaxation was completely finished, and their values at given depths correspond to hydrostatic pressure. In sandy soil excess pore pressure becomes' equal to hydrostatic stress of water after relaxation; in loam soil there is a small divergence of 0.03 MPa.

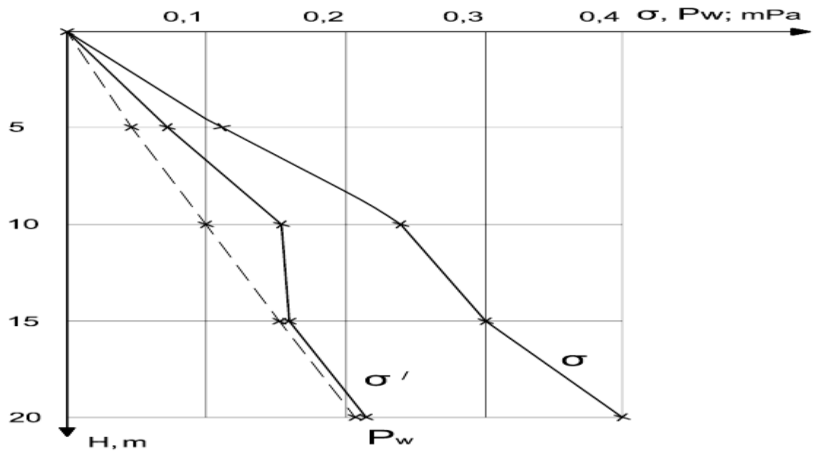

Figure 2. Distribution of pore water pressure and stress with depth.

Despite the insignificant divergences in excess pore water pressure after relaxation, it is possible to conclude that pore pressure reduces to hydrostatic stress of water at a given depth. It is also clear that saturated soils are completely stable and have strong structures of contact between firm particles. Therefore measured stress could not reach the theoretical values, as the initial structures of contact between firm particles are not exactly restored to their original positions.

4 SUMMARY AND CONCLUSIONS

A technique to estimate initial stress condition for saturated ground of natural deposition is developed.

The reduction of excess pore water pressure and stress depends mainly on the type of ground conditions. In sandy soils, the process relaxation with time is very intense and a stable value reaches within an hour, and its further fall with time are insignificant. For loam soil relaxation in pore water pressure is less intense and it also takes much longer time, than in sandy soil. The attenuation factors confirm the above assumption and accordingly for loam: pore water pressure - 0.50; and stress - 0.49, and for sand: pore water pressure - 0.76 and stress - 0.40 and for soil: pore water pressure - 0.63 and stress - 0.39. The values of attenuation factors suggest loam have a degree of creep, when sandy soil do not have that property.

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