ON SETTLING OF THE SOIL SEMI-SPACE SURFACE UNDER LOCAL LOAD

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Abstract:
The article discusses the issues of determining a soil semi-space surface subsidence under the local load influence.
The total sediment is presented as a sum, consisting of the sediment accumulated due to volumetric shear deformations. On the basis of these solutions it was determined the relations between the soil surface settlements accumulated due to volumetric and shear deformations, as well as the total settlement.

Keywords: settlements, deformation deviator, settlement rate, initial density, volumetric deformation, shear deformation.

Introduction. An important element of the stress-strain state analysis of the soil foundation is its surface settlement assessment:

$$S_o = q\frac{(1-\mu_o)}{\pi G_o}\left[(x+b)\ell n(x+b)^2 - (x-b)\ell n(x-b)^2\right] (1)$$

This formula structure is such that it does not reflect the volumetric and shape changes proportion in the soil in the total draft [1]. Meanwhile, such division would make it possible to more fully analyze the stress-strain state of the soil foundation in the compaction phase.
Let us represent the total subsoil surface settlement (S_o) as a sum consisting of the sediment accumulated due to volumetric deformations (S_v) and due to shear deformations (S_γ) [4], i.e.
$S_0 = S_v + S_\gamma$(2)

Methods and materials.
To determine the settlement S_v and S_γ, we use the known [1,5] relationships between linear deformations and the deformation deviator components, ie we have:

$$\left.\begin{aligned} \varepsilon_x &= e_x + \varepsilon = \frac{\sigma_x - \sigma}{2G_o} + \frac{\sigma(1-2\mu_o)}{E_o}, \\ \varepsilon_y &= e_y + \varepsilon = \frac{\sigma_y - \sigma}{2G_o} + \frac{\sigma(1-2\mu_o)}{E_o}, \\ \varepsilon_z &= e_z + \varepsilon = \frac{\sigma_z - \sigma}{2G_o} + \frac{\sigma(1-2\mu_o)}{E_o}. \end{aligned}\right\} \quad (3)$$

Since the soil surface subsidence can be defined as the sum of deformations

$$S_o = \int_0^\infty \varepsilon_z dz \quad (4)$$

Based on (3), we obtain $S_v = \int_0^\infty \frac{\sigma(1-2\mu_o)}{E_o} dz$ (5)

the value of (S_v) can be easily determined (S_γ) by formula (2), i.e. we have

$$S_\gamma = S_o - S_v (6)$$

Substituting into (5) the values (σ)

$$\sigma = \frac{1+\mu_o}{3}(\sigma_x + \sigma_z) = \frac{2(1+\mu_o)}{3\pi} q(\alpha_1 - \alpha_2),$$

assuming $\alpha_1 = arctg\,\frac{z}{x-b}$; $\alpha_2 = arctg\,\frac{z}{x+b}$ (see Figure 1.)

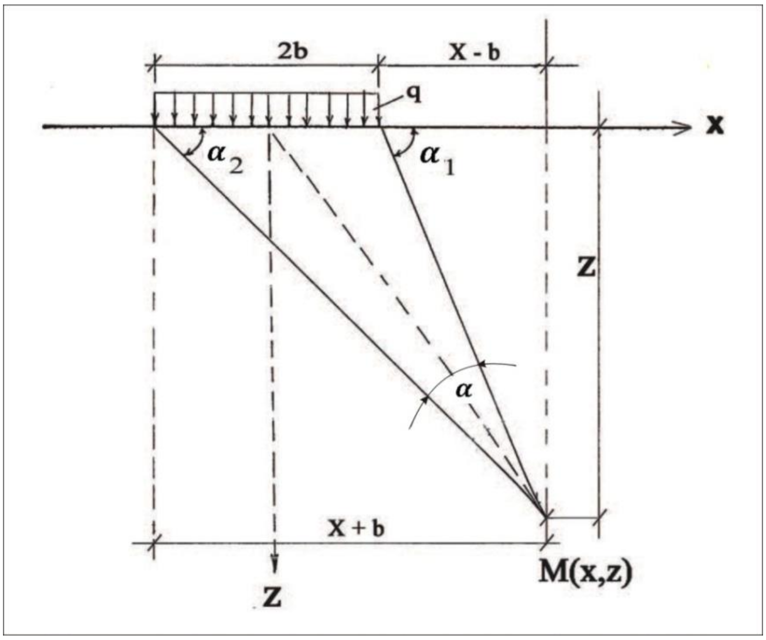

Figure: 1. Action scheme of a uniformly distributed load in a plane problem.

we obtain after integration the following expression

$$S_v = \frac{(1-2\mu_o)(1+\mu)}{3\pi E_o} q\left[(x+b)\ell n(x+b)^2 - (x-b)\ell n(x-b)^2\right] \quad (7)$$

Comparing this expression with (1) we see that they differ only in a constant factor value, since $E_o = 2G_o(1+\mu_o)$. Then, taking into account (1), (6), (7), we obtain

$$S_\gamma = S_o - S_v = \frac{q}{\pi G_o} \cdot \frac{6(1-2\mu_o)-(1-\mu_0)}{6}\left[(x+b)\ell n(x+b)^2 - (x-b)\ell n(x-b)^2\right] \quad (8)$$

Based on these solutions, it is easy to determine the relationship between the soil surfaces accumulated due to volumetric deformations (S_v) and shear deformations (S_γ), sediments as well as the total settlement S_o. So we have:

$$S_\gamma / S_o = \frac{6(1-\mu_o)-(1-2\mu_o)}{6(1-\mu_o)} \quad (9)$$

$$S_v / S_o = \frac{(1-2\mu_o)}{6(1-\mu_o)} \quad (10)$$

$$S_\gamma / S_v = \frac{6(1-\mu_o)-(1-2\mu_o)}{1-2\mu_o} \quad (11)$$

Results.

The obtained relations have important theoretical and practical values, since they make it possible to quantify sediment proportion accumulated due to volumetric changes and shape changes in the soil skeleton in the total sediment separately [4].

This makes it possible to improve the methods for predicting the rate of structures foundations settlement, if the rheological soil skeleton parameters are known at all-round compression and at pure shear separately [2,5], i.e. we have

$$\dot{S}_o = \dot{S}_v + \dot{S}_\gamma \quad (12)$$

Since the sedimentation $\left(\dot{S}_\gamma\right)$ rate will not depend on volumetric changes, it will not depend on consolidation processes. We only note that the settlement rate caused by volumetric soil skeleton deformations in the case of saturated soils will completely and fully depend on the consolidation rate and will not depend on the shear skeleton creep.

Thus, both volumetric and shear deformations occur in the soil mass under the local load influence in the compaction phase [3], the relation of which depends on the initial density – soil moisture. The lower the soil saturation degree, the greater the volumetric deformation proportion in the soil skeleton and the more the soil skeleton is compacted and hardened. However, at a humidity exceeding the optimum, the volumetric deformation decreases sharply, and at full water saturation it reaches a minimum.

Conclusion.

Based on the above material, the following conclusions can be drawn:

1) In a clayey subsoil under the local pre-limit load action, a complex stress-strain state (compaction phase) arises, which significantly depends on the initial density-moisture of the soil.

2) In unsaturated soils of a loose constitution, the compaction phase is accompanied by significant volumetric skeleton deformations by its strengthening.

3) The total subgrade sediment in the compaction phase can be represented as the sum of two sediment components arising from volumetric changes and shape changes in the soil skeleton in depth.

These settlements relation along the entire length of the soil surface is constant for the case of a linearly deformable model and depends only on Poisson's coefficient.

4) With Poisson's coefficient equal to 0.5 or with complete pores saturation with water, the surface settlement due to volumetric deformations is zero, and the settlement due to deformation is not zero, but tends to its minimum value.

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