DESIGN

EFFECT OF THE EXCAVATION OF SOIL ON THE REDUCTION IN ITS SLUMP-TYPE SETTLEMENT UNDER ITS OWN WEIGHT

I. G. Rabinovich

Basic positions of procedures and calculations of the slump-type settlement of loess soils under their own weight in the presence of excavations for deep basements are analyzed; this is associated with their use as anti-slump-type-settlement measures (with simultaneous use of the underground space) under soil conditions classed as type II in terms of proneness to slump-type settlement.

The excavation of soil for the installation of deep multistory basements in constructing buildings on soils prone to slump-type settlement contributes to a reduction in slump-settlement deformations in soils classed as type II in terms of proneness to slump-type settlement and ensure the following:

1) a reduction in the stratum prone to slump-type settlement due to its being “cut-through” by a basement;
2) a pressure reduction due to the soil’s own weight as a result of the excavation of soil for a basement in the portion of the stratum prone to slump-type settlement that has not “been cut-through;”
3) an increase in the depth from which slump-type settlement of the soil will occur under its own weight;
4) a sharp reduction or complete lack of slump-type settlement of soils under their own weight (as a function of the depth and width of the basement, the thickness $H_{sl}$ of the stratum prone to slump-type settlement, the pattern of distribution of relative proneness to slump-type settlement with depth, etc.); and,
5) a reduction in negative-friction forces on foundations, for example, pile foundations subject to slump-type settlement.

Research [1-5] on the influence exerted by excavations on slump-type settlement applies to comparatively narrow excavations with a width of up to 7-8 m, which conform to sources of wetting in terms of dimensions.

According to Krutov [2], the slump-type settlement of a soil under its own weight with a rise in the water table was reduced from 13 to 5.5 cm during the installation of a basement 6.5-m deep at a project in Zaporozh'ye.

According to Kovalev [4], slump-type settlement was reduced from 75 to 20 cm when the depth $b_e$ of the source of wetting was increased to 6 m in a stratum prone to slump-type settlement with $H_{sl} = 25-30$ m, and was virtually lacking when $b_e = 8$ m. At the same time, slump-type settlements initiated at $b_e = 1$ m for a constant depth of excavation $b_e = 1.5$ m and an increase in its width $b_e$ (in this case, the width of the wetted area) from 0 to 12 m, and reached a maximum value of 110 cm when $b_e = 8$ m, but increased negligibly with a further increase in $b_e$.

The reduction in slump-type settlements is explained not only by the “through-cut” excavation of a portion of the stratum prone to slump-type settlement and by unloading of the underlying soil, but also by the appearance of the so-called “arch effect,” which is associated with interaction between the wetted mass and the soil surrounding it, the latter having a natural moisture content; here, this effect increases as the width and depth of the excavation decrease and increase, respectively.

The procedure for calculating the influence exerted by the “arch effect” on the reduction in the average vertical stresses under a strip-shape excavation is discussed in [1, 2, 5] in which corresponding differential equations and formulas, as well as some results of the calculations are cited on the basis of familiar premises of the theories of a linearly deformable medium and limiting equilibrium (as applies to soils).

In the general case, the components of the vertical stresses (pressures) of the soil due to its own weight (additional stresses due to an external loading are not considered in this case) when excavating for a deep basement include the following:

Translated from Osnovaniya, Fundamenty i Mekhanika Gruntov, No. 2, pp. 7-9, March-April, 1998.
Fig. 1. For calculation of stresses and slump-type settlements of soils under their own weight beneath excavations, a) schematic stress diagrams: 1) excavation; 2) ground surface; 3-7) $\sigma_{zg}$, $\Delta \sigma_{zg1}$, $\Delta \sigma_{zg2}$, $\Delta \sigma_{zg3}$, and $\sigma_{zg}$ diagrams, respectively; b) plots showing variation in coefficient $\alpha$: 1) $\sigma_{zg}$ diagram; 2-4) $\alpha$ values when $b_e = 5$, 10, and 20 m; c) plots showing relationship between "remaining" slump-type settlements $S_{slg}$ below excavations and their width $b_e$: 1, 2) when $h_e = 5$ and 10 m; 1', 2') slump-type settlement for unrestricted width of excavation.

1) the load-induced stress $\sigma_{zg}$ due to the soil's own weight;  
2) the unloading stress $\Delta \sigma_{zg1}$ due to the excavation, which is uniformly distributed over its width;  
3) the unloading stress $\Delta \sigma_{zg2}$ due to interaction between the wetted mass and the surrounding soil with a natural moisture content for an excavation width equal to the source of soil wetting; and,  
4) the load-induced stress $\Delta \sigma_{zg3}$ due to the effect of the weight of the soil located in the walls of the excavation.

The total stress below the bottom of the excavation is

$$\bar{\sigma}_{zg} = \sigma_{zg} - \Delta \sigma_{zg1} - \Delta \sigma_{zg2} + \Delta \sigma_{zg3}$$ (1)

Schematic diagrams of the stresses below the center of the excavation are presented in Fig. 1a, where the line of symmetry of the excavation is adopted as the axis of ordinates; the diagrams of the load-induced stresses (conventionally “positive”) are located to the left of the axis of ordinates, while the unloading stresses (conventionally “negative”) are located to the right.

The stress due to the weight of the soil itself varies linearly with depth in accordance with the law

$$\sigma_{zg} = \gamma_{sat} z,$$ (2)

where $\gamma_{sat}$ are the layer values of the soil’s specific gravity in the saturated state (for soils prone to slump-type settlement, it is assigned for a degree of saturation $S_e = 0.9$ in kg/cm$^3$, and $z$ is the depth within the limits of the stratum prone to slump-type settlement, as referenced from the grade elevation, in m.

As a “negative” load, unloading stress $\Delta \sigma_{zg1}$, which is uniformly distributed over the width of the excavation at the level of its bottom, is

$$\Delta \sigma_{zg1} = \gamma_{sat} h_e \alpha$$ (3)

where $\alpha < 1$ is the reduction factor of the stresses established for foundations from Table 1 of Appendix 2 to Construction Rule and Regulation 2.02.01-83 [6] as a function of depth $z$; here, $\alpha = 1$ and $\Delta \sigma_{zg1} = \Delta \sigma_{zg1} h_e$ at the bottom of the excavation. Calculation of the other two stress components $\Delta \sigma_{zg2}$ and $\Delta \sigma_{zg3}$ is complex, although possible in principle: for $\Delta \sigma_{zg2}$ – on the basis of the procedure outlined in [1, 2] for calculation of the average vertical stresses $\Delta \sigma_{zgavg}$ in the stratum prone to slump-type settlement when wetted from sources of limited dimensions in plan, and for $\Delta \sigma_{zg3}$ – with use of the “corner-point” method, which is presented in Construction Rule and Regulation 2.02.01-83.