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The Subsidence of Granular Soils Arising from the Combined Effect of Water Absorption and Loading

L'Affaissement de sols granuleux provenant de l'absorption d'eau et du chargement

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SUMMARY

According to the author's earlier tests the subsidence of granular soils due to the effect of capillary water depends on the grain size, compactness, and developing degree of saturation of the soil. Tests described in this paper proved that the subsidence of granular soils—contrary to that of loess—decreases considerably under the effect of a small load. This might serve to explain why unloaded pavings frequently settle to a greater degree than do foundation bodies resting on the same loose soil. The author tries to determine the cause of this phenomenon and presents an example for the computation of the combined value of settlement and subsidence.

SOMMAIRE

D'après ses premiers essais, l'auteur arrive à la conclusion, que l'affaissement des sols granuleux sous l'action de l'eau capillaire dépend du diamètre des grains, de la densité, et du degré de saturation en formation dans le sol. Les essais, présentés dans cet article, démontrent que l'affaissement—contrairement au loess—diminue remarquablement sous l'action d'une petite charge. Ainsi s'explique, qu'une chaussée sans charge s'abaisse souvent dans une plus grande mesure que les fondations posées sur le même sol. L'auteur essaye de déterminer la cause de ce phénomène et présente un exemple pour le calcul de l'abaissement et de l'affaissement.

THE STATISTICAL INVESTIGATION of damaged buildings proves that the damage is caused most frequently by water seeping under the foundations (Rétháti, 1961). Water may cause erosion in the soil, it changes the consistency of cohesive soils, and in loess and loose soils it gives rise to subsidence.

On the base of laboratory tests carried out with dry sand to determine the effect of capillary water absorption, the following could be established.

(1) A decrease of the average grain size of the sand fraction is followed by the increase of the maximal specific subsidence (ζ_{\max}) which is measurable in the loosest state ($e = e_0$). According to tests carried out with cylinders having a diameter of 4 cm and a height of 6 cm, the maximal subsidence of the single fractions was as given hereunder.

D (mm)	ζ_{\max} (per cent)
0.50 — 0.29	2.65
0.29 — 0.217	4.02
0.217 — 0.145	4.77
0.145 — 0.08	5.71

(2) At first, together with a decrease of the void ratio, the subsidence rapidly decreases, eventually taking an almost constant (from the viewpoint of practice, negligible) low value.

(3) In the case of a certain soil an unambiguous laboratory determination of ζ_{\max} is impossible for two reasons. First, e_{\max} and so ζ_{\max} also depend on the geometrical dimensions of the cylinder (ring), chiefly on the ratio between the diameter and the height. E.g., when investigating the fraction, the grain size of which is 0.29 — 0.217 mm, for $D(m) = 0.68$, $e_0 = 0.803$, $\zeta_{\max} = 1.94$ per cent, whereas for $D(m) = 4.95$, $e_0 = 0.709$, $\zeta_{\max} = 1.32$ per cent. Secondly, using a certain ring the value of ζ also depends on the degree of saturation developing in the course of the capillary absorption (Fig. 1), the magnitude of which is determined by the

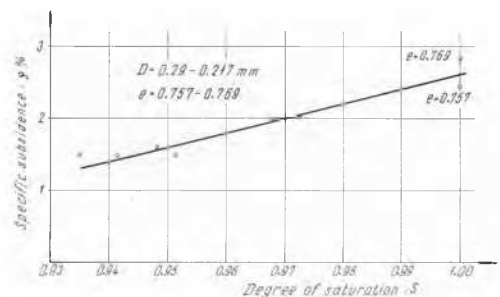


FIG. 1. The specific subsidence as a function of the degree of saturation.

diameter of the covering plate and the uniformity of water absorption.

The investigations made so far referred to an unloaded soil. However, it is well known that the magnitude of the load influences the subsidence of loess to a decisive degree. For $p = 0$, the subsidence of loess practically equals zero; with an increasing load the subsidence gradually increases, in spite of the decrease of the void ratio, and reaches its maximal value—according to observations—at a load of approximately $p = 3.0$ kg/sq.cm.

To investigate this problem the author carried out laboratory tests using an oedometer put together in the usual way. The diameter of the ring was 8.0 cm, its height 2.0 cm, the diameter of the filtering stone covering the sample was 7.5–7.6 cm. The investigated material was a fine sand having a grain size of 0.29–0.217 mm. The sand was placed into the apparatus with different initial void ratio and then subjected to a compression of $p = 0, 0.2, 1.0$, and 2.0 kg/sq.cm. After

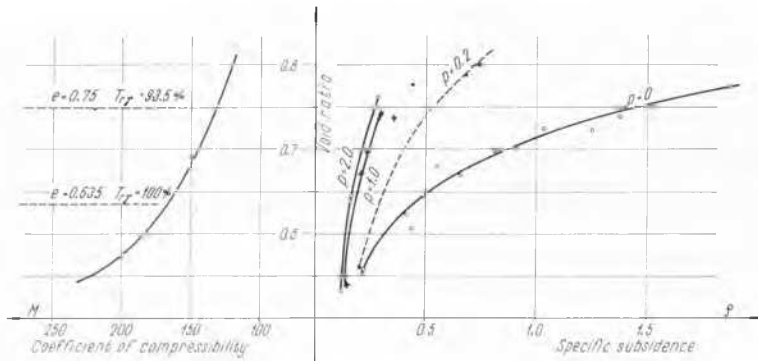


FIG. 2. The specific subsidence as a function of the load and void ratio developing due to the load effect (on the left-hand side the coefficient of compressibility).

the process of consolidation took place the sample soaked water from below. The specific subsidence can be computed from the following formula:

$$\zeta = [\Delta e / (1 + e')] \times 100$$

where Δe is the decrease of the void ratio due to the effect of water absorption, and e' is the void ratio which developed due to the effect of the load p .

Choosing the load p as parameter, the curves $\zeta = f(e'; p = \text{const})$ can be plotted (Fig. 2). The measurements proved, without doubt, that in the case of one and the same void ratio the subsidence of a loaded soil is smaller than that of an unloaded one. The two corresponding subsidence values differ from each other to a considerable degree chiefly in the case of a soil in the loose state. A significant decrease of the subsidence is already due to the effect of a load of 0.2 kg/sq.cm. observable, the equivalent of the weight of a 1.0–1.2-m thick layer of soil. In a case where the investigated sand fraction is in the loose state the decrease was in the order of 40–60 per cent. The relation $\zeta = f(p)$ pertaining to the void ratio $e = 0.75$ is shown in Fig. 3.

An example for the approximate computation of a subsi-

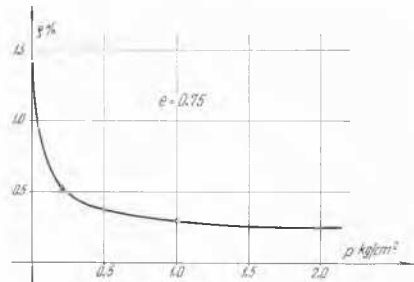


FIG. 3. The specific subsidence of the investigated sand caused by the effect of different loads and subsequent water absorption.

dence taking place owing to the combined effect of a static loading and subsidence is presented in Fig. 4. An 0.8-m broad strip foundation subjected to a load of 2 kg/sq.cm. is assumed to rest on a 2.4-m thick, dry sand fill consisting of the same sand which was used for the aforementioned tests,

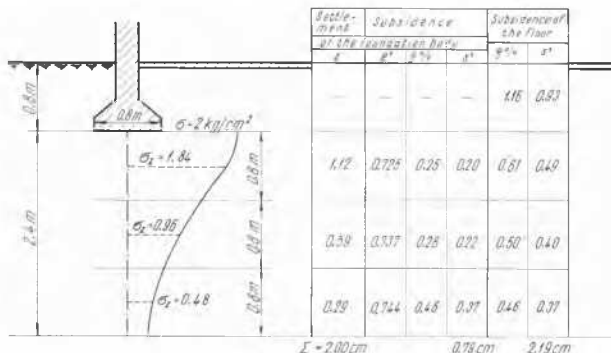


FIG. 4. Numerical example for the computation of the settlement occurring due to the simultaneous effect of loading and water absorption.

i.e., it has a grain size of $D = 0.217\text{--}0.29$ mm. The void ratio is $e = 0.75$ ($T_{1\gamma} = 93.5$ per cent. The settlement of the foundation, taking place owing to the combined effect of the load and an occasional subsidence, as well as the settlement of the paving occurring due to the subsidence, have to be determined. The computation can be performed with the aid of Fig. 2. Owing to the effect of vertical stresses arising in the centre lines of the individual lamellae the original void ratio $e = 0.75$ decreases to e' . The latter can be computed with the aid of the coefficient of compressibility, which can be read from the diagram on the left-hand side of the figure for $e = 0.75$. The specific subsidence pertaining to the value of e' and the corresponding stress $\sigma_x (=p)$ can be determined from the system of coordinates to be found on the right-hand side of the figure. The settlement sought for is:

$$s = 80 \sum_{i=1}^n \left[\frac{0.75 - e'_i}{1.75} + \frac{\xi_i}{100} \right],$$

while the settlement of the paving is

$$s = 80 \sum_{i=1}^4 \frac{\xi_i}{100}.$$

When computing the *subsidence* of the soil mass lying below the paving, stresses due to its own weight and falling to the share of the centre lines of the individual lamellae should also be taken into consideration. However, it might be mentioned that the settlement taking place owing to the effect of the latter is generally negligible.

According to computations the subsidence of the unloaded paving occurring due to water absorption is 2.5 times that of the foundation body, and 1.1 times the settlement of the foundation body caused by the effect of a stress of $p = 2.0$ kg/sq.cm. In the case of a subsidence the value of which approaches the values given in the beginning of this paper, the situation is far graver. It should be mentioned that with regard to actual conditions, the occurrence of such a situation might be expected at any time (compare with Fig. 1).

CONCLUSIONS

Dry granular soils subjected to the combined effect of loading and capillary water absorption behave in exactly the opposite way to loess. This means that if subjected to an increasing load their specific subsidence rapidly decreases. The different behaviour of these two soils might be explained as follows. The subsidence of loess is caused by its special physical and chemical properties, whereas that of granular soils is a phenomenon related merely to physical and mechanical structure. In the latter case the increase of the load results in an increase of forces pressing the grains together; consequently the resistance against the displacement of a grain also grows. Beyond a certain load each pair of grains becomes subjected to stress such that even the maximal capillary force developing in the smallest capillary vessels is not able to move them from each other. This is also proved by Fig. 2: the increase of the load is followed by only a slight decrease of the subsidence, while diagrams characterizing the relation (e, ξ) proceed towards the vertical position. This means that independently of the looseness of the accumulation of grains only a motion having an "accidental character" could be effective.

The tests in question also give information on the problem of the frequency of considerable subsidences occurring under unloaded or lightly loaded structures (pavings, partitions). The specific subsidence should be considered of decisive importance when designing the compactness of fills. In the case of tests related to this subject it should be noted that the specific subsidence depends on the void ratio and the developing degree of saturation, but the maximal specific subsidence depends on the dimensions of the ring as well.

REFERENCES

- RÉTHÁTI, L. (1961). Behaviour of buildings founded on embankments. *Proc. Fifth International Conference on Soil Mechanics and Foundation Engineering*, Vol. 1.
 — (1963). Die Sackung von rolligen Böden infolge der Aufnahme von Kapillarwasser. Europäische Baugrundtagung (Wiesbaden).