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The Compressibility of Loess Soils

La Compressibilité des loess

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SUMMARY

On the basis of a great number of results obtained by various methods, the author concludes that the structure of macroporous loess soils is disturbed in the course of sampling and preparation in the laboratory. It may be supposed that the deformation and strength characteristics of loess soils when determined in the laboratory cannot represent, even approximately, the true properties of the soil.

SOMMAIRE

En se basant sur de nombreux résultats obtenus à l'aide de différentes méthodes, l'auteur conclut que la structure des loess macroporeux se détériore au cours de l'échantillonnage et de la préparation en laboratoire. Il semble que les caractéristiques de déformation et de résistance des loess, déterminées en laboratoire, ne représentent pas, même approximativement, les propriétés naturelles des sols.

THE LITERATURE OFTEN REPORTS considerable deviation between calculated and actually measured settlements. Such deviations may have several causes. Some authors believe that differences between loads rated for static computations and those actually existing are responsible for the deviations; others object to the methods of computation, while others consider that the data of soil physics used as a basis for the computations is not reliable enough. Computations are generally derived from the compression curve of the soil or, occasionally, of the coefficient of compressibility. Several authors have been engaged in determining the sources of error in confined compression tests, including the void between sample and oedometer, the inequalities of load on the compressed surfaces of the sample, friction between ring and sample, even the unfavourable geometrical proportions of the soil sample.

It has been repeatedly stated that the oedometer test lends itself well to the examination of soft and saturated soils, but is not suitable for study of laminated, shaly, or hard soils. No doubt has been raised up to the present, however, as to its applicability for loess soils. For the experimental determination of the compressibility of these soils, confined compression tests are generally used. The oedometer test is also applied, with an implied acceptance of the reliability of compression tests, in investigations into the important problem of the subsidence of loess soils. In this paper, experience gained during preliminary work and the results of settlement measurements taken on a large loess area in Hungary are discussed.

THE INDICES OF THE COMPRESSIBILITY OF SOILS

In order to make the comparison of results simpler, only the coefficients of compressibility deduced from full compression curves are used. The coefficient of compressibility is expressed by the inclination of the tangent corresponding to the original depth of the sample. There is no doubt that this method results in an increase in the modulus of compressibility as a function of depth. This assumption is by no means contradictory to empirical facts or to general opinion, however. Some authors prefer to consider the chord of the compression curve, determined in one of several ways, more authoritative than its tangent. We will not go any deeper into this problem, since the differences are comparatively small, and, as will be demonstrated, are completely insignificant from the viewpoint of the final results.

Compression moduli determined in the above way are compared with Young's moduli gained from the deformation curves of unconfined compression tests as well as with the results of comparatively large-scale field-loading tests.

TEST DATA AND RESULTS

The area examined consists of a comparatively thick and extensive non–pre-loaded homogenous loess layer created by uniform conditions and of uniform geological history. In our comparative investigations only samples with plasticity

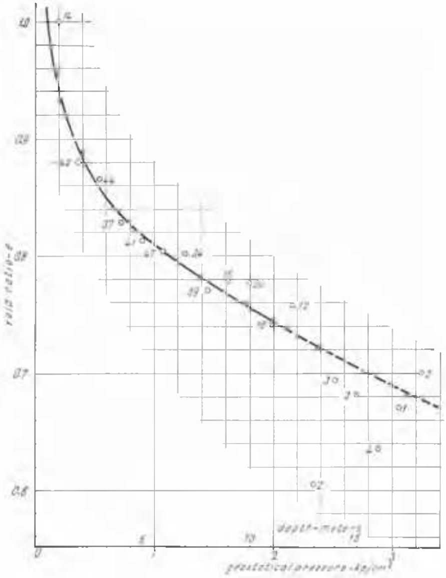

FIG. 1. Relation between the average initial void ratio of the natural soil samples and depth.

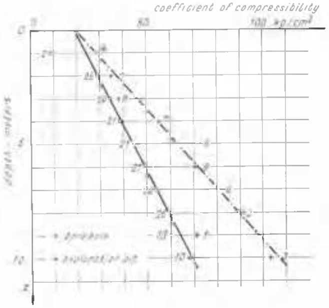

FIG. 2. Relation between the average values of the coefficient of compressibility and depth.

indices between 5 and 12 per cent were used. The examinations were routine tests carefully conducted under general laboratory conditions, but without scholarly precision. At the time of the soil exploration groundwater was 10 metres below the surface. Fig. 1 illustrates the relation between the average initial void ratio of the natural soil samples and depth. Figures near the points represent the number of data averaged. Fig. 1 supports the assumption that in its natural state the soil is in a compressed condition, since a weighted average line drawn by estimation through the points is practically identical with the usual compression curves.

Fig. 2 illustrates the relation between the average values of the coefficient of compressibility and depth. The coefficients were measured on samples in a natural state taken from boreholes and exploration pits. Figures near the points indicate the number of data averaged. The two straight lines were drawn on the basis of the coefficients computed by the method of minimium squares. There is a significant and unequivocal deviation between the two. It is noteworthy that the deviation increases as a function of depth. This may indicate an increase in disturbance with greater depth of drilling and sampling.

Fig. 3 demonstrates the relation between the initial void ratios of samples and depth. Samples were in a natural state as taken from boreholes and exploration pits. A deviation between the results is conspicuous in this case also, but is not great enough to explain the deviations found in Fig. 2. In Fig. 3 the relationships between the degree of saturation and the depth are also shown.

Fig. 4 demonstrates the averages of the various elasticity indices of samples taken from exploration pits as a function of depth. The figures near the points show the number of data averaged. The continuous line represents the coefficient of compressibility determined from the compression curve. The dotted line is the initial tangent of the deformation curve of the unconfined compression test. The broken line shows the depth changes of the elasticity modulus computed from the inclination of the chord of the hysteresis loops determined before the 2 per cent deformation. It should be noted that samples taken from the pits were

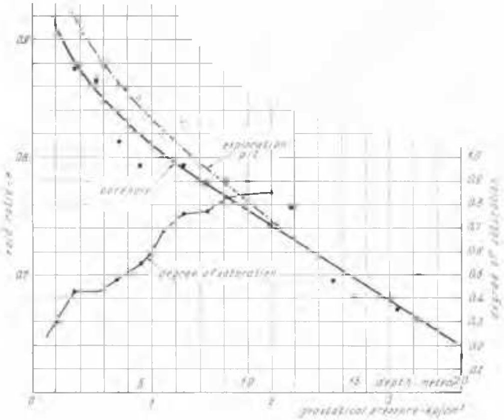

FIG. 3. Relation between the initial void ratios of samples taken from boreholes and exploration pits and depth.

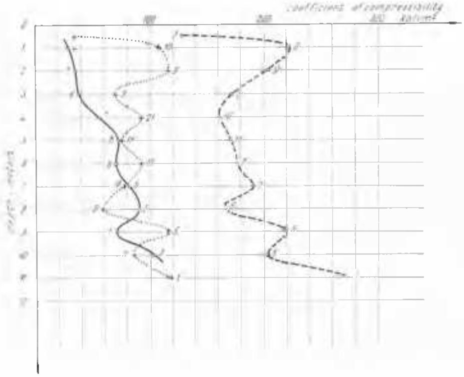

FIG. 4. Various elasticity indices of samples taken from exploration pits as a function of depth.

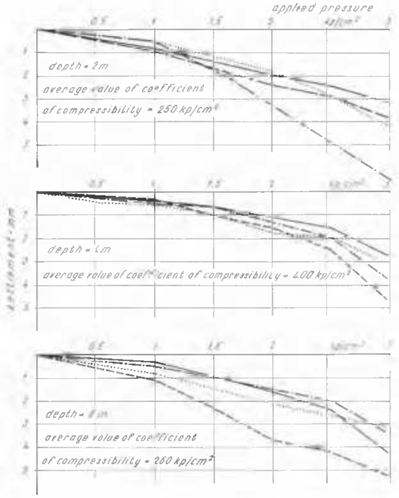

FIG. 5. Results of loading tests made, with load discs 29.5 cm in diameter.

large and permitted both confined and unconfined compression tests to be carried out on material from the same sample.

Fig. 5 shows the results of loading tests made in four different exploration pits with load discs 29.5 cm in diameter, at various depths. The same figure shows the averages of compression moduli computed from test loading results. They were determined by computation methods (Tsytovich, 1951) from the formula

$$K = (\Delta\sigma/\Delta y) \cdot A \cdot \omega \cdot B$$

where $\Delta\sigma$ and Δy are the differences of stresses and settlements, respectively, between the initial and final points of the settlement curves.

Fig. 6 shows the results of loading tests made in the pit at two different depths with a rigid loading sheet of 5,000 sq.cm. (71 × 71) surface area. It also shows the average of the compression moduli computed in the manner detailed earlier. The settlement of buildings erected on the territory mentioned had been regularly measured during a longer period of time. The results of these measurements and their evaluation are given by Egri and Réthati (1959–1960). Fig. 7 has been prepared on the basis of the data of these two authors. It shows the occurrence frequency of calculated/measured settlement ratios on the basis of a total of 105 data. The unweighted arithmetical average of the ratios is 4.49.

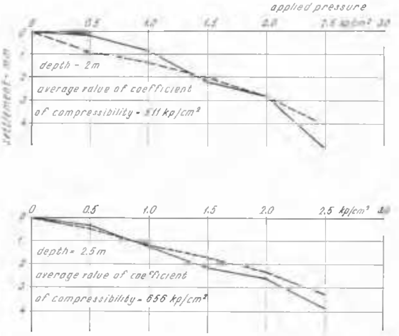

FIG. 6. Results of loading tests made in pit with a rigid loading sheet of 71 × 71 = 5,000 sq.cm.

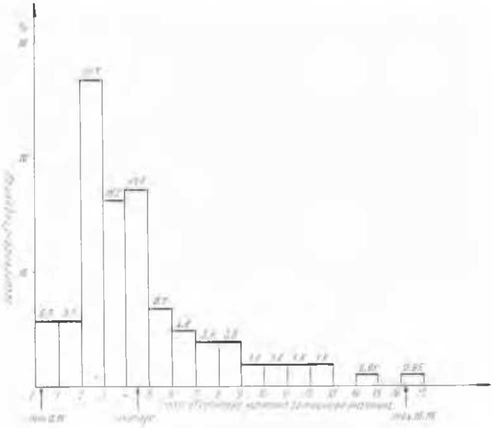

FIG. 7. Occurrence frequency of calculated/measured settlement ratios.

CONCLUSIONS

1. Average compression moduli computed from loading tests executed in boreholes at depths from 2 to 6 m are between 250 and 400 kg/sq.cm. Loading tests made with rigid discs with an 0.5 sq.m. surface area gave an average of about 550 kg/sq.cm. It is remarkable that under loading sheets of larger dimensions the values of the compression moduli were higher. From experiments made in the laboratory on samples from the same depths, compression moduli of 35 to 60 kg/sq.cm. could be expected. The difference between the compression moduli determined by the two methods is considerable. It may not be chance, however, that this difference shows good agreement with the average of the quotient of calculated and measured settlements.

2. The results summarized in Fig. 4 are in contradiction to the basic principles of elementary elasticity. Reasonable explanations for this and for the statements made in the preceding paragraph can only be found if we suppose that the soil sample in the oedometer is not under confined compression stress. As a consequence of comparatively large voids in loess soils the lateral bracing supposed completely rigid is inefficient at the beginning, until the large voids have not fully collapsed, since lateral stresses are not able to decrease the vertical deformation to a significant extent due to the possibility of these voids closing. Consequently, the loess sample in the oedometer is, at the beginning, almost entirely in a state of unconfined compression. This is complicated by the disturbing effect exercised upon the sample during the course of sampling and placement in the oedometer ring.

3. In the usual course of core sampling, the loess is subjected to comparatively rude mechanical effects. These effects may result in changes (fissures) in the structure of the loess which are not indicated by significant changes in the void ratio although they have affected most of the strength of the soil. Such a deteriorated loess sample could be best compared to a cracked egg shell; it seems intact, it shows no loss in volume but it is barely able to resist pressure.

4. That which we examine under laboratory conditions cannot represent the actual physical properties of the soil. It is not only soil but it is also a product of soil sampling whose properties show significant differences from the original, undisturbed soil.

5. It is natural to suppose, that such effects have a significant influence (giving a conservative but uneconomical answer) upon the results of subsidence and shear strength examinations.

6. Laboratory tests made on samples taken from boreholes have not too much significance in practice, since, as proved by Figs. 2 and 3, the disturbing effect will only be increased in the course of drilling.

7. Consequently, in the examination of the strength properties of loess soils it is best to use methods which do not require sampling.

REFERENCES

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Tsytovich, N. A. (1961). *Mehanika gruntov*. Moscow.