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DEFORMATION-STRENGTH-DENSITY

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Abstract

Over sixty triaxial tests were carried out on samples of the same lateritic soil at previously set moisture contents, densities and side pressures. Test results allowed to draw conclusion about the influence of these variables on the continuous alteration of strength and deformation, correlated by internal strength parameters φ and c.

Most important indication of the results says that it is a bold habit in the design procedure to take arbitrary values for φ and c, because these are strongly bound to each other and depend simultaneously on the conditions determined by all three variables.

Inserted two figures are fully explanatory.

Keywords: internal strength parameters φ and c, design values for foundation and earth stability, laterite.

Homage to Professor Dr. Jáky

The honourable professor insisted on being informed — at eight o'clock sharp every morning — by the assistants about the ongoing events in tuition, research and engineering design in his domain, to set forth the aim, to supervise the progress, and to evaluate the course of issues. One of my tasks was to find some close correlations between the terms in the title above and to carry out relevant experiments in the interest to shed light on, presumably, still hidden relations.

Fate has deprived me from enjoying the professor's valuable guidance, but the assigned task took a continuous priority in my mind.

Herewith, I would like to render report about a partial result of a later (1971) accomplished experiment in the wake of the given commission.

1. The Experiment

The same lateritic soil (w_L 38.8%, $Wp = 19.0\%, \rho_S = 2.65$ gr/cm^3) was used to produce samples (dia: 3.8 cm, height: 8.9 cm), in split samplers, for triaxial tests.

Water was added in precalculated quantities to the dried and pulverized soil and then tamped with different efforts to gain — despite the predetermined five moisture contents — unique dry densities of $\rho = 1.68$ and $\rho = 1.85$ gr/cm^3 for the five samples at each density level.

Average results of two tested specimens were included in the oncoming evaluation (if deviation seemed tolerable: less than 1/2 pc in moisture content, or 1 pc in dry density).

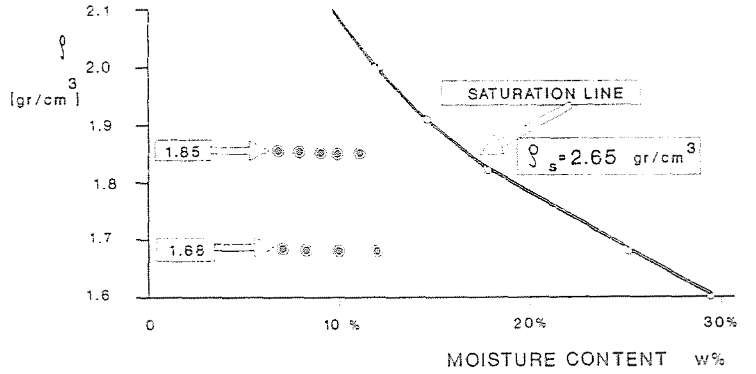

Fig. 1. Condition of samples

Side pressures of a $\sigma_2 = 0$, 70 and 140 kN/m^2 were aimed for the tests. So, 2×5 samples by moisture contents, multiplied by two for the densities and by three for the side pressures, all together over 60 samples had to be prepared and tests performed in sequence.

The samples were placed in a desiccator and the first test took place beyond an hour lapse.

Vertical pressure was applied through a piston in continuous movement of 0.125 cm/min. Side pressure was tried to be maintained by means of an air barrel, on the nominal level. The process was controlled by help of a proving ring, a dial indicator and a stress gauge.

Reading time was registered in 5 to 12 sec intervals. Measured data permitted to plot the deformation curves as well.

2. Testing Results

There was need to carry out some minute corrections on the test results, due to errors in sample preparation, faulty coincidence of readings and technical deficiencies, but this intervention has by no means faded away the characteristic trend which could be derived from the process.

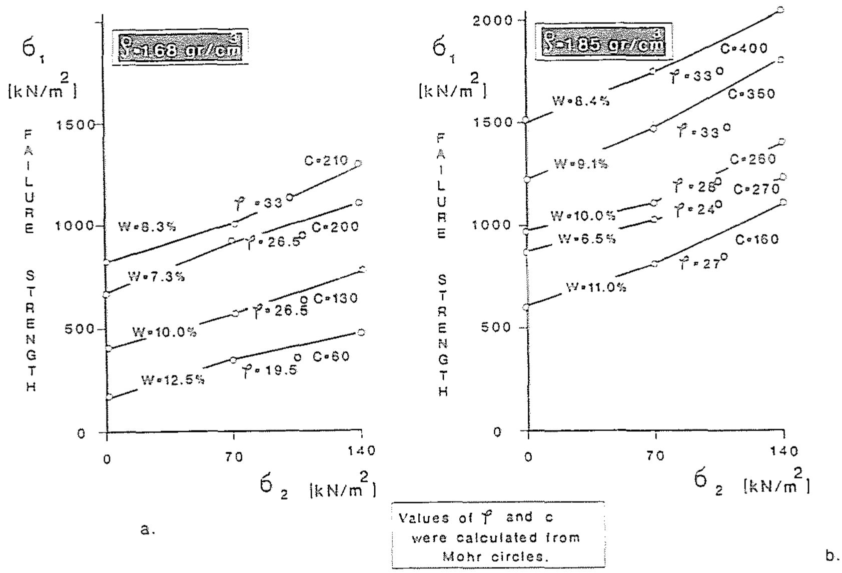

Fig. 2a.–2b. Crushing values

Figs. 2a and *2b* reveal the values of ultimate (failure) stresses and the pertinent strength parameters which were calculated on the basis of the relevant Mohr circles. *Figs. 3a* and *3b* represent the set of deflection curves plotted against the selected side pressures, moisture contents and densities.

3. Considerations

It can be envisaged at the first gliance in the diagrams that any change in circumstances and/or in condition in order magnitude evokes a substantial and characteristic difference as regards the behaviour of the soil. The figures call the attention to the fact, that the trend of deformation depends substantially on the simultaneous values of density, moisture content and side pressure. It deserves to mention the following findings:

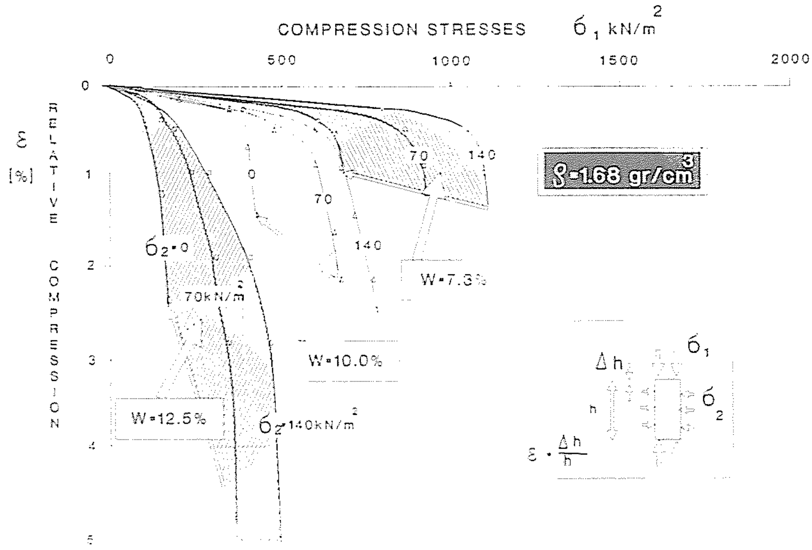

Fig. 3a. Deformation curves

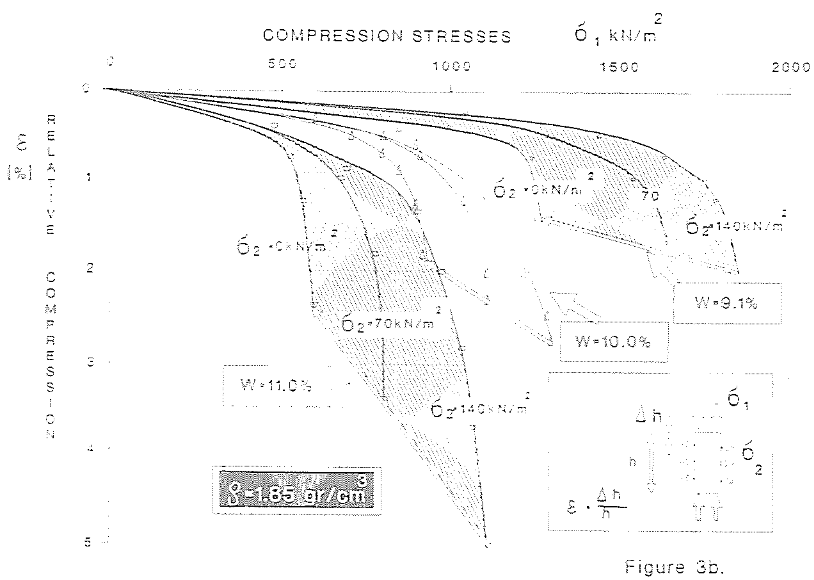

Fig. 3b. Deformation curves

a) Examination of ultimate (failure) values of the samples prepared on the wetting leg — in contrast to drying — shows that first a moisture condition has to be achieved (which is independent from density and side pressure), but at which the maximal ultimate value ensues. This value though in the same moisture range — is higher at more elevated densities.
b) At elevated densities the soil is more sensitive to increasing moisture content than at lower densities.
c) The same soil loses its strength at a brittle failure when its moisture content is low (Hook's straight line), but attains a plastic failure when the moisture content is high.
This particular behaviour is therefore not a characteristic property of 'certain' soils — as it was often described, but is an inherent feature of all soils, in dependence of their condition.
d) Exposed to the effect of sequential increments of side pressures, the deformation curves take the shape of a set of curves: the value of ultimate failure increases proportionalliy with side pressure and ensues at a higher degree of deformation.
e) Different side pressures would not alter the values of strength parameters (φ and c) if the moisture content and the density remained the same.

4. Conclusions

Paying attention to the before mentioned findings, the following conclusions can be derived:

f) Strength parameters (φ and c) must not be taken as indicators to describe a particular soil or soil type, because these values depend on the condition in a given soil.
g) If the density of a soil remains constant and the side pressure is altered, the values of φ and c remain also constant and may undergo a change only when the moisture content also altesed simultaneously.
Even then the values of the two parameters remain in a close and regulated correlation to each other and one may not take an arbitrarily guessed value that is independent from the other. An obvious explanation for this statement can be given by the fact that at any side pressure only a single Mohr circle can be drawn tangentially to the enveloping straight line (Coulomb's) which is bound by both parameters.
It is therefore not a good habit to pick out unrelated φ and c values for the design from 'tables' or as 'guessed soil properties', i.e. to await

some alien property from the soil for which it is not fit and is not able to produce under otherwise bound conditions.

h) It is also a bold habit to assume the alliowable strength of a soil to the half or the third of the failure strength, because by using this practice, no account is given to actually developing deformation, what may influence the design procedure in either direction.

i) Really low φ and c values can be met only at very low densities and/or at very high moisture contents: even as the corresponding value-pairs have to be applied in the design. If such conditions are apparently not prevailing in the soil (in accordance with the boring logs), it should be scrutinized whether the soil would be able to take up so much moisture under the given stratification as to swell up and lose density to give way for the occurrence of such a phenomenon?

5. Design Procedure

The importance of the before mentioned findings will gain emphasis when we try to incorporate the testing results in the frame of a technical design procedure.

Either proclaimed or hidden but the dominant guid-eline in every engineering structural design is the wish to protect the designed facility against any unwanted *deformation.*

This ambition will be expressed in soil mechanics by recommending certain soil *strength*, based on the calculated bearing capacity of the soil. As it is well known strength increases — with the exception of very wet soils – when *density* is enhanced and so, it is customary to demand high compaction levels where it is amenable (by earthwork, for example).[1] Safety factors are then applied to eliminate the influence of unforeseen uncertainties and to modify (or adjust) calculated or acquired results toward the desired range.

It can be stated therefore that the purpose of a structural design procedure is to prevent deformations, and strength parameters are used — with the inclusion of density requirements — as a means to achieve this goal.

Anticipated settlement (or deformation) of a facility is mostly assumed from the evaluation of a confined compression test in the oedometer on the basis of calculated allowable stresses.

[1] This has a backside effect, however, since a densely compacted soil mass becomes more sensitive in respect of deformation when moisture uptake occurs.

This testing method gives, however, no indication about the correlation between the real bearing capacity and the pertinent deformation line, which are of importance, as it has been demonstrated in the foregoing text.

Consequently, this important aspect remains hidden in the design process. Additionally, the wide range from which the values of strength parameters (with the inclusion of various 'moduli') can be selected, opens the way to neglect significant reserves in the soil, which on the other hand, may lead to uneconomically designed structures.

It would be wise therefore if for the design of demanding facilities as well as in all esteemed soil mechanical reports a paragraph were be reserved for the thoughts inspired by the above described considerations.