Dynamic Triaxial Tests of Compacted Unsaturated Soils

Essais triaxiaux dynamiques de sols compactés et non saturés

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SUMMARY

The author presents results of dynamic triaxial tests carried out on compacted unsaturated soils. Behaviour under hydrostatic pulses and under deviator stresses was studied. Volumetric strains are practically unaffected by the frequency of applied pulses. Deviator strains, for loads applied during the same time, increase significantly with the frequency of applied deviator stresses.

SOMMAIRE

On présente des résultats d'essais triaxiaux dynamiques de sols compactés et non saturés. On a étudié le comportement d'échantillons soumis à des contraintes hydrostatiques et à des contraintes variables. Les déformations volumétriques ne dépendent pratiquement pas de la fréquence des forces appliquées. Au contraire, les déformations augmentent très sensiblement avec la fréquence des contraintes variables.

THE TEST RESULTS PRESENTED in this paper form part of a basic study underway at Laboratório Nacional de Engenharia Civil. This study is concerned with the dynamic behaviour of soils under vibratory loads, in the frequency range of interest for seismic studies, i.e., from 0.5 Hz to 5 Hz (1 Hz = 1 cycle per second). These studies started with alluvial undisturbed soils (Folque and Esteves, 1961) and then were extended to cover other kinds of undisturbed soils and also compacted soils, in connection with studies of earth dams.

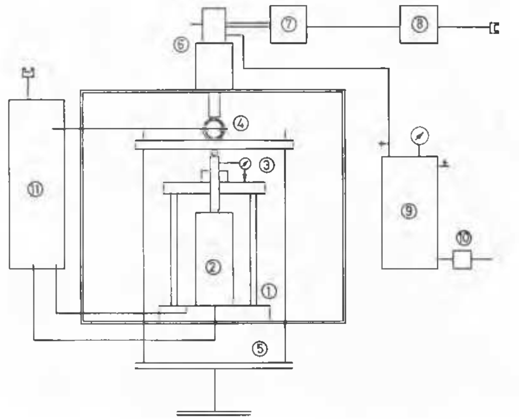

FIG. 1. Outline of equipment for deviator stress tests. 1, triaxial cell; 2, sample; 3, dial gauge; 4, dynamometer; 5, yoke; 6, air jack; 7, electric motor; 8, speed regulator; 9, air tank; 10, pressure regulator; 11, multi-channel oscillograph.

The tests reported herein were performed on a residual clayey soil with the following index properties. Atterberg limits: liquid limit, 42 per cent; plastic limit, 20 per cent. Grain-size distribution: silt, 60 per cent; clay, 15 per cent. The samples were compacted according to the standard Proctor compaction procedure. The moisture content adopted was 2 per cent below the optimum. The degree of saturation was about 85 per cent.

EQUIPMENT

The aim of the tests was to study independently the behaviour of the samples under hydrostatic pulses ($\sigma_1 = \sigma_2 = \sigma_3$) and under deviator stresses. Fig. 1 shows an outline of the equipment used in the latter tests. By means of a rotating valve (Fig. 2) an air jack is alternately connected with a compressed air tank and with the atmosphere (escape). The rotating valve is operated by a variable-speed electrical motor.

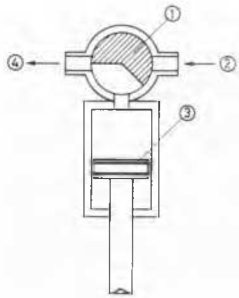

FIG. 2. Air jack. 1, rotating valve; 2, compressed air; 3, piston; 4, opening to atmosphere.

Applied forces were measured by means of a rigid dynamometer with electrical strain gauges whose readings were recorded in a multi-channel oscillograph. The same oscillograph also recorded the readings of two pressure transducers in order to measure pore pressures developed inside the sample. One pressure transducer was connected with the triaxial cell and the other with the bottom porous plate. Fig. 3 shows a general view of the equipment. In the hydrostatic pressure tests the rotating valve was directly connected with the triaxial cell (Fig. 4) instead of with the air jack.

FIG. 3. General view of equipment for deviator stress tests.

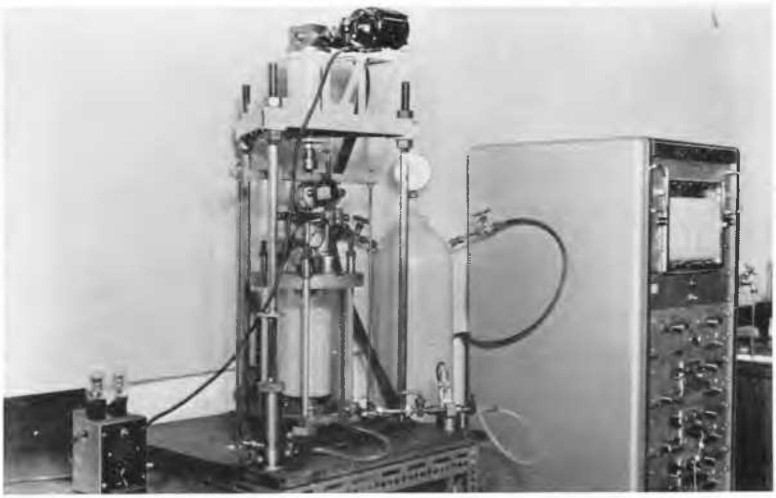

FIG. 4. General view of equipment for hydrostatic stress tests.

RESULTS OBTAINED

The behaviour of samples under hydrostatic pulses was studied by means of tests during which the samples were subjected to a hydrostatic pressure increasing in increments. Measurements were taken of the volumetric strain, ϵ_v, and pore pressure, u, developed in each sample. Water drainage from the samples was prevented. The time elapsed during each load increment was one minute. Static tests were also performed in which the load remained applied for one minute during each increment.

Volumetric deformation of these soils is very small as can be seen in Fig. 5 which shows test results plotted in terms of effective stress, $\sigma - u$, *versus* ϵ_v. The scatter of the results is evident but it seems that it can be concluded that the behaviour of these soils is not very much affected by the frequency of pulses. The scatter of all results is practically of the same order of magnitude as that for the static tests alone; and for all the tests, minor variations in the moisture content or in the degree of compaction, which always occur in actual fills, affected the behaviour much more than the frequency of applied forces.

The effect of deviator stresses was studied by means of tests during which the samples were subjected to increasing increments of deviator stress. Measurements were taken of deviator strains, ϵ_0, and pore pressure developed in the samples. Water drainage was prevented. The time elapsed during each load increment was one minute. The frequency parameter ranged between 0.5 Hz and 5 Hz. Static tests were also carried out. Fig. 6 shows the results obtained in terms of effective stress for $\epsilon_0 = 1$ per cent. Results are plotted in terms of deviator stress *versus* mean stress. The behaviour of samples under dynamic deviator stress is strongly affected by the frequency of pulses, as can be seen in Fig. 6. For loads applied during the same time and for the same deviator strain and mean stress, the deviator stress decreases when frequency increases.

In rheological terms these facts suggest that plastic elements (St. Venant elements) play an important role in structural behaviour (Folque, 1961) being responsible for irreversible strains which increase with the number of applied pulses.

REFERENCES

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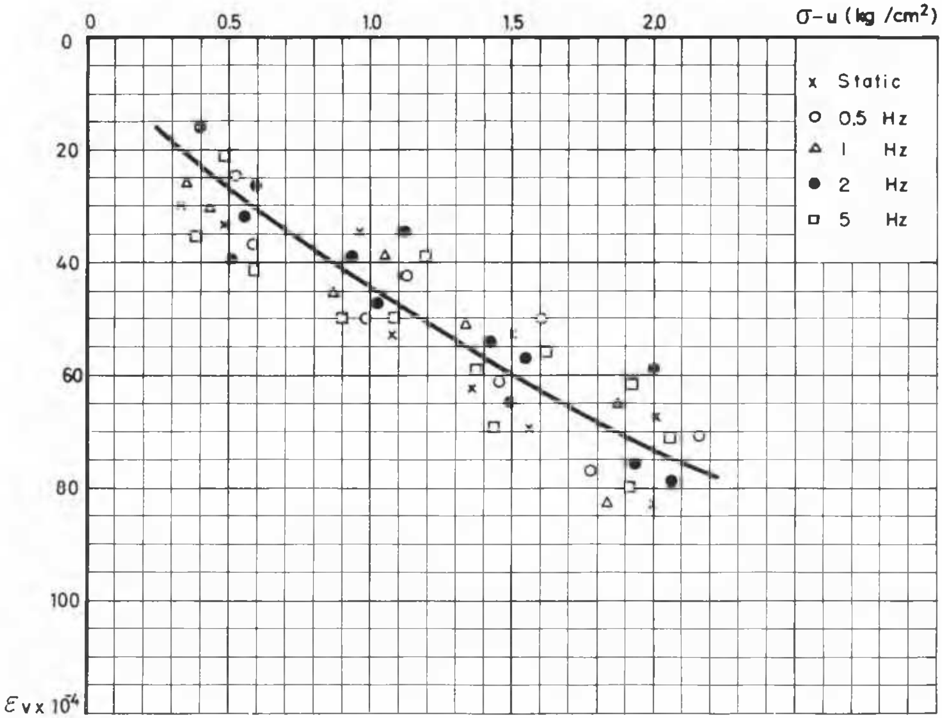

FIG. 5. Volumetric strain *versus* effective mean stress.

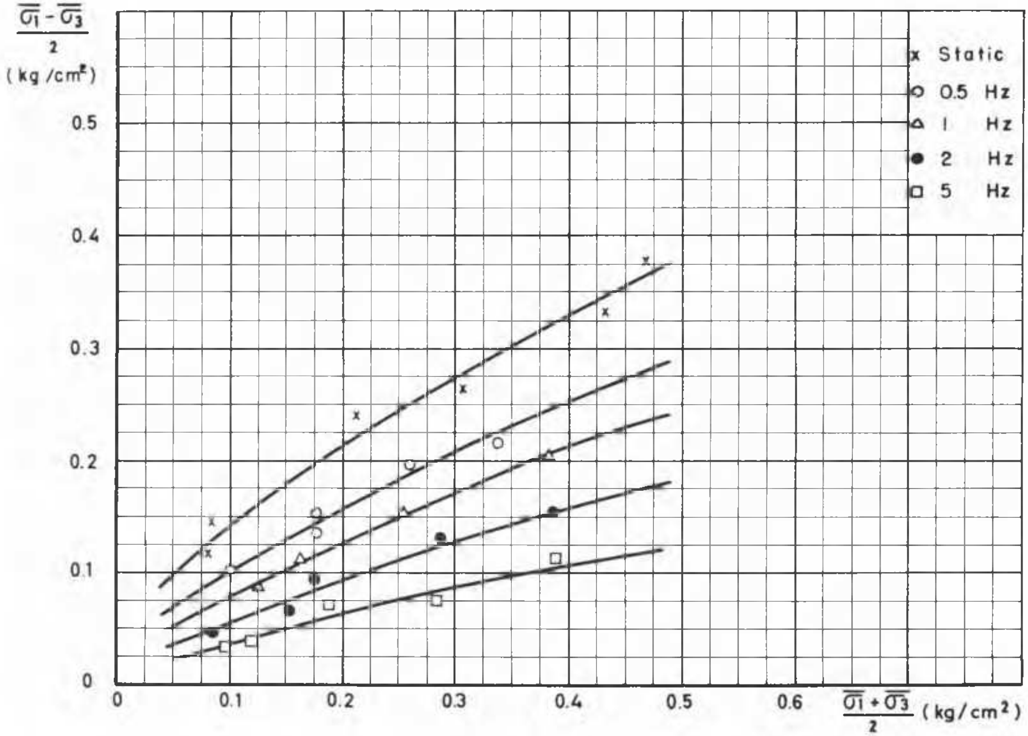

FIG. 6. Deviator stress *versus* effective mean stress for $\epsilon_0 = 1$ per cent.