Tensile Behaviour of Compacted Clays by Field Test

Essais de Fissuration "In Situ" des Sols Compactés

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SUMMARY A field test for the investigation of the deformability conditions of a compacted soil under a tensile stress field is presented. It overcomes the inconvenients of laboratory tests. It is very interesting in order to study the appearance of cracks in earth or earth-rock dams, very frequently observed near the crest.

1. INTRODUCTION

The strenght and the deformability of saturatud or unsaturad soils under a tensile stress field, is a very interesting problem, in relation with some earth works. The cracking of high earth embankments and specially the cracking of earth or rock-fill dams with clay core, is a problem which calls the attention of the design and construction civil engineer.

The investigation of such soil characteristics is made - normally in a laboratory scale. The direct tensile test (Tschebotarioff, 1953), the deflection beam test (Ajaz and Parry, 1975), the point-load test (Fang and Chen, 1971), the Brazilian test (Gopala and Einsenstein, 1974), are - the most commonly employed methods. These test are - very usefull for establishing the influence of several parameters, like the soil type, the density and moisture content of the soil, etc., but they present some inconvenients when we intend to apply the results to foreseen the behaviour of real earth works. The main reasons, to - the authors opinion, about the differences observed between calculated and observed movements before the cracking, are the following.

a) A great stress and strain gradient across the laboratory sample within very short distances, which has influence on the strenght of tensile zones.

b) In many cases, the laboratory experimentation is carried out on the finest fraction of the core material. The fraction above 3/4" or 1/2" is normally neglected, but its influence can be great on the results, if the percentage is greater than, say, 10 or 15%, depending on the type, of soil or particle size.

c) The structure of the soil in laboratory may be different than the "in situ" core material, due to the different method employed for the compaction.

The large scale investigations is restricted up to now to the analisis and interpretation of the observed cracking in earth embankments. The data obtained are not easily extrapolated to another cases due to the scarce and erratic measurements available in the stress-strain field before failure, or on the real conditions of the soil after the compaction (Leonards and Narain, 1963).

In this report a large scale "in situ" tests is presented. This test allows the investigation of the tensile behaviour of compacted soils, without the limitations above mentioned.

2. TEST DESCRIPTION

One experimental embankment, 8, 5 m wide on its base and 2, 5 m high compacted with the same soil and with the same machinery employed in the real works, is heaved by means of a special flat jack placed transversally across the base (Fig. 1). This jack is composed

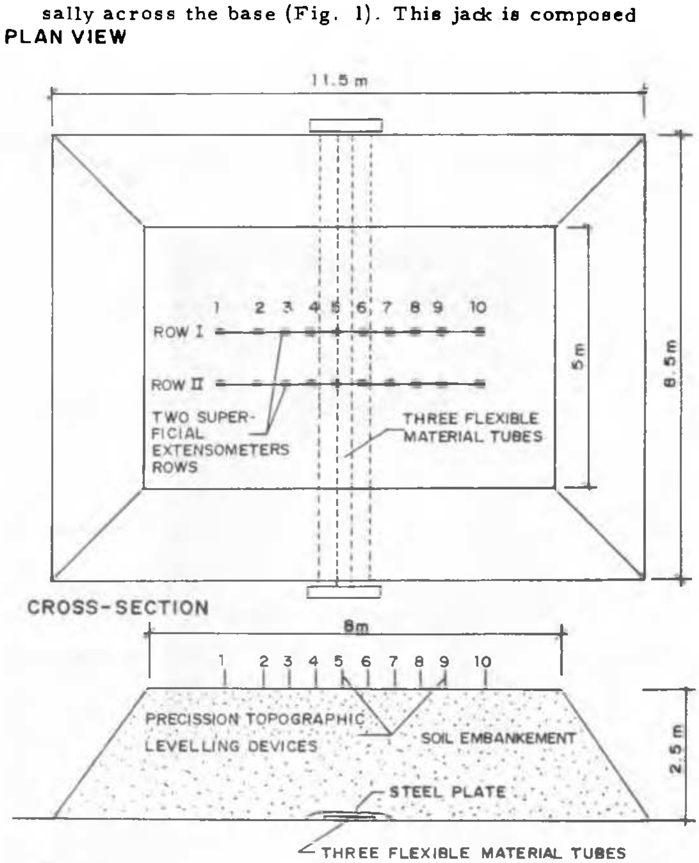

Fig. 1. - Experimental embankment lay out. Flat jack and extensometers situation

2. TEST DESCRIPTION

One experimental embankment, 8, 5 m. wide on its base and 2, 5 m. high, compacted with the same soil and with the same machinery employed in the real works is heaved by means of a special flat jack placed transversally across the base (fig. 1). This jack is composed by three flexible material tubes, 20 cm. diameter when inflated (fig. 2). The three tubes are protected between PVC

Fig. 2. - Hidraulic flat jack composed by three flexible material tubes

plates, and covered by mild steel plates, 3 mm. thick - (fig. 3 and 4). These plates distribute the jack pressure

Fig. 3. - The flat jack covered by PVC. and steel plates

Fig. 4. - Embankment compaction on the flat jack

on the compacted clay embankment fill. The flexible hoses are put under pressure by water. The fill is pushed upwards until the tensile stress induced in the surface produce the cracking of the fill. The first fissure appearence is specially noted and observed.

The horizontal strains are measured between fixed points (fig. 1) by means of pirex rods and extensometer 1/100 mm. precision (fig. 5). The vertical movements are measured by means of levelling devices situated at the same reference points. Two rows of such points, 50 cm. apart, in the central zone of the fill, and 75 cm in the external zone are placed on the upper surface of the embankment (fig. 6)

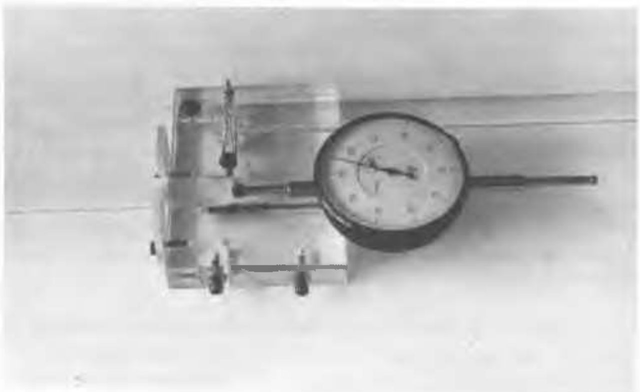

Fig. 5. - Extensometer device. The tensile strain is measured between fixed points, by means of pirex rods

In order to avoid moisture content losses during the preparation and performance of the test, the clay is covered with parafine oil. In addition a thin plaster powder is extended on the measuring zone for a better observation of the appearance of the cracking.

Fig. 6. - Two rows of extensometers for measuring tensile strain in the embankment surface.

3. TEST RESULTS

The first experimental fill was constructed at the Canales dam site, near Granada. It is under construction, - and when completed will be the highest rock fill dam in Spain (150 m.). The clay core is subvertical and thin.

The rock abutments have a slope 1 h: 3v, but the right one has an abrupt change in the upper third of dam height, to 2, 5 h: 1 v. By these reasons the possibility of the - cracking of the crest is investigated by all the available methods.

The clay material, withwhich the core and the experimental fill is constructed, has the following mean characteristics:

Liquid limit 65 %
Plasticity index 40 %
Dry density 1, 65 T/m^2
Moisture content 19 %

This moisture content is about 3 - 4 % below Optimum Proctor.

The fill was compated in layers 30 cm. thick with 6 passes of taper-foot type sheepsfoot roller, as it is the case at the dam site.

In figure 7, the vertical upward displacement of the embankment surface is plotted for different jack pressures, it can be observed the typical dome shape of the fill profile. In figure 8 the strains, either tensile or compressive, between each pair of reference points is plotted against the jack pressure.

The first crack appeared between points 5 and 6 for a - jack pressure of 3, 4 kg/cm^2. At this moment the unit tensile strain between such points was 0, 24%. The maximum vertical displacement of the surface was about 19, 2 m (point nº 7).

For a better interpretation of the test, it was analized by

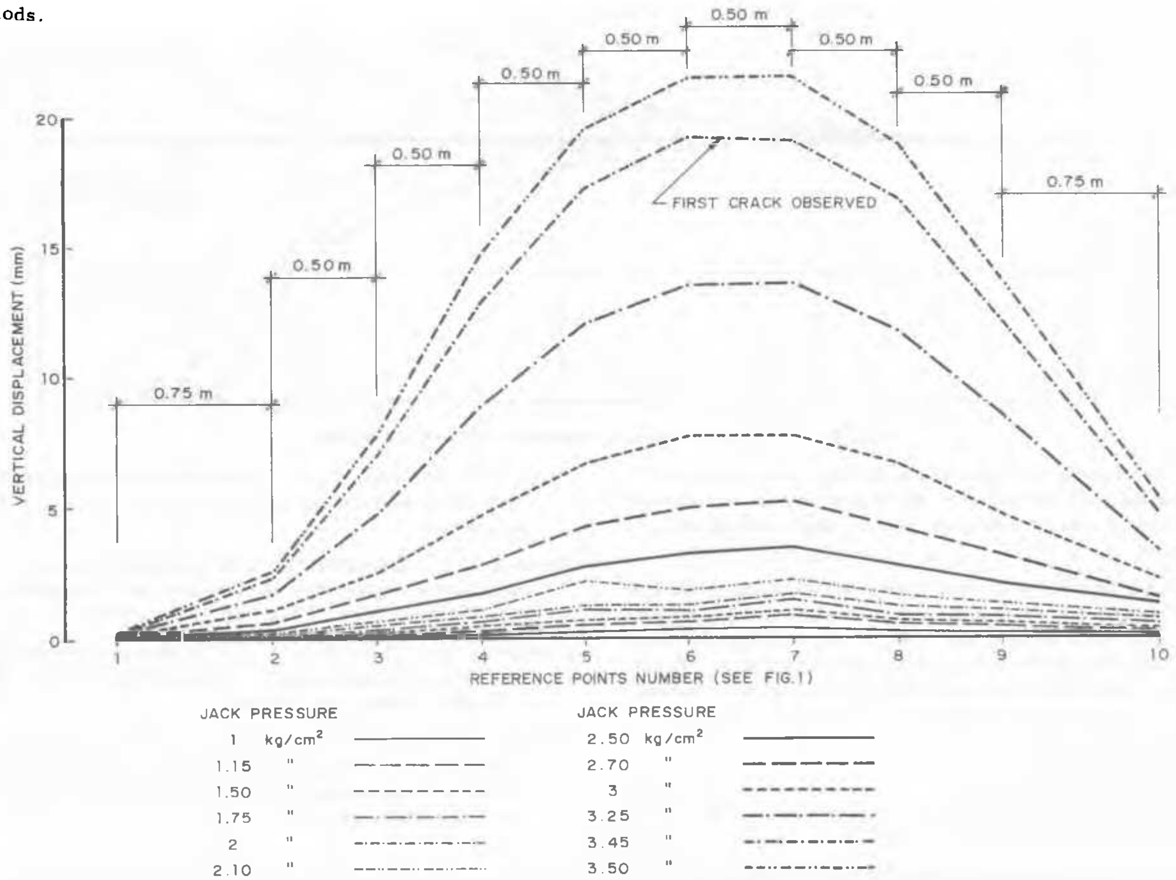

Fig. 7. - Vertical displacements of the reference points

the finite element method. The soil was supposed to be elastic, with a poisson ratio of 0, 3, for compressive and tensile stress field.

From the comparation between calculated and observed movements, the following conclusions can be deducted:

1º) Until a flat jack pressure of about 2 kg/cm^2 the behaviour of the fill can be considered elastic, for tensile strain up to 5×10^{-4}, due to an almost linear relation between movements and pressure.

The mean elastic modulus within the tensile zone was in the range 240-390 kg/cm^2, and for the compressive zone, between 130-300 kg/cm^2.

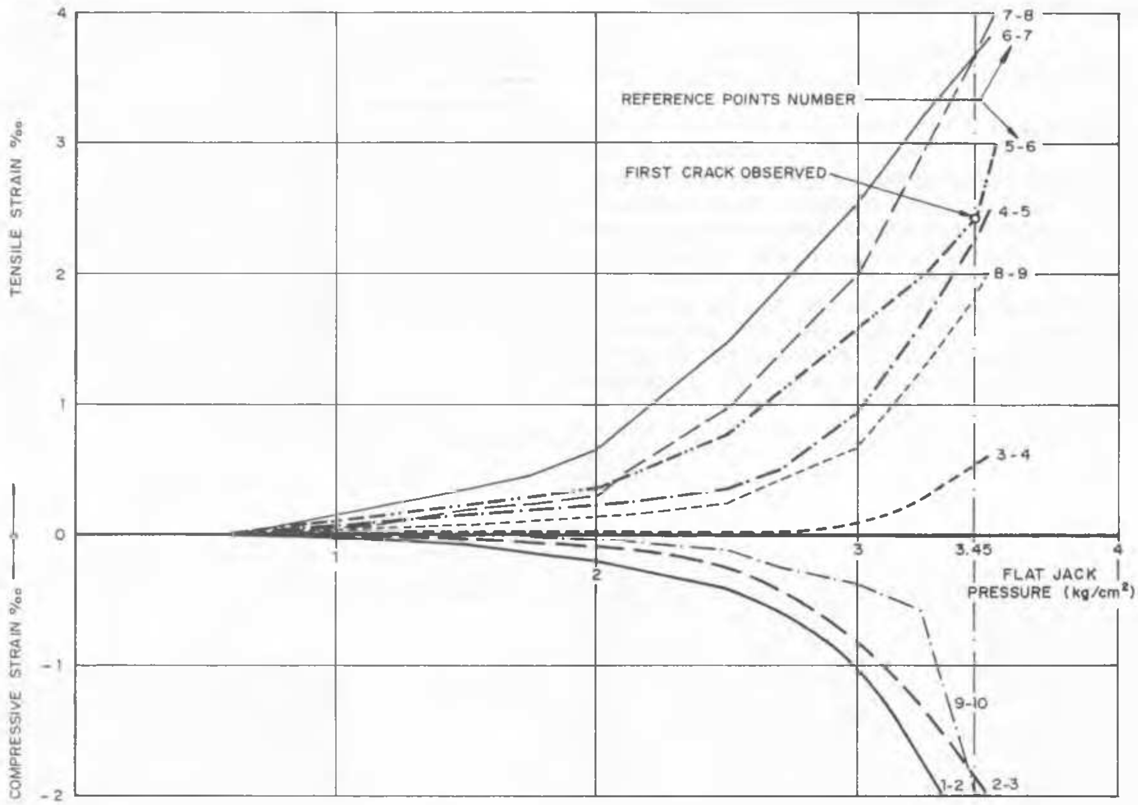

Fig. 8. - Horizontal strains between reference points

2º) For greater values of the strain, the behaviour is not elastic, till the failure. When the first crack appeared, the mean elastic modulus in this zone was about 120 kg/cm^2.

3º) The field tensile strain before cracking measured (0, 24%) is situated among the values obtained in laboratory tests, but in this case the results were rather erratic, although the soil particles greater than 3/4" were removed. That figure fits also well within the limits obtained with other clays compacted near the optimum proctor conditions (0, 1-1%).

4. FINAL REMARKS

The described field test is really a great scale flexo-traction test on a soil beam of 2, 5 m thick.

The complete test duraction was about nine hours. Nevertheless, if it is convenient to investigate the reological properties of the soil, the test duration can be elarged to several days, without difficulty. In the same way, it is well adapted to study the erodability of the soil, due to the filtration of water through a fissure. It is possible to investigate also the risk of piping, by reproducing together a zone of the core and filters. Both are fissured by the explained method. The percolation of water throught the cracks can be examined, and the autosealing or not of the fissure, studied.

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