Properties and Tests
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EXPERIMENTAL RESEARCH OF FRICTION BETWEEN SOIL AND GEOMEMBRANES OR GEOTEXTILES USING A 30 x 30 cm^2 SHEARBOX

PRÜFUNG DES REIBUNGSVERHALTENS VON BODEN UND GEOTEXTILIEN ODER BODEN UND GEOMEMBRANEN MIT EINEM CASAGRANDE-GERÄT (SCHERFLÄCHE 30 x 30 cm^2)

ETUDE EXPERIMENTALE DU FROTTEMENT SOL-MEMBRANES ET SOL-GEOTEXTILES A L'AIDE D'UNE BOITE DE CASAGRANDE DE 30 x 30 cm^2

The use of geotextiles or geomembranes is becoming increasingly frequent in civil engineering. Familiarity with the properties of friction is required for correct design. The CEMAGREF (Aix) has developed a large-scale Casagrande box for this purpose. The characteristics of this apparatus are presented below, together with the results from friction tests between soil and geotextiles or membranes. It would appear that the behaviour of these materials depends largely on the normal stress to which they are subjected.

I. INTRODUCTION..

The use of geotextiles or geomembranes is becoming increasingly frequent in civil engineering constructions such as dams. They have recently comme into use in large dams. The use of these materials requires familiarity with their frictional properties in order to be able to calculate the angle of the slopes on which they are laid. Therefore we have built a large scale Casagrande box for this purpose.

II. DESCRIPTION OF THE EQUIPMENT.

The apparatus is composed of :

a - a hydraulic motor by means of which compressive and shearing stress is stabilised and regulated,

b - a rigid metal structure supporting hydraulic jacks wich transmit stress to the shearbox, the internal measurements of which are 30 x 30 x 30 cm^3.

2-1/ : HYDRAULIC MOTOR :

The hydraulic motor is composed of an oil tank and an electric pump to obtain the hydraulic pressure necessary for supplying the different components. This pressure feeds pressure control valves as well as electro-distributors which control the power applied to each of the jacks.

- Applying and stabilising compressive stress :

Pressure is stabilised by means of a pressure control valve throughout the test. This regulated pressure feeds an electro-distributor which operates a hydraulic jack by means of which stress is applied to the soil at about 1,4 MPa.

- Applying and regulating lateral shearing stress :

The principal is the same but the control valve is driven electrically by a rheostat powered by an electric motor functioning at different speeds. This makes it possible to obtain translation speeds of 0,8 to 1,6 cm per hour. This regulating makes it possible to increase pressure in the electro-distribution which operates two hydraulic jacks permitting a maximum shear stress of about 1.1 MPa.

2.2/ - METAL STRUCTURE AND CASAGRANDE BOX:

The box's internal dimensions are those of a 30 cm sided cube. The lower half of the box is fixed onto a rigid framework, while the upper part slides freely over 8 cm in the direction of the shearing. Shearing stress is applied to the upper half of the box using a swan neck which enables this stress to be applied in the shearing plane. The direction of this stress remains invariable throughout the whole test.

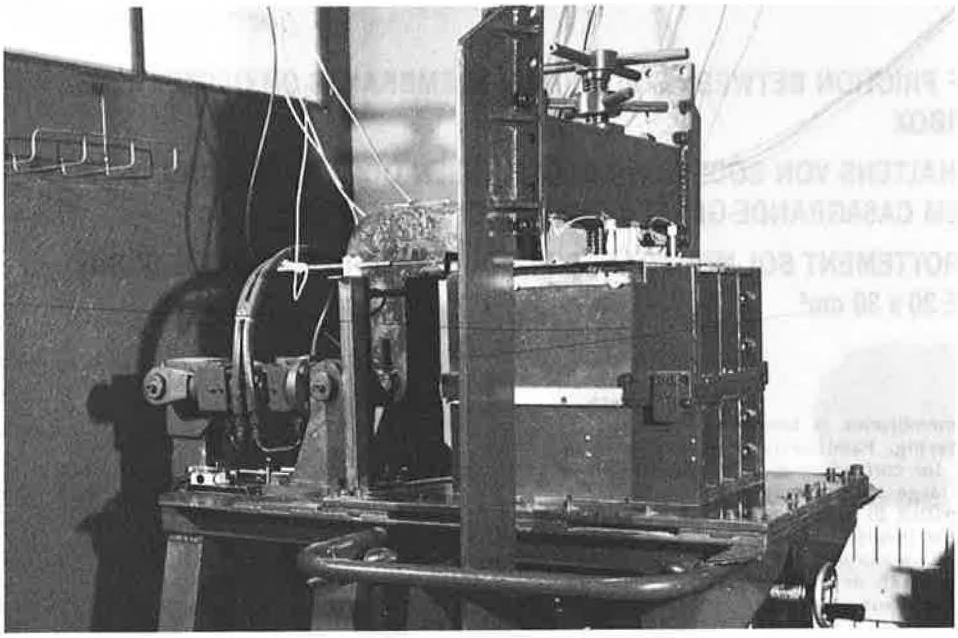

Figure 1 : Overall picture of the box with its metal clamp and the horizontal jacks.

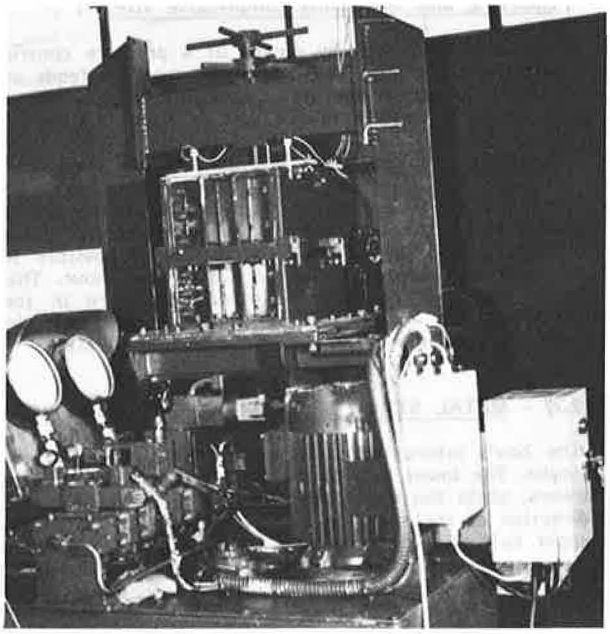

Figure 2 : Front view with its metal clamp and the hydraulic motor in the foreground.

A jack applies the vertical compressive stress to the upper part of the sample by means of a rigid metal plate. This stress is transmitted by means of a metal clamp which overlaps the shearbox. The possibility of adjusting the jack's position enables the lateral component of the compressive force to be compensated if breaking occurs accompagnied by a large relative shift.

2.3/ - RECORDING MEASUREMENTS :

Shearing stresses and lateral or vertical shifts are measured using pick-ups attached to a measuring unit (one pressure pick-up one lateral, shift pick-up, three vertical shift pick-ups).

III. - OPERATING METHOD.

3.1/ - COMPACTION :

The density of the soil in the box is that which corresponds to the energy of the Proctor Normal. To achieve it, five layers of soil per half-box are compacted by static pressing. This pressing is performed by the jack used to transmit the normal stress during the shear test. The pressure applied is increased until the layer to be compacted reaches the thickness corresponding to the required density.

To determine the internal properties of a soil, the same procedure is followed in the two half-boxes one on top of the other but with an overall odd number of layers.

3.2/ - MEMBRANE OR GEOTEXTILE :

Subsequently, the word "sheet" will be used to designate both geotextiles and geomembranes.

To avoid measuring both frictional stress and staying stress, the sample sheet (30 x 30 cm²) is stuck onto a rigid movable frame placed in the lower half-box. This frame consists of a sheet of waste plywood on which the sample is glued and placed on a block of hard wood. Screws placed under this block can be adjusted to make the upper surface of the sheet coincide with the shearing surface. (see fig. 3).

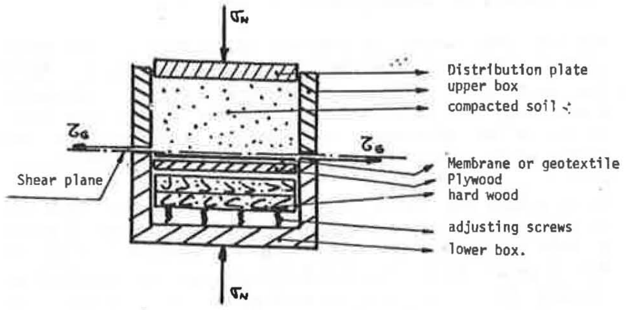

Figure 3: Working : principal of the friction test between soil and membrane or geotextile.

3.3/ - TEST BETWEEN SOIL AND SHEET :

The soil is compacted in the upper half-box, placed above the lower half-box, sealed off by the sheet and its frame.

Each test comprises 4 or 5 breaks reached under high normal stresses of between 0.2 and 1.2 MPa.

IV. - RESULTS :

4.1/ - SOILS STUDIED :

Friction has been studied using two substances - sand and clayey sand :

- the sand has a narrow granulometry (d_{60}/d_{10} = 2,

  d_{50} = 0,3 mm).

  It was used in a dry state (water content 5,2 %) and relatively loose (dry density = 1,60). Its internal friction angle ϕ is 39°.

- the clayey sand has 23 % elements less than 80 microns and 7 % elements less than 2 microns. Its plasticity index is 13 %. It was compacted to a water content of 12,5 % with a dry density of 1,84. Its mechanical properties are :

  c = 50 kPa et ϕ = 35,5°.

The mechanical properties indicated are measured with the same apparatus used for the friction tests.

4.2/ - ASSESSMENT OF THE RESULTS OBTAINED WITH THE LARGE BOX :

For two different standard pressures we carried out a large number of tests in the same conditions using the sand. The maximum divergence of the maximal shear stresses measured in only ± 5 % around mean values.

Comparative tests were carried out using the sand with the large box and a box 5 x 5 cm². The results (see fig. 4) agree where strong normal stresses are concerned. On the other hand, for weak stresses, the large box gives values systematically superior. We consider that this divergence is due to wall effects (silo effect, thrust, friction between soil and walls) greater in the small box. Indeed if the same degree of normal stress is applied to a sand having the same initial density, it is observed that density after consideration is greater in the large box.

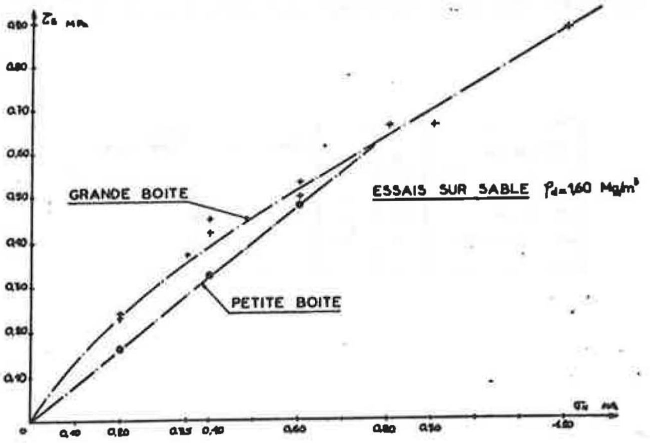

Figure 4 : Comparison of characteristic curves of sand measured in the 30 x 30 box and the 5 x 5 box.

4.3/ - RESULTS OF FRICTION MEASUREMENTS :

In the table below are found :

- the friction angles measured : internal and with sheet (average values are concerned in the 0,2 à 1,2 bracket).
- the value of the ratio f = τ_g/τ_s for various normal stresses where.

τ_g = maximal shear stress between soil and sheet.

τ_s = maximal shear stress on soil.

This ratio can also be written f = tg ϕ_g /tg ϕ_s with

ϕ_g = friction angle soil/sheet approaching the degree of normal stress under consideration.

ϕ_s = internal friction angle of the soil under the same conditions.

We shall see that the evolution of this coefficient f under normal stress presents a certain interest.

The diagrams relating to this test are attached in fig.5.

TESTES LARGE BOX	ϕ_S	ϕ_G	Values of f for σ_n (MPa).				
			0,2	0,35	0,6	0,9	1,2
Sand - Geotextile 1	39°	36°	0,81	0,76	0,87	0,86	1,0
Sand - PVC	39°	36°5	0,69	0,78	0,88	0,98	
Saturated sand - PVC	39°	36°5	0,83	0,76	0,88	1,01	
Clayey sand - Geotextile 1	33°5	39°	1,2	1,0	1,0	1,17	
Clayey sand - PVC	33°5	35°	0,76	0,80	0,87	1,06	

Below we are also giving the results of work carried out under the same conditions but with a small 5 x 5 box.

TESTS SMALL BOX	ϕ_S	ϕ_G	Values of f for σ_N = 0,2 MPa
Sand - Geotextile 2	39°	34°	0,85
Sand - Concrete	39°	34°	0,85
Sand - Crude strip steel.	39°	25°5	0,59

We observe :

- that the state of the water content in the sand studied does not influence its behaviour towards a smooth material.

- that the friction obtained using the clayey soil is superior to that obtained with the sand against a geotextile.

- that the clay "slides on the smooth material" and slides less on the geotextile (more precisely, things happen as though the geotextile agglomerated the grains of sand near the surface in contact when their diameter is inferior to its mesh. Then, rather a soil/soil or even soil/reinforced soil friction is measured. We considerer that in that case it is more correct to limit the friction value to that obtained for the soil alone).

- the ratios f = τ_g / τ_s increase distinctly with the applied load. This last result is important. On one hand, it cancels the hoped-for possibility of finding a coefficient characteristic of the sheet like, for example, the ratio . On the other hand, under low stress, the friction coefficient can be very considerably lower than that of the soil. (It can be about half under very low stresses). Therefore one must refrain from using a friction measurement result without taking into consideration the range of compressive stresses for which it was established - this could verge on insecurity.

- Finally, for the very heavy stresses, of about a MPa, the coefficient f is more or less equal to 1. Everthing happens as though under the effect of the load, the geotextile or the membrane became part of the soil or absorbed it.

V. - CONCLUSION.

The apparatus and the operating method used have enabled us to measure soil/geotextile and soil/membrane friction. The results make sense and the equipment enables a wide range of normal stresses to be tested with maximal values of the same nature as those encountered in large constructions.

- When the granulometry of the soil is fine in comparaison to the mesh of the geotextile, the geotextile/soil friction approaches the internal soil friction (adherence effect).

- For very high compressive stresses, of about a MPa, a similar result is obtained, whatever the soils and sheets used (effect of impregnation by the soil),

- But for soils which are coarser in relation to the mesh of the geotextile, and for low stresses (up to 0.3 MPa) the geotextile's friction coefficient can be noticeably lower than the soil's internal friction coefficient (from 20 to 50 %). Moreover, the relation between these two coefficients varies strongly with the state of stress.

- As a result, the angle of a slope ensuring the stability of a geotextile or a membrane can be appreciably inferior to that needed for the stability of the embankment alone. For a small dam, this disadvantage can be avoided by staying the sheet and counting on its resistance to traction. But for big dams, the way the sheet behaves under friction becomes a most important parameter and it would be as well to choose the different interfaces in terms of this question.

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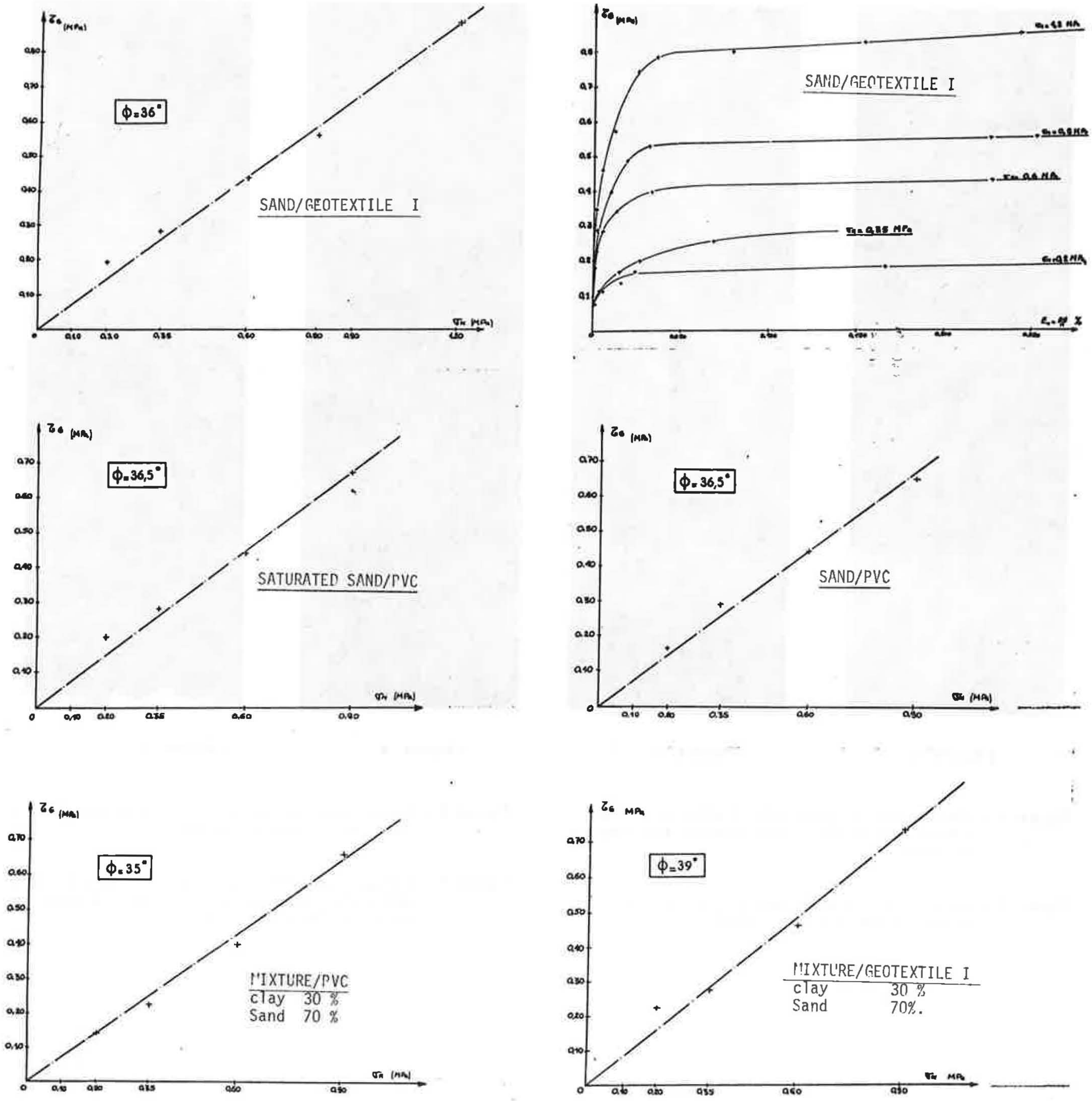

Figure 5 : Diagrams of friction tests in the big box.

FIGURE 6.

FIGURE 7.

FIGURE 8.

FIGURE 9.

Figure 6 : Partial view of geotextile 1 after test under a high normal stress. The material has dragged in places.

Figure 7 : Partial view of geotextile 1 after a test under a low normal stress (0,2 MPa).

Figure 8 : Partial view of PVC after a test under 0.9 MPa The furrows will be noticed.

Figure 9 : Partial view of PVC after a test under 0.9 MPa where the membrane became detached from the ply-wood. (test left out).