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In situ shear resistance of soils and particular materials measured by the Phicometer

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ABSTRACT: Since the development, in 1986, of the Phicometer in situ shear test (French standard XP P94-120), more than a few thousands tests have been carried out. Various types of natural or artificial soils and materials have been thus tested. After a brief description of the equipment and the testing procedure, the paper presents results of in situ shearing tests carried out in particular grounds and materials, which are difficult to sample and test in laboratory. Among these materials and grounds, one quotes : coarse grounds, fine sands which can hardly be sampled, treated soils with lime and/or cement and also compacted municipal solid waste (MSW), as well as clinker and ash resulting from MSW incineration. The carried out experiments demonstrate the feasibility of a direct measurement of the in situ direct shear strength. The shear strength characteristics (c and ϕ) obtained from the correlation rules established for soils from previous research appear, in first approach, satisfactory. However, for a better validation of this, they need to be compared to those which correspond approximately to the observed behaviour of the concerned works and structures and established for example by means of back-analysis calculation or simulation.

1 INTRODUCTION

The shear resistance of soils and materials, characterised by the friction angle and the cohesion, represents an important parameter for the geotechnical engineer while studying the stability of construction works and structures in relation with soils and materials.

Usually, this resistance is measured in the laboratory using triaxial tests or direct shear tests carried out on field samples. Of course, this measure makes sense only if sampling, conservation and preparation make it possible to consider the samples as non remolded and thus the test specimens as sufficiently representative.

Many categories of grounds and materials do not allow to meet these conditions. Among those, it is possible to quote granular medium to coarse sands, friable soils (tender chalks, sandstones), coarse and heterogeneous grounds and other various materials like fills, Municipal Solid Waste, slag heap, clinkers of incineration, etc.

In the event of such soils and materials, Phicometer in situ shear tests allow a very useful measurement of the limit resistance to shearing and the determination of the usual parameters c and ϕ .

2 PHICOMETER TEST PRINCIPLE

2.1 *Description of the apparatus*

The Phicometer device is entirely described in the AFNOR standard XP P94-120. It includes three principal bodies (figure 1).

- The Phicometer probe (A), which consists in a hollow cylindrical slotted tube includes a radially expandable cell. A series of annular teeth are provided in the central part of the probe to form the cylindrical surface of shearing. The initial diameter at rest of the probe (deflated state) is 58 mm. The surface of shearing during the test varies but remains close to 500 cm².

- Link and connection devices (B) of the Phicometer probe to the control and measurement equipment located at the ground surface, such as rods and tubes for injecting cell fluid.

- The control and measurement equipment (C) located at the ground surface which includes a pressure-volume controller to measure the volume of the inflatable cell and control the pressure applied to the ground through the cylindrical surface of shearing of the phicometer probe, two bearing plates and a hollow jack for exerting the pull out shearing effort and a force measuring device. The pull out

shearing speed is maintained constant to 2mm/min.

2.3 Data reduction – Calculation of the limit shear stress τ

After having determined, by means of a calibration, the relation between the measured cell volume and the external diameter of the shear surface of the probe and the relation giving the probe pressure loss, the data reduction of the measurements is carried out as described hereafter, following the parameters defined in figure 2.

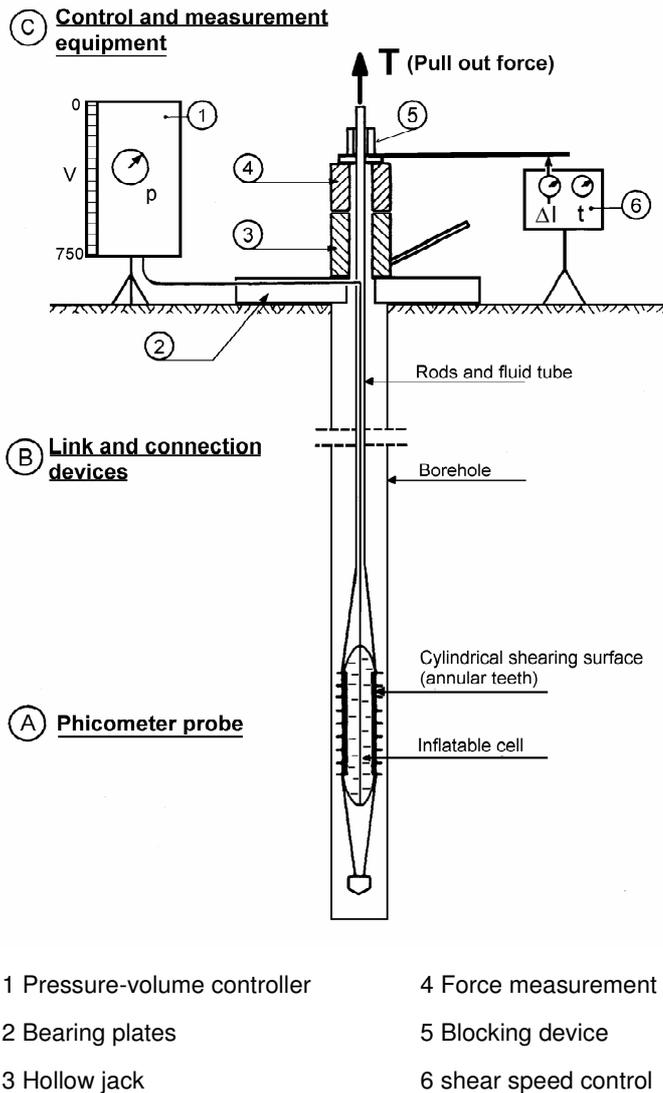


Figure 1. Diagram of the Phicometer apparatus.

2.2 Phicometer test procedure

The Phicometer shear test consists in introducing at a defined depth, in a previously made borehole, the Phicometer probe, to inflate this probe to make penetrate the annular teeth into the material at the wall of the borehole, then to shear the material by slowly pulling out the probe from the ground surface. During a pull out shearing step the pressure in the probe is maintained constant. Several shearing steps are carried out under successive increasing stages of pressure holds, thus giving the relation between the applied normal pressure and the corresponding shearing resistance of the tested material.

The AFNOR standard XP P94-120, details the test procedure and the loading steps program to achieve regarding the strength and type of material.

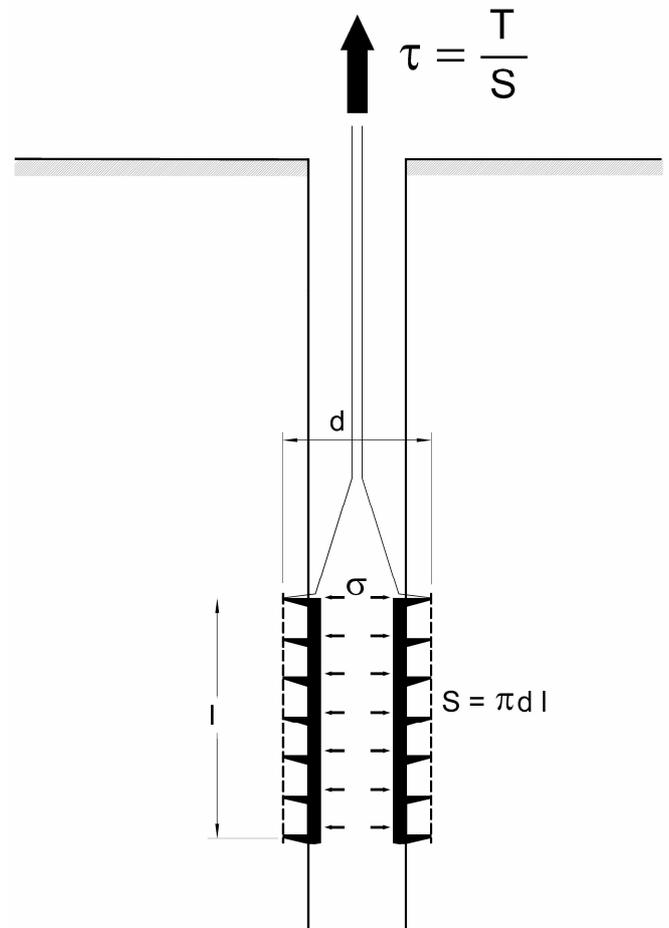


Figure 2. Phicometer test principle and parameters.

Under a pressure hold σ , the area of the shearing surface is given by :

$$S = \pi \cdot d \cdot l$$

Where, d is the external diameter depending on the cell volume and l is the length of the shear surface. The corresponding limit shear resistance t is given by :

$$\tau = T / S$$

Where T is the maximum measured pull out force.

Thus, couples of values (σ_i, τ_i) are determined for

each load step. A linear adjustment is then made on the significant couples of values to determine the shearing parameters c and ϕ corresponding to the cohesion and friction angle of the coulomb envelope. These in situ shear parameters are called cohesion c_i and friction angle ϕ_i . They are “short term” type parameters from which it is possible to derive the usual design shear parameters (Philipponnat and Zerhouni, 1993).

3 TEST RESULTS IN PARTICULAR MATERIALS

3.1 Test Results in a Municipal Solid Waste

More and more, there is a need to characterise the geomechanical behaviour of Municipal State Waste in landfills. The knowledge of the shear resistance is necessary to study stability in landfill design and management. The MSW materials are very heterogeneous. Their composition can vary from one area to another and with time. Their granulometry includes either bulky and large size elements and small and very fine elements as well, which can influence their shear strength.

Figure 3 shows the results obtained from a Phicometer test in a MSW landfill in Belgium carried out at 18m depth.

This waste has been compacted following the landfill management rules.

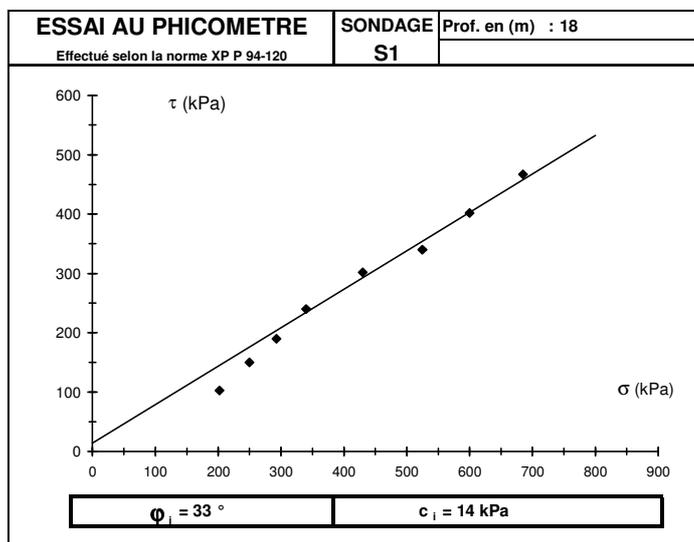


Figure 3. Phicometer shear test results obtained at 18m depth in a compacted municipal solid waste landfill.

Except the two first points in the diagram, the other experimental measured points follow the same linear adjustment giving thus an in situ cohesion of 14 kPa and an in situ friction angle of 33° .

These values correspond to a high shear strength material, mainly like a granular soil behaviour.

In the same manner, another test, carried out at 14m depth (figure 6), has given quite different values, showing another behaviour of the MSW in the tested zone. The corresponding in situ cohesion and friction angle are 26 kPa and 18° .

In this case, the behaviour can be considered as similar to a clayey soil.

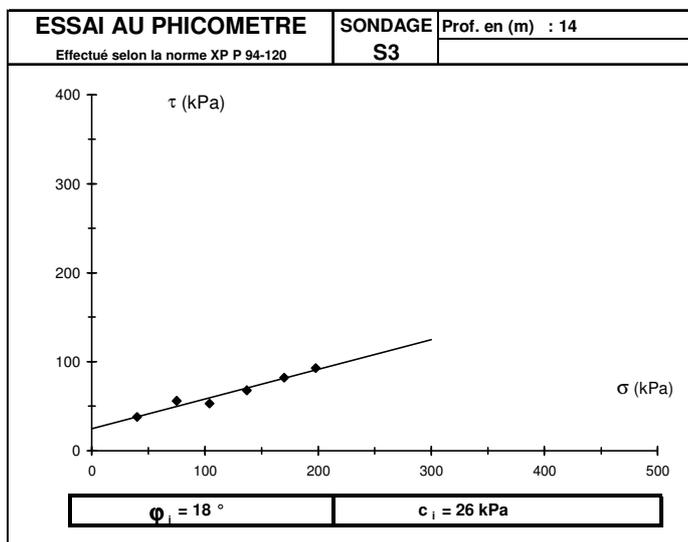


Figure 4. Phicometer shear test results obtained at 14m depth in a compacted municipal solid waste landfill.

These two tests show a different behaviour for a same material and an important difference in their shear characteristics and therefore, the need for being careful in choosing the corresponding characteristics and design values of shear strength, especially in the case where a few number of tests are available.

The description of such a dispersion is shown in the diagram of Figure 5, where the superposition of the measured couples of all the in situ shear tests carried out in the same MSW landfill are represented.

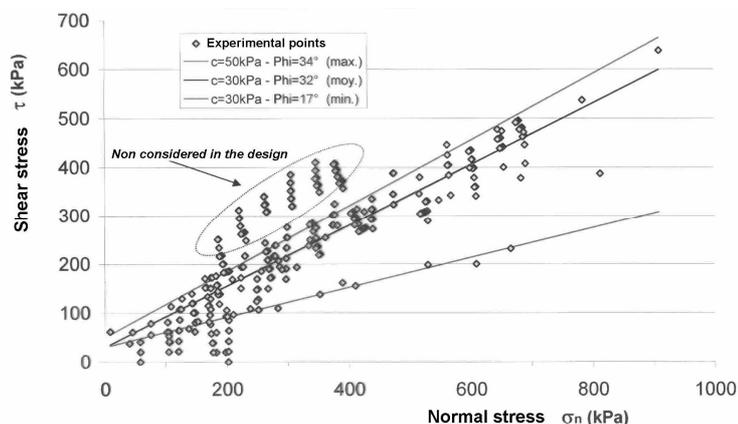


Figure 5. Superposition of all the measured shear resistance in a same MSW landfill, at different depths

The interpretation of this diagram leads to possible design values for this compacted Municipal Solid Waste ranging from 17 to 34° for the friction angle and from 30 to 50 kPa for cohesion.

3.2 Test Results in a MSW incineration clinker

The Incineration of Municipal Waste generates ash and clinker. Depending on the corresponding regulations, some categories of MSW incineration clinker can be reused in some construction works, like filling under certain conditions.

The knowledge of their geomechanical properties becomes then interesting.

Figure 6 shows a typical result of a Phicometer shear test carried out in a heap of incineration ash, at 1.4m depth.

This ash/clinker material was approximately one year old, corresponding to a certain degree of maturation.

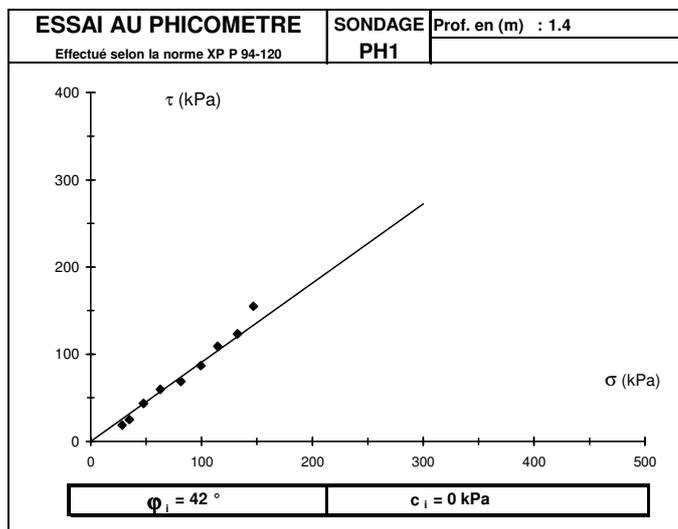


Figure 6. Phicometer shear test results obtained at 1.4m depth in a one year old MSW incineration clinker.

Most of the experimental points lie on a same linear adjustment giving an in situ friction angle of 42° and no cohesion, showing a behaviour similar to a coarse granular material one.

4 CONCLUSION

Through a selection of some Phicometer in situ shear test results, it is possible to characterise the shear strength of grounds and particular materials, usually difficult to test in laboratory, like coarse soils, heterogeneous municipal solid waste, ash and clinker resulting from MSW incineration and many other materials in which intact sampling is difficult to achieve.

The Phicometer in situ measured characteristics are “short term” type characteristics giving thus a direct measurement of typically undrained properties. Depending on the nature and the permeability of the materials, the effective characteristics can be estimated through correlations. These correlations have been established for soils from comparisons with test results of shearing in laboratory. It seems appropriate however, before generalising these correlations to particular non-soil materials, to confirm these estimates by the observation and analysis of the real behavior of the works concerned.

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