Xth DANUBE -EUROPEAN CONFERENCE OF SOIL MECHANICS AND FOUNDATION ENGINEERING

Bearing capacity of "Pneusol"

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Old tyres constitute a waste that has excellent mechanical properties and is available in quantities in all parts of our countries . While old tyres do not contribute directly to pollution (unless they are burned in the open air) .

The first research in France on the use of old tyres to reinforce soils was done in 1976 by the LCPC and in 1978 to the submission of a report to the Délégation Générale à la Recherche Scientifique et Technique.

Generally speaking, Pneusol (registered trade mark), a combination of tyres and soils (natural, artificial or others wastes), not only helps to consume stocks of old tyres, but also improves the mechanical properties of soils.

To day (October 1993) more than 500 structures have been built in France, in Algeria , in England, in Canada, in USA,.......... in Roumania (protection of slopes against erosion) covering a wide range of civil engineering applications mainly in order to reinforce earth structures at lower cost than conventional technologies..
(Retaining structures, reduce active earth presssure, stiffening slopes, energy absorption, creation of arching, light ground fill, safety device of banks and slopes, military aplications.........)

Our paper deals with researchs on three dimensional model. Bearing capacity tests on a small scale model have demonstrated the good influence of Pneusol on the distribution of stress under the slabs in function of differnt parameters (number of layers, space of each layers..........) .

BEARING CAPACITY OF PNEUSOL

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SYNOPSIS

This paper shows one of the way to use the Pneusol "Tyresoil" material in Civil Engineering : the Pneusol as a distributor of vertical pressures.
It presents some results of total pressure measurement made under a foundation of Pneusol and it stresses the influence of that last on the distribution of the pressures.
It also stresses the influence of the loading-unloading cycles on the rheological characteristics of the Pneusol material.

1. INTRODUCTION

The world deposit of used tyres is huge. In France more than 35 millions of tyres (450000 t) are thrown away every year. In Europe this quantity reaches 2.5 million of tons.

The problem of the elimination of those wastes had been solved only a few years ago, when they had been put in controlled dumps.
Since, even if numerous valorising processes had been invented (retreads, incineration, farm use, rubber powder, ...) an important quantity of tyres remains nevertheless unused.
So as to use a part of those wastes, the Pneusol material had been invented by the Laboratoire Central des Ponts et Chaussées (Long et Valeux, 1989). Its constitution results by the combination of two elements : old tyres an soils (natural or artificial materials, or wastes).
Since 1974, more than 250 structures using the Pneusol had been built in France and more than 500 others had been built in the world.
Generally speaking, the Pneusol has the advantage of being able to improve the mechanical properties of the soil, other in an isotropic way or in anisotropic way.
The Pneusol material is actually used all over the world : retaining structures, reduce earth pressure, stiffening of slopes, energy absorption, creation of arching and pressure distribution (Lareal et Long, 1987 ; Lareal et al 1995).
Our paper deals with this last application of the Pneusol material. It highlights the influence of a Pneusol foundation on the distribution of vertical stress under a superficial rigid slab charged on surface.

2. DEFINITION AND BEHAVIOUR OF THE PNEUSOL

The Pneusol is made up of the combination of whole tyres partly or totally cut up, placed in a linear way or in layers able to support important efforts of traction and a soil of any nature.
The whole tyre with its different components has a good resistance and an excellent soil-tyre adhesion. Covered by a hard core they can resist to the effect of ultraviolet rays, the only factor capable of damaging the rubber.
The numerous tests made in situ (Long 1987) on structures of Pneusol made of whole tyres, revealed the existence of a light Pneusol (8 to 10 kN/m3), with a dynamic modulus of about 10 to 12 MPa. It is also characterised by an appreciable absorbent power of about 25%.
We have developed an experimental programme of tests in laboratory so as to precise that influence.

3. EXPERIMENTAL ANALYSIS

The experimental study had been realised in the Laboratoire Géotechnique de l'INSA de Lyon in a three-dimensional small-scale model in a cylindrical container with a 1500mm diameter and a depth of 600mm.
The equipment and the material (tyres, sand, slab,,,) used are described in Boutin et al 1993.
The test consists in loading the sand with a superficial slab of 350mm diameter and a 35mm thickness. The influence of the presence of a foundation of Pneusol under the slab (figure 1) is studied.
The foundation of Pneusol used is constituted by tyres arranged one on the others in double staggered rows. Its thickness depends on the number of layers used (3, 5, 7, 9). This foundation is placed in a Hostun RF sand (Flavigny et al 1990).
The distribution of normal pressures under the foundation of Pneusol is measured by kyowa BE-10KC sensors, beforehand calibrated. Similar measures are carried out on a normalised sand, loaded in identical conditions.
The slab is loaded until 123 kPa and it is subjected to 20 cycles of loading-unloading. So as to study the reliability of measures, each manipulation is repeated at least 3 times.
We study the influence of :

- the number of tyres on the distribution of normal pressures ;
- the number of loading-unloading cycles on the pressures distribution and on the rheological characteristics of Pneusol.

4. EXPERIMENTAL RESULTS

4.1. Pressures under the slab

The Pneusol mattress is placed 20 mm from the slab. Five total pressure cells are placed 20 mm under the Pneusol foundation (Figure 1). In the referential tests, those cells are placed at the same depth.
The comparative study of the results had been based on the Factor of Absorption of Pneusol (FAP). This factor is the ratio of vertical pressure under the Pneusol foundation to the vertical pressure in the referential soil.

$$FAP = \frac{P_{Pneusol}}{P_{référence}}$$

It allows to quantify the Pneusol influence on the distribution of the stresses in a reinforced soil.
The evolution of the FAP is presented in function of the number of layers constituting the mattress of Pneusol, in the axis of the slab and under the edges.
One notices that the FAP decreases notably under the central axis of the slab (Figure 2). Beyond 3 layers (42 mm thick), its value gets stabilised between 0.6 and 0.8. This decrease (from 20 to 40%) is observed on the two sensors juxtaposing the central one.

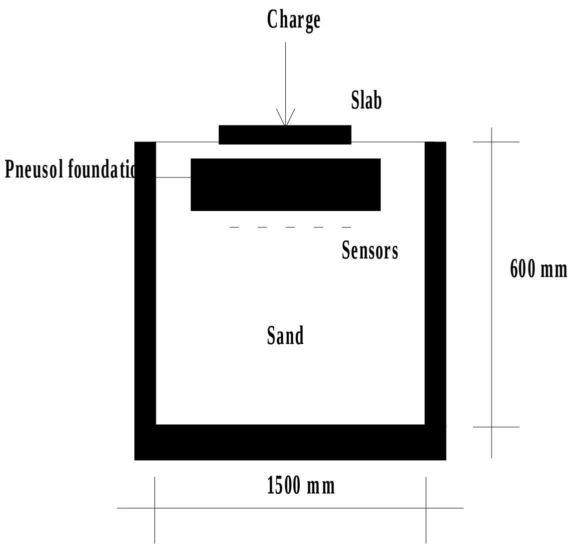

Figure 1. Principle of the experimentation.

Under the edge of the slab (Figure 3), the FAP increases gradually until a maximal value of 1.5. This result is obtained for 7 layers of tyres loaded until 123 kPa. This increase of nearly 50% observed under both edges decreases for 9 layers and is limited to nearly 20%.
Those results clearly bring to light fore the pressures distributor effect played by a foundation of Pneusol : whereas the pressure decreases at the centre, it increases under the edges.

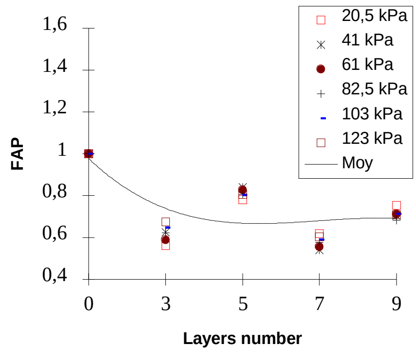

Figure 2. FAP evolution under the centre of the foundation.

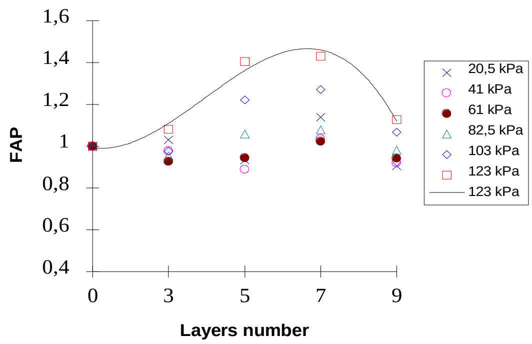

Figure 3. FAP evolution under the edges of the foundation.

4.2. Normal pressure in depth under the central axis of the slab

Five total pressure cells had been placed in a way as to study how a foundation of Pneusol constituted by five layers of tyres influences the distribution of the stresses in depth under the central axis of the slab (Figure 4).

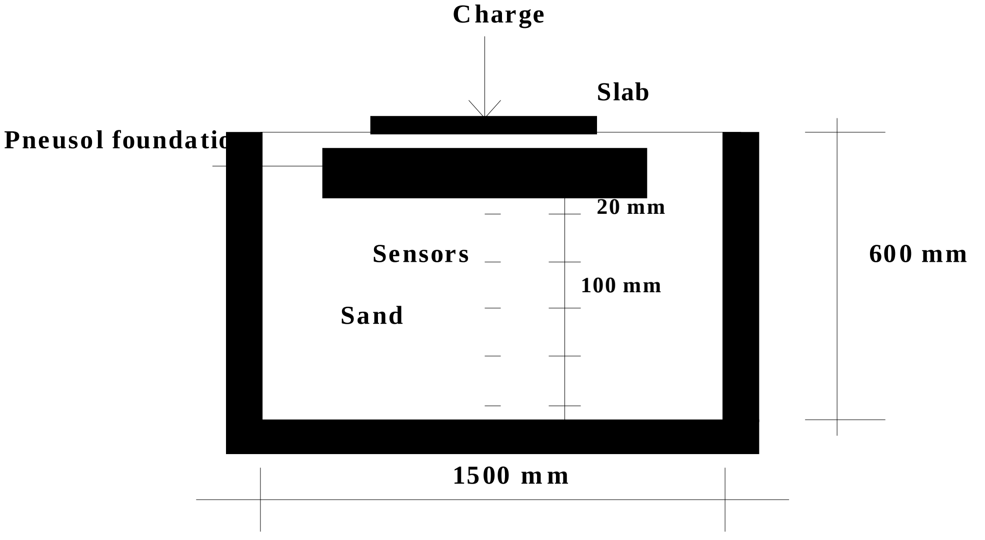

Figure 4. Principle of the experimentation.

Figure 5 presents the evolution of the stresses measured under the Pneusol foundation and in the referential soil depending of the ratio depth/slab diameter. When the pneusol is used, the vertical stresses are markedly lower and the difference is all the more visible as the loading is important.

The FAP represented on Figure 6 shows that this diminution reaches 25% between 0.5 and 1.2 times the slab diameter and 20 to 35 % at 0.28 and 1.5 times this diameter.

Those results confirm the Pneusol influence on the distribution of pressures in depth under the central axis of the slab. That influence can be more important on the foundation interface and at important depths.

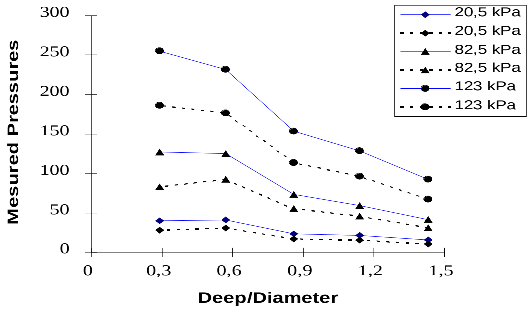

Figure 5. Pressure distribution.

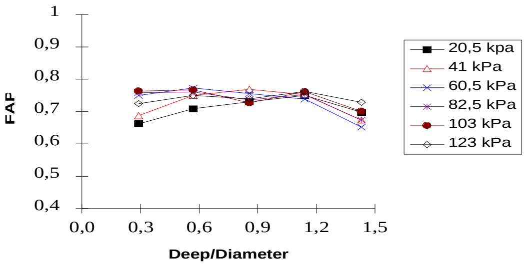

Figure 6. FAP evolution with depth.

4.3. Vertical pressure in depth under the edges of the slab

So as to study the distribution of the pressures in depth under the edges of the slab, the five total pressure cells placement is outlined according to Figure 7.

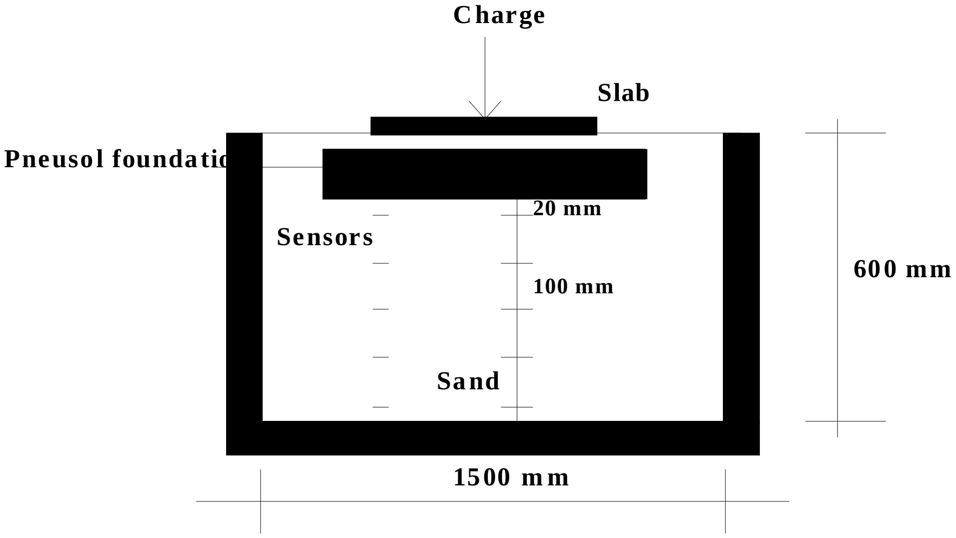

Figure 7. Principle of the experimentation.

Figure 8 shows the evolution of the normal pressures depending on the depth-slab diameter ratio ; it stresses the influence of the Pneusol foundation which is rendered by an increase of the stresses under the edges of the slab.

The evolution of the FAP which correspond to it is presented on Figure 9. The pressures under the Pneusol foundation are more important than in the soil. The more important is the depth the higher is the FAP.

For the low charge increment (20.5 kPa), the FAP goes from a value of 0.8 at 0.28 times the diameter of the slab to a value of 3 at 1.5 times this diameter ; nevertheless, for the high increment of charge (123 kPa), the FAP goes from a value of 1.4 to 1.6.

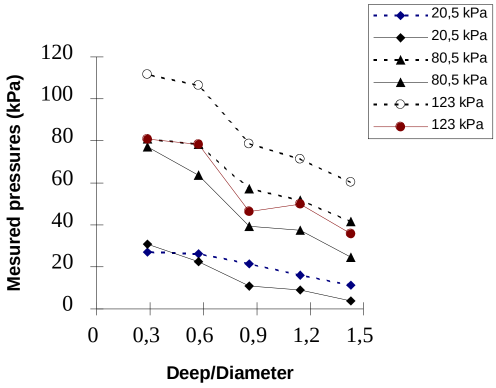

Figure 8. Pressure distribution.

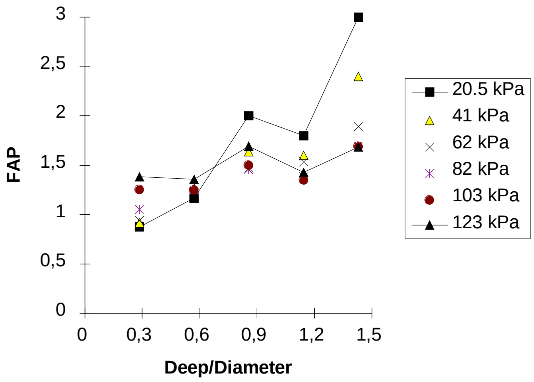

Figure 9. FAP evolution with depth.

Those last results show the effect of a Pneusol foundation : whatever the depth, an important part of the stresses generated under the slab is distributed outwards of the influence zone. Consequently, the pressures are reduced under the central part and increased under the edges. Qualitatively speaking, those results have been confirmed by a numerical study made by the ENTPE de Lyon (Boutin et al 1993).

4.4. Cycles influence

The cycles influence is represented on figure 10. It concerns a Pneusol foundation of 9 layers of tyres subjected to 20 loading-unloading cycles. If the pressures measured during the 20th loading and the pressures of the first one are compared it is noticed :

- an increase of the pressures linked to a weak increment of loading (20.5kPa);
- concerning the 41 kPa, an increase of the pressures under the central part of the slab and a decrease under the edges ;
- from 60 kPa, an increase of the pressures under the central part of the slab (from 5 to 10%) and a decrease of about 10 to 15 % under the edges.

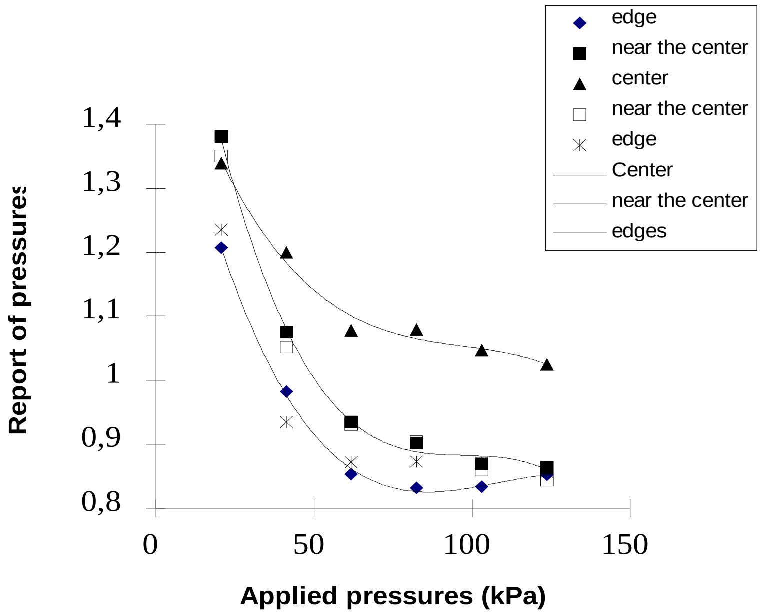

Figure 10. Cycles influence.

Those statements are accompanied by a number of rheological modifications of the material. It is characterised by an increase of the equivalent modulus of the Pneusol determined from the load-deformation curves, going from 1.2 MPa to 4 MPa and by a permanent elastoplastic behaviour.

5. CONCLUSION

The results presented in this paper confirm the stress distributor effect played by a foundation of Pneusol reinforcing a crushed sand charged on surface by a rigid slab.
Beyond 3 layers of tyres, whatever the depth the influence of the Pneusol is characterised by an important diminution of the pressures under the central part of the slab : between 20 and 40 % and an important increase of the pressures under the edges.
Those different results clearly point out the mechanical function of the Pneusol, which consists in the distribution of the loads outwards the influence area of the slab.
The cycles effect on the Pneusol material is characterised by a number of rheological modifications.

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