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Study of confinement effect in geocells

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ABSTRACT : Recent studies have proved that the cell and the enclosed soil behave essentially as a unit, having higher properties than the content alone. In order to explain the effect of geocells as a reinforcing member and the mechanism of confinement, tests using large scale and small scale specimens were carried out. Study of the cells size upon the size of footing is presented. The result of rigourous finite element analysis are compared with a standard analysis. As a result, numerical simulation were consistent with loading tests, and it was confirmed that the both analysis : finite element which considered the discontinuity and standard method which considered an homogeneous material were effective analysis method for geocells.

1 INTRODUCTION

One of the most advantage of overall confinement being that it makes the mass homogeneous with a material of equivalent properties. The development of this new technique required the elaboration of a reliable as well as practical design procedure. A major objective in analyzing such structure is to determine the increase of the factor of internal stability. Knowledge of the magnitude and orientation of the confinement effect throughout the wall is of prime importance when designing the structure.

2 EXPERIMENTATION

In order to investigate this aspect and isolate the performance benefit confer by the confinement, tests were carried out using compression tests . The tests carried out by Bathurst (1993) and Shimizu (1990) highlight the influence of the slenderness.

table 1: Features of the honeycomb structure textile

characteristic	mass per unit area	thickness	tensile strenght	elongation at failure
notation	ρ	e	Rt	ε
unit	g/m²	mm	kN/m	%
BD700	310	1,2	75	10
PS750	350	3	26	30
PS350	350	1,9	20,2	25

The main characteristics of the materials used are presented in table 1. The cellular meshes used in these tests were stitch material type.
The load was applied at a constant vertical displacement rate of 2mm/min. Load and displacement transducers were employed for force and displacement measurements. Displacement transducers were installed along the height and diameter of the cell. Readings from instrumentation were taken for each loading stage applied.
The effects of the reinforcement properties (stiffness and strenght figure 2a. and 2b.) and geometry (study of the influence of cells size) upon the deformation behaviour have been investigated.

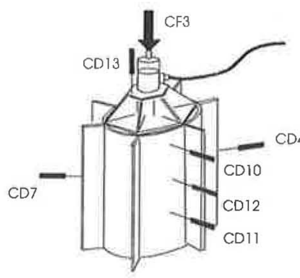
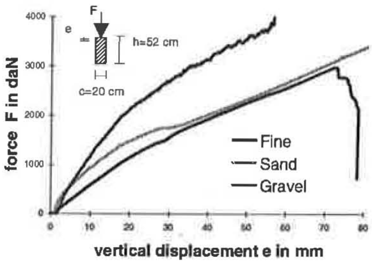


Fig.1 compression test



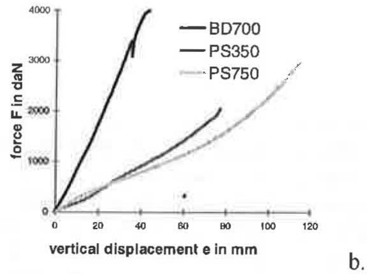


Fig.2 Results of compression tests

The compaction increase the lateral tension in cells. In this way, the required tensile force needed to have the effect of confinement is obtained and the vertical resistance is increased. In first approximation, we obtained

$$C_r = \frac{\sigma_{1r}}{2}.\tan(\frac{\pi}{4}-\frac{\phi}{2}) = 36\,kPa \qquad (1.1)$$

at γ=10% for loose dry sand and for the non-woven PS350 described in table 1. The observed shear strenght increase, due to reinforcement, can be attribute to the developpement of an effective lateral equivalent confining pressure $\Delta\sigma 3$ experienced by the soil.

The effective confining stress can be compute using relations between the cohesion and the caracteristics (Bathurst 93). For reinforced cohesionless soil or drained cohesive soil the increase in shear strenght is given by :

$$C_r = \frac{\Delta\sigma_3}{2}.\tan(\frac{\pi}{4}+\frac{\phi}{2}) \qquad (1.2)$$

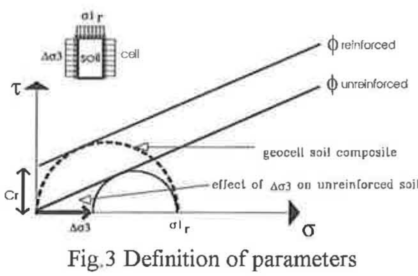


Fig.3 Definition of parameters

where

$$\Delta\sigma_3 = \frac{2.J}{D}.\frac{1-\sqrt{1-\varepsilon_a}}{1-\varepsilon_a} \qquad (1.3)$$

where ε_a = vertical strain, J= textile modulus and D=diameter of the cell.

The other method is a numerical modelling conducted in plane strain and axisymetry using the computer program CASTEM2000 (distributed by CEA). The aim of the study is to quantify the confinement effect and the influence of rough plate boundaries on the deformation. The Finite Element method used here allows an approach of the behaviour during the deformation by taking into account the geotextiles distorsion capacity

The space discretization of the soil consists of 400 rectangular elements, the one of the fill consisting of 20 shell elements. The mesh and displacement boundary are shown in figure 4. Our model is based on the exact geometry of tests with their different zones. The model is blocked on its lateral boundaries.

The soil was modelled using elastic-perfectly plastic material with a Mohr Coulomb yield criterion. The reinforcement was represented by means of line elements with no bending stiffness and a linear axial force-extension relationship. The requested parameters are then the Young modulus, the Poisson ratio, the internal friction angle, the cohesion and the density. Interface elements were provided between the reinforcement and the soil (Figure 4). These permitted slip according to a Mohr Coulomb criterion.

Two of the most obvious factors are the reinforcement properties and interface properties. The magnitude of displacement is very sensitive to the modulus values for both soil and geotextile. Therefore attention should be paid to the determination of elastic parameters as Young modulus and bearing capacity of the interface. We do not take in account the densification of the soil.

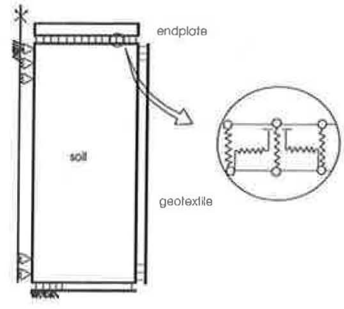


Fig.4 Geometry and boundary conditions

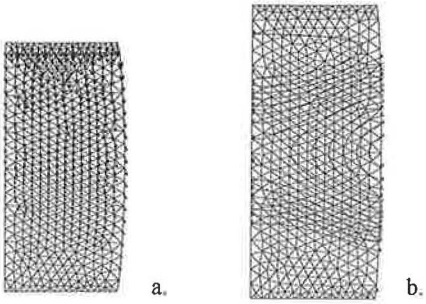


Fig.5 Displacement and plastic strain

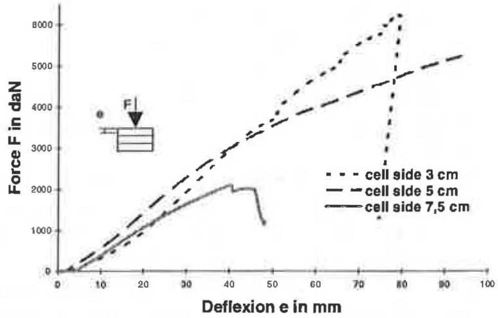


Fig.8 Influence of cell size

The results are quite relevant to those obtained by X-ray technique. Confinement effect creating apparent cohesion we obtain bulging. At large strain the cell confine the infill soil which is in plastic state (Figure 5b). The relation between vertical deformation and force is then proportionnal to the stiffness of the textile.

The application of geocells as a reinforcement of road on soft ground, has been investigated by Mhaiskar (1994) De Garidel (1986) Khay (1986). The analysis of the load-settlement curves obtained shows that in this application the geocells mat behave in a first time by increasing the load bearing capacity in correlation with the stiffness of textile and in a second time for large settlement a membrane effect.

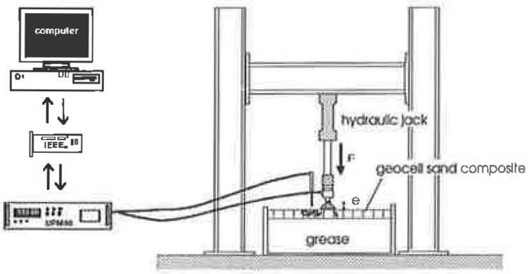


Fig.6 Presentation of the testing apparatus

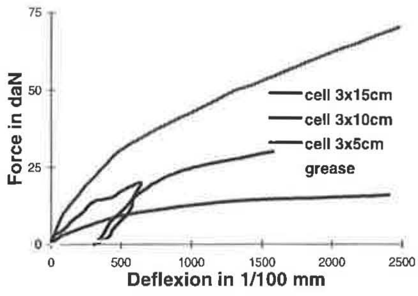


Fig.7 Results for different slenderness

The bearing capacity becomes large with large depth and small side. The presence of cells reduces the lateral spreading of granular materials that occurs under repeated loading in the structure.

Tests on three layers of scale model of geocells with differents diameters show the influence of the 'density' of cells under the footing. The cellular meshes used in these tests were glued material type.

At first presence of cells perturbate and when the confinement effect appearsdu to densification the rigidity is in correlation withe the number of cells. The rupture of a glued junction cause prejudice more important to the structure for cell with large diameter.

CONCLUSION

The results illustrate that the magnitude of the stiffening effect and strength increase imparted to the soil by the enhanced confinement effect are well reproduced by the modelling. The methods presented here have proved successful in explaining the action of the reinforcement. The composite structure obtained have higher mechanical properties than the content alone and it seems logical that the mobilized strength should be different for different angle of orientation. The aims of this study is to propose a strenght criterion that can be included in a stability analysis method (Gourvès 1996).

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