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Geogrid efficiency in a push test

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ABSTRACT: The paper presents the experimental results obtained on the models of the reinforced unbound layer placed onto the soft subsoil. The cone push test was applied. The influence of geogrid stiffness to the interlocking effect was studied. It is shown that stiff geogrid increases the pushing force.

1 INTRODUCTION

A planar geosynthetic with open structure used as reinforcement of a thin sub-bases increases bond in the soil system due to the interlocking of the soil particles with the reinforcement apertures. Usually, a geogrid is used for this purpose. When granular soil particles are compacted over these geogrids, they partially penetrate through the apertures to create a strong interlock. Confining effect occurs together with interlocking. These mechanisms are characterized by the increase in the bearing capacity onto sub-base surface and the reduction in its vertical deformations.

There is a common question if geogrids in a variety of sizes, polymers, stiffness and structures work in the same way. Some of geogrids cannot generate the same very efficient interaction and confinement of the aggregate.

Two-dimensional small model tests were performed to clarify the mobilized confining effect (Yasufuku et al., 2001). Experimental verification of confinement effect was carried out to introduce this into a design method (Kawamura et al., 2000). In order to quantify confinement to index properties of geosynthetics standard tests as well as the newly developed “confinement” test were done (Sprague & Kern, 2001).

In order to clarify the interlocking effect of the two different geogrids under sub-bases made of crushed stones, a set of model laboratory tests was carried out.

2 METHODOLOGY

2.1 *Test equipment*

Materials were placed in a steel container with inner diameter of 260 mm. After placing clay to 60 mm of container depth, geogrid with free end was placed over clay and crushed stone filled up the container. Materials were poured into container in layers of approximately equal depth of 30 mm. Each layer was statically compacted with the same energy.

Figure 1 shows the schematic layout of the test apparatus.

2.2 *Procedure*

The vertical load has been applied through a standard cone with diameter of 25,2 mm. The cone was laid in the center of container. As shown in Figure 1 the position of the cone at the test start was of 55 mm above geogrid. The vertical displacement rate of cone has been equal to 8,6 mm/min for all tests. All tests have been performed, until the cone intersects potential initial geogrid plane or the sub-base/sub-grade line (Baslik et al., 2001).

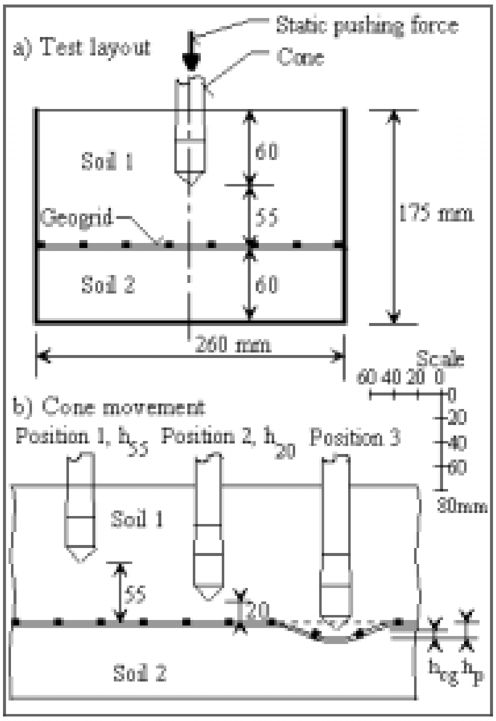


Figure 1. Push test

During the test the vertical load has been recorded. After the cone movement was stopped, the sub-base soil was removed carefully and the deformations of geogrid were recorded.

2.3 *Materials used*

Two types of soils were used for this experimental works. High plasticity clay was chosen as an optimal cohesive sub-grade soil. Physical characteristics of the clay (C) were:

moisture content:	37 %
density:	1584 kg.m^{-3}
plastic limit:	27 %

classified as high plasticity clay (CH).

Physical properties of the crushed stone (CS) were:

particle size:	2/32
mean particle size, D_{50} :	10 mm

grading curve in Figure 3
classified as gravel poorly graded (GP).

The geogrids generally produced are either stiff geogrids or flexible geogrids. For the present study the two geogrids were used. The physical properties of these geogrids are given in Table 1.

Table 1. Properties of soils.

Property	Unit	Biaxial geogrid	
		Stiff	Flexible
Material type		PP	PET
Tensile strength	kN/m		
longitudinal		30,0	22,0
transverse		30,0	30,0
Load at 2% strain,	kN/m		
longitudinal		10,5	8,5
Rib shape		rectangular with square edges	flat, irregular surface and edges
Mesh size	mm	39 x 39	33 x 35
Grid opening area	%	80	68
Product		integral extruded	woven

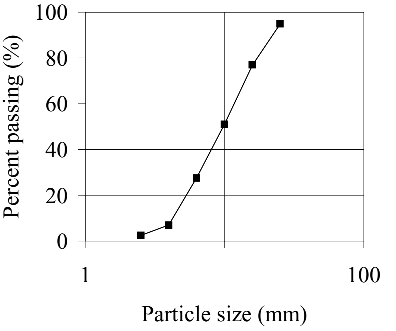
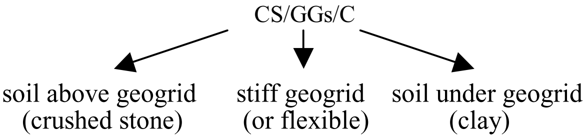


Figure 2. Particle size distribution curve of crushed material.

3 RESULTS AND DISCUSSION

Figure 3 shows the observed results of the push tests. Figure provides the typical results of the relationship between static pushing force and the cone position to the initial subgrade surface. Symbols in figure are as follows:



The pushing force variation during pushing of the cone through the crushed stone layer into aperture center is clear in Figure 3. Each cone contact to the large soil particle and its releasing has immediate response in pushing force value. Line CS/-/C has the different shape in comparison with CS/GGs/C line and CS/GGf/C line, respectively.

The development of pushing force in both CS/GGs/C and CS/GGf/C tests is approximately similar up to h_{10} value in Figure 3. As can be seen the pushing force of CS/GGs/C line is higher at the end of the test compared to CS/GGf/C line. The increasing of the pushing force is result of increasing the resistance during the cone through the arching zone created over the stiff bearing ribs and junctions.

We know, that the compaction method in laboratory is the different one than in site. During compaction of thin sub-base at construction site by rollers the soil particles are not only pushed into open grid structure in vertical direction but also in inclined direction. Because of that, the stiff geogrid is pre-stressed. As a result, interlocking is very effective and a new composite material provides the high performance.

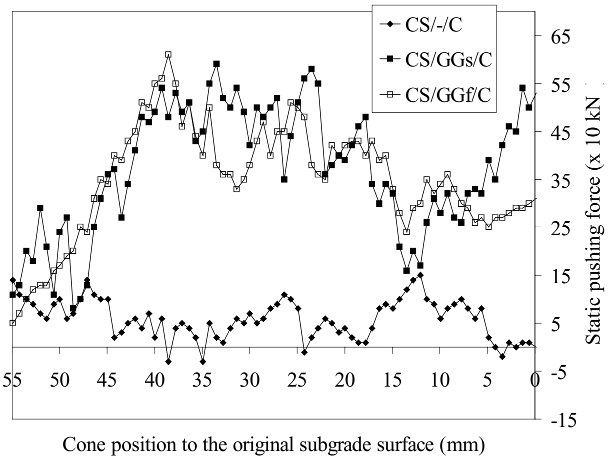


Figure 3. Relationship between cone position and pushing force.

The development of average static pushing forces versus cone position to the initial sub-grade surface is shown in Figure 4.

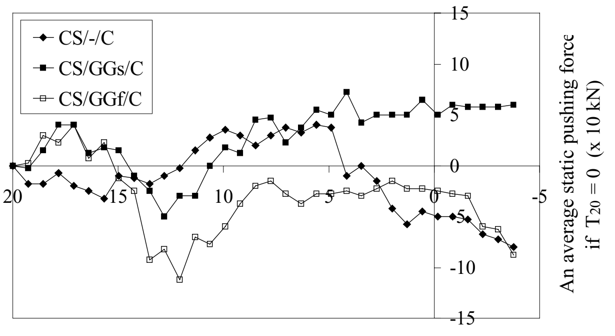


Figure 4. Relationship between cone position and pushing force at the end of the test.

Figure compares the three test arrangements. It shows is shown the test interval from h_{20} (the cone is 20 mm above initial geogrid level) to the end of the test. In order to compare the different lines, the average pushing force for point h_{20} was mentioned as follows: $T_{20} = 0$.

The level of 20 mm above geogrid level was mentioned as a top surface of improved thin layer consists of interlocking fill particles.

The difference between three lines is evident. There is a significant increase in the pushing force associated with the use of stiff geogrid.

The results obtained in this first phase of this research are summarized in Figure 5. Straight lines express the average static pushing forces. This figure is based on Figure 4. It can be noted that the pushing force decreases in system without reinforcement and in system with flexible geogrid as well. The effect of flexible geogrid from the point of view of interlocking is negligible in this case.

In system with stiff geogrid is put onto sub-grade, the pushing force is increasing at the end of the test. If the cone is close to geogrid, interlocking effect will be probably created. Resistance to the penetration of cone is slowly increased.

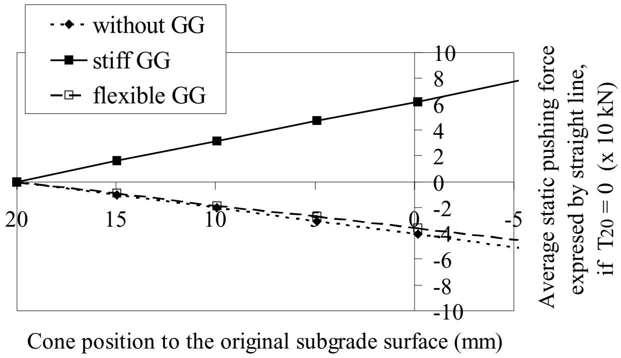


Figure 5. Relationship between cone position and average pushing force at the end of the test.

Figures 6, 7, 8 and 9 show the details of geogrids when the sub-base fill is removed.

Figure 6. The cone at the test end

Figure 7. Stiff geogrid after the test

Stiff geogrid is pushed into the soft subsoil together with fill particles (Figure 7). The most deflection is under the cone, but the deformed area is relatively large. Bending stiffness of this geogrid type is applied. Initial shape of aperture and ribs is unchanged.

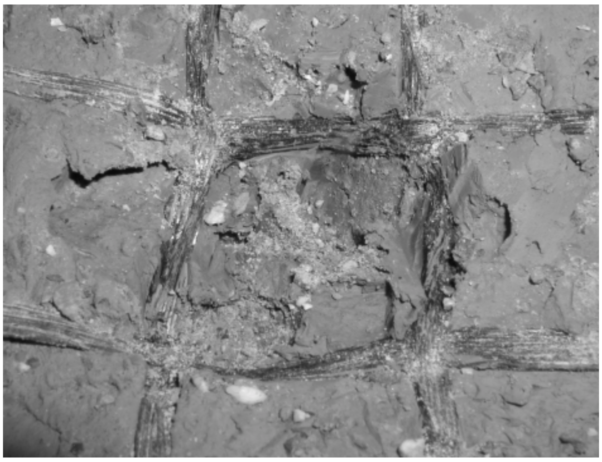


Figure 8. Flexible geogrid after the test

Figure 9. Aperture shape of flexible geogrid after the test

Figures 8 and 9 show the aperture shape of flexible geogrid after the push test. There is also changed shape of rectangular aperture and flat tensile members.

4 CONCLUSIONS

Based on the results discussed in this paper, we will study the interlocking effect, and continue to perform additional tests in an effort to establish the effectiveness of geogrids in thin sub-base on soft subsoils. The following conclusions would be pointed out.

1) The push test used to verify the interlocking effect provides suitable results for studying this phenomena.
2) The layer of crushed stone creates a very inhomogeneous mass for cone penetrating. Many tests must be done to obtain an average pushing force curve of different systems.
3) The effect of stiff geogrid in improving cone resistance was confirmed. The value of static pushing force significantly increased when cone penetrates the arching zone over geogrid.
4) The use of flexible geogrid between the sub-base and the underlying soft soil increased the pushing force just a little bit.

5) The test results showed the difference in effectiveness of stiff geogrid in comparison with flexible geogrid. If the cone penetrates the zone close to stiff geogrid surface the pushing force is increased but when the flexible geogrid is used the pushing force is decreased.
6) Further testing is underway in an effort to understand the aggregate/geogrid interaction.

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