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INTERFACIAL FRICTION PROPERTIES OF GEOCELL REINFORCED SAND

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ABSTRACT

Modified direct shear tests were carried out to investigate the interface shear properties of sand-geocell interfaces. Two different geonets with high contrast in tensile strength properties and aperture size were used to fabricate geocells. Geocells were fabricated using geonets by hand stitching in case of weaker geonet and by connecting with steel wire in case of stronger geonet. Effects of geocell pocket size on the interface shear properties was investigated for both types of geocells. Three different geocell arrangements of cell diameter 150mm, 100mm and 75mm were used in the tests. Results showed that sand-geocell interfaces showed adhesion unlike the sand alone interface, which only exhibited interfacial friction. It was observed that the tensile stiffness of geocell material plays significant role in governing the interface friction characteristics of geocell reinforced sand, apart from the pocket size of cells.

Keywords: Interface, Geocell, Geonet, Reinforced sand, friction angle.

1. INTRODUCTION

Use of geosynthetics as reinforcement in soils for mproving the performance of retaining walls, foundations and slopes etc. has received considerable attention. Any geosynthetic material employed as reinforcement has the main task of resisting applied stresses or preventing unacceptable deformations in reinforced soil structures. Soil-geosynthetic interaction parameters play important role for design and performance of reinforced soil structures. In general, cohesionless soils are preferred as backfill or neighboring soil to the reinforcement for better performance. Geocells are three dimensional cellular network of geosynthetic material, fabricated from geogrids or custom made by ultrasonic welding of polymeric sheets. These are filled with sand or aggregate and extensively used for soil reinforcement in retaining walls, embankments and roads. Several researchers tried to investigate the beneficial effects of geocell reinforced soils (e.g. Bathurst and Karpurapu, 1993; Rajagopal et al. 1999; Latha et al., 2000). Interfacial friction properties of geocells are very important to design these structures because slight variation in the adhesion or friction properties at the interface will have considerable effect on the overall performance of the structure because the additional stability of strength to the structures imparted by geosynthetic reinforcement is governed by the pullout and shear resistance offered by the geocell confined soil. Studies available on interfacial friction properties of geosynthetic reinforced soils are many

(Wang et al. 2008; Liu et al. 2009). This paper investigates the change in interface shear characteristics of sand filled geocells with the variation in the pocket size of the cells and type of geocell material through modified interface direct shear tests.

2. MATERIAL USED FOR TESTING

Sand

The soil used in the large direct shear tests was manufactured fine sand. The photograph of the sand used and its Scanning Electron Microscopic (SEM) image are shown in Fig.1 that depicts the higher angularity of the sand particles. Properties of sand are shown in Table1. Grain size distribution of sand is given in Fig. 2.

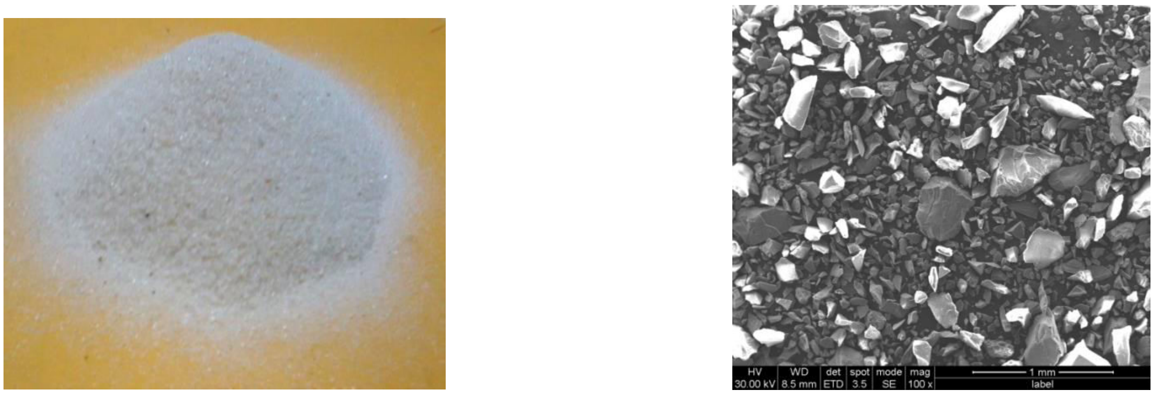


FIG 1: SAND USED AND ITS SEM IMAGE.

TABLE 1: PROPERTIES OF SAND

Sl. No	Properties	
1	Effective opening size (D10)	0.065mm
2	Co-efficient of Uniformity (Cu)	4.46
3	Co-efficient of curvature (Cc)	1.36
4	Soil Classification	SP

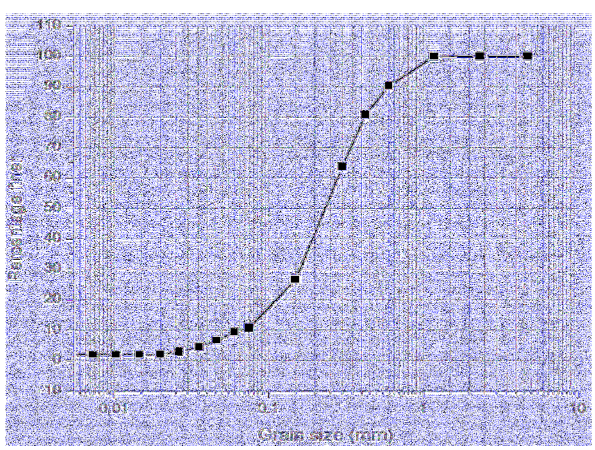


FIGURE 2: GRAIN SIZE DISTRIBUTION OF SAND

All tests were carried out at relative density of 70%. Various techniques such as pluviation technique, funnel method and multi sieve pluviation were tried to achieve this relative density. But, in no case desired density was achieved. So in this work, desired relative density was achieved by manual tamping with a steel rod. The soil was compacted in the shear box by manual tamping to provide adequate and uniform compaction at a relative density of 70%. The compaction process was carried out until the allotted soil is filled into a particular layer.

Geocell

The testing programme considered three different geocell arrangements. The diameter of the cell pockets was varied. The shear tests were conducted on three geocells of cell diameter 150mm, 100mm and 75mm. The tests were also conducted on unreinforced sand to evaluate the increase in strength. Two types of Geonets were used for making geocells as shown in Fig 3. Properties of these Geonets are given in Table 2. The geocell was fabricated by stitching a Geonet in order to get honey-comb like structure. The height of the geocell was equal to height of sand sample in lower half of the shear box. The geocell was connected to a layer of geogrid at the bottom to maintain the shape of cell. Geocell arrangements used in the study made of Geonets 1 and 2 are shown in Figure 4.

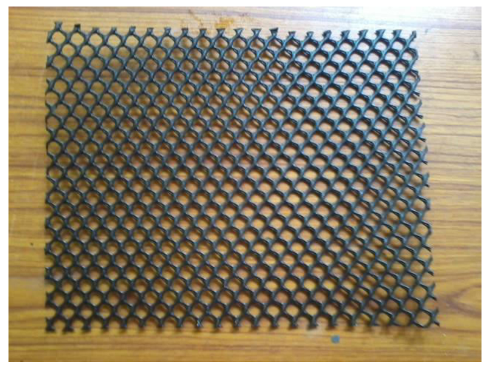


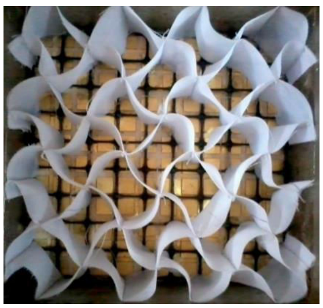
FIGURE 3. GEONETS USED TO MAKE GEOCELLS

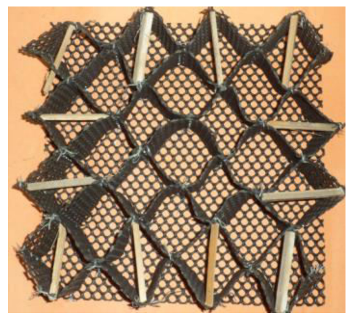
TABLE 2 PROPERTIES OF GEONETS USED TO FABRICATE GEOCELLS

Properties of Geonet	Geonet 1	Geonet 2
Mass per unit area (g/m2)	200	1200
Nominal thickness (mm)	0.5	3.0
Wide width tensile strength (KN/m)	11.6	5.96
Secant modulus of seam at 5% strain (KN/m)	38	62

Pocket size of 150mm

Pocket size of 100mm





Pocket size of 75mm

FIGURE 4 GEOCELLS MADE WITH GEONET 1(ON LHS) AND WITH GEONET 2 (ON RHS)

3. TEST SETUP

Large scale direct shear apparatus (Fig. 5) was used for conducting the tests. The dimensions of the both upper and lower half of the shear box were 304.8 mm x 304.8 mm x 115mm with a sample height of 150mm. The geocells were placed in the lower half of the shear box such that the top edge of geocells is in level with the horizontal shear plane. Sand was placed in these geocells and was compacted by tamping with a steel rod. The upper half of the box was filled with sand. The soil was compacted in the shear box by manual tamping to attain relative density of 70%. The compaction process was carried out until the allotted soil is filled into a particular layer.

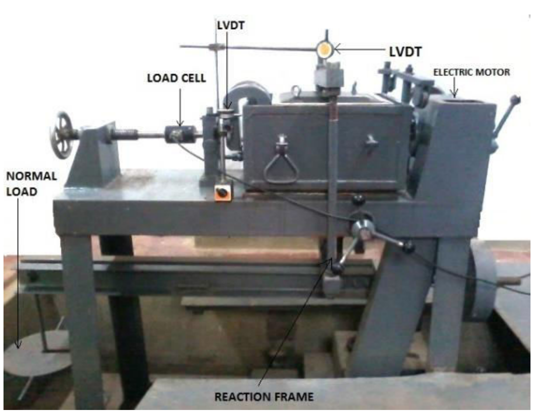


FIGURE 5: LARGE SCALE DIRECT SHEAR TEST SETUP

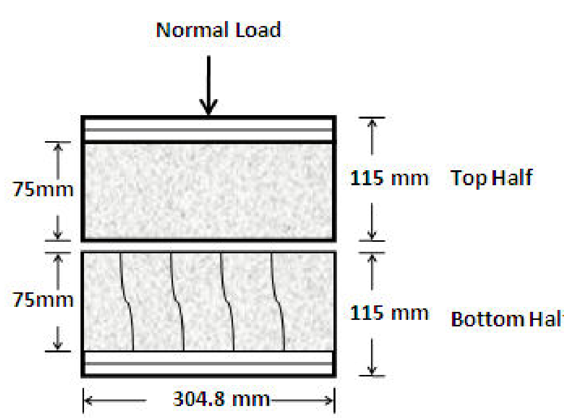


FIGURE 6: SCHEMATIC DIAGRAM SHOWING DIRECT SHEAR BOX

Shear force applied was measured using the digital load cell and the horizontal and vertical displacements were recorded using dial gauge.

4. RESULTS AND DISCUSSION

The experiment is repeated with all three types of geocells at three different normal stresses ie, 25, 50 and 75kPa. From the observed readings, shear stress- strain curve was plotted for all tests and analysed. As shown in Fig.7, in case of unreinforced sand, the shear stress increases with increasing shear displacement and only a marginal decrease in post peak shear stress was observed. Even in case of sand reinforced with geocells made of Geonet 1, the behavior is similar to that of unreinforced sand because Geonet 1 is a flexible material and does not offer much shear resistance at the interface (Fig 8).

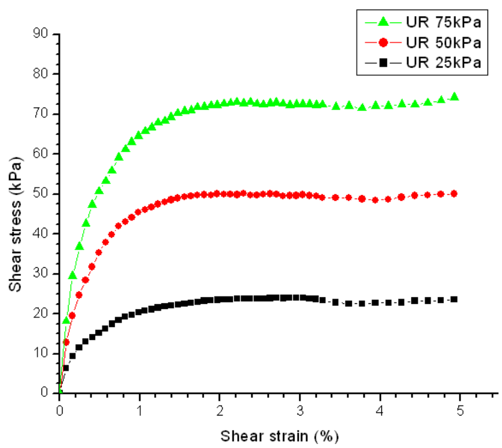


FIGURE 7: SHEAR STRESS-STRAIN BEHAVIOR OF UNREINFORCED SAND

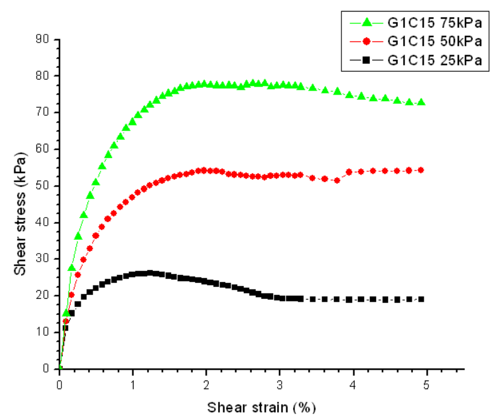


FIGURE 8: STRESS-STRAIN BEHAVIOR OF GEOCELL (G1) REINFORCED SAND

But in case of sand reinforced with geocells made of Geonet 2, which is a stiffer material, all the stress-strain curves showed clear strain softening, with significant reduction in post peak shear stresses as shown in Fig. 9. The reason for this is that initially there is a considerable degree of interlocking and additional friction on the interface between soil and geocell reinforcement.

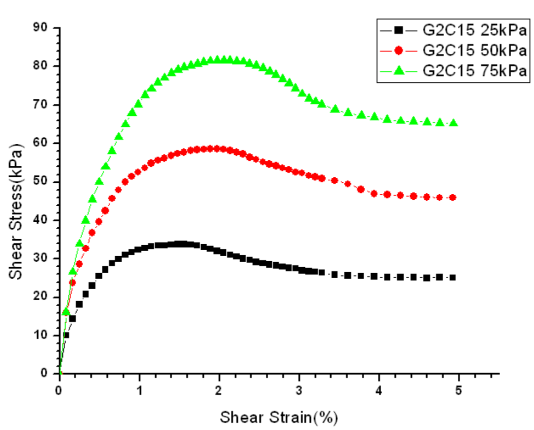


FIGURE 9: STRESS-STRAIN BEHAVIOR OF GEOCELL (G2) REINFORCED SAND OF 15 CM DIA

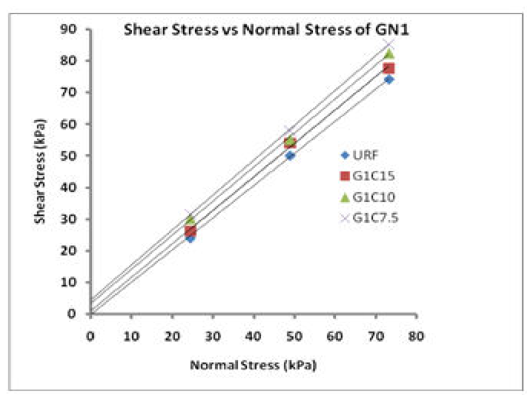


FIGURE 10 : NORMAL STRESS VS SHEAR STRESS FOR GEOCELLS MADE OF G1

Therefore, in addition to the frictional resistance at contact points, this interlocking and additional friction must be overcome before shear failure takes place. The shear stress necessary for additional deformation decreases after overcoming the interlocking and additional friction. These aspects are clearly observed from Fig. 9 for all the stress-strain plots at different normal stresses.

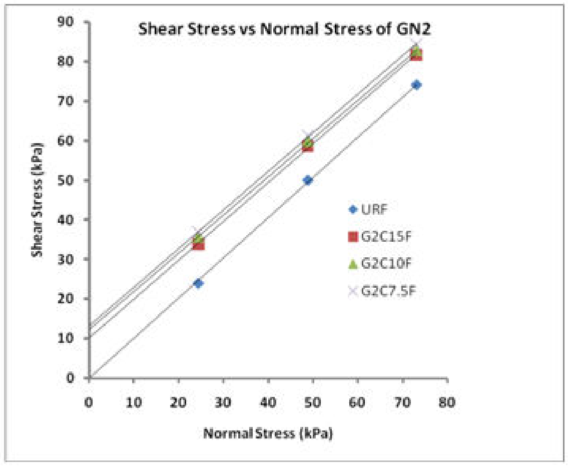


FIGURE 11: NORMAL STRESS VS SHEAR STRESS FOR GEOCELLS MADE OF G2

The normal stress vs. shear stress plots for unreinforced and geocell reinforced sands are shown in Figs. 10 and 11 for geocells made of Geonet 1 and Geonet 2 respectively. The cohesion intercept and interface friction angle observed in different tests are reported in Table 3.

TABLE 3. INTERFACIAL SHEAR PROPERTIES OF SAND

Type of sand	Geocells made of Geonet 1 c(kPa)	ϕ	Geocells made of Geonet 2 c(kPa)	ϕ
Unreinforced sand		45.4°		45.4°
Geocell 150mm dia	1.2	46.6°	10.2	44.45°
Geocell 100mm dia	3.5	47°	12.3	44.04°
Geocell 75mm dia	4.5	47.8°	13.18	44.33°

The results show an apparent cohesion even for the cohesionless sand. This cohesion can be interpreted as the apparent cohesive strength imparted by the confinement offered by the geocell reinforcement. The cohesion intercept in case of geocells of 75 mm diameter is greater than that of geocells of 100 mm and 150 mm diameter. This is due to increase in the area of soil confined by the cells

as the number of cell pockets are more. This behavior is observed for both Geonet 1 and Geonet 2 geocells.
To study the interface shear strength quantitatively, shear strength co-efficient (α) is used. The shear strength co – efficient is the ratio of shear strength of geocell reinforced soil (τ gs) to the shear strength of unreinforced soil (τ us) under same normal stress.

$$\alpha = \tau_{gs} / \tau_{us} \quad (1)$$

These shear strength coefficients calculated for various geocell reinforced cases are shown in Table 4.
The values of α shown in table are the average value of three values α for three normal stresses 25, 50, 75kPa. It is observed that, provision of geocell arrangement considerably increases the shear strength of the soil. The shear strength co–efficient is more for geocell arrangement of 75 mm diameter cells since the number of cells are comparatively more. And the α values for Geonet 2 is found to be even higher around 1.30 which shows that by using geocells made by a material with higher stiffness and tensile strength is more effective.

TABLE 4. SHEAR STRENGTH COEFFICIENT OF SAND

Type	Average Shear strength co– efficient (α)	
	GEONET 1	GEONET 2
Geocell 150 mm diameter	1.07	1.22
Geocell 100 mm diameter	1.15	1.26
Geocell 75 mm diameter	1.20	1.30

5.CONCLUSIONS

With the provision of geocells, there is an increase in the interfacial shear strength of the sand. This higher shear resistance is due to the confinement of sand within the geocells. The inclusion of geocells imparts cohesion to the sand and slight variation in friction angle.
The apparent cohesion increases with increase in number of pockets and area confined by the geocell.
Type of geocell material plays important role on the interface friction properties. Geocells made with stiffer materials exhibited better interfacial friction.

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