Sliding Shear Testing of Nonwoven Geotextile Reinforced Pilani Soil

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Abstract- Geotextiles and related products support many civil engineering applications. Geotextile is permeable textile material. Geotextile is made up of natural as well as of synthetic fibers which could be woven or nonwoven. Woven geotextiles consist of fibers or yarns of a polymer that are oriented in two perpendicular directions, one over the other. There are four main fiber types which are used to manufacture woven geotextiles: monofilament, multifilament, slit-film and fibrillated fibers. Nonwoven geotextiles consist of discrete fibers which may be oriented or randomly distributed. There are also different fiber types used to manufacture nonwoven geotextiles: continuous filaments; and staple fibers. Nonwoven geotextile made up of synthetic fiber and used as reinforcing agent in local soil has been used in present study. Sliding shear testing of nonwoven geotextile reinforced experimental soil was conducted at four different water contents to investigate the effect of water content on adhesion and on interface friction angle under these conditions. Testing was done under fully drained conditions.

Keywords - Geotextiles, Woven Geotextiles, Nonwoven Geotextiles, Sliding Shear Testing, Water Content, Adhesion, Interface Friction Angle

I. INTRODUCTION

Geotextiles were originally intended to be an alternative to granular soil filters. Thus the original, and still sometimes used, term for geotextiles is “filter fabrics”. Work originally began in the 1950s with R.J. Barrett using geotextiles behind precast concrete seawalls, under precast concrete erosion control blocks, beneath large stone riprap, and in other erosion control situations. He used different styles of woven monofilament fabrics, all characterized by a relatively high percentage open area (varying from 6 to 30%). He discussed the need for both adequate permeability and soil retention, along with adequate fabric strength and proper elongation and set the tone for geotextile use in filtration situations.

Geotextiles and related products have many applications and currently support many civil engineering applications including roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, bank protection, coastal engineering and construction site silt fences. Usually geotextiles are placed at the tension surface to strengthen the soil [1].

Geotextiles can improve soil strength at a lower cost than conventional soil nailing, In addition, geotextiles allow planting on steep slopes, further securing the slope. Coir (coconut fiber) geotextiles are popular for erosion control, slope stabilization and bioengineering, due to the fabric's substantial mechanical strength. Coir geotextiles last approximately 3 to 5 years depending on the fabric weight. The product degrades into humus, enriching the soil. Geotextile is made up of natural as well as of synthetic fibers. It could be woven or nonwoven. One important application of geotextile is as an reinforcing material in soil. In this application, geotextile interacts with soil through friction and/or adhesion to resist tensile as well as shearing forces. This friction and/or adhesion is determined using sliding shear testing [6] as one of the testing techniques.

Nonwoven geotextile made up of synthetic fiber has been used in present study. Experimental soil was collected from Birla Institute of Technology & Science, Pilani campus. Sliding shear testing of nonwoven geotextile reinforced experimental soil was conducted at four different water contents to investigate the effect of water content on adhesion and on interface friction angle under these conditions. Testing was done under fully drained conditions. Practical significance of study has also been discussed.

II. LITERATURE REVIEW

Geotextiles have been used for thousands of years. These early geotextiles were made of natural fibres, fabrics or vegetation mixed with soil. Objective was to improve road quality, particularly when roads were made on unstable soil. Only recently have geotextiles been used and evaluated for modern road construction.

A geotextile is defined as any permeable textile material that is used with foundation, soil, rock, earth, etc to increase stability and decrease wind and water erosion. A geotextile may be made of synthetic or natural fibers. It is designed to be permeable enough to allow the flow of fluids through it or in it [5]. Geotextile made up of synthetic fibers is commonly used.

Although there is a wide variety of geotextiles, they generally fall into one of two categories, woven or nonwoven.Woven geotextiles consist of fibers or yarns of a polymer that are oriented in two perpendicular directions, one over the other. Nonwoven geotextiles consist of discrete fibers which may be oriented or randomly distributed. Woven and nonwoven geotextiles vary significantly in their basic physical properties. Woven geotextiles typically range from 80 - 200 g/m^2 in mass per unit area, 0.3 - 3mm in thickness, 0.0008 - 0.01 cm/s in permeability and 0.15 - 0.85 mm for *AOS* (apparent opening size). Nonwoven geotextiles typically range from 50 - 1700 g/m^2 in mass per unit area, 0.25 - 9 mm in thickness, 0.003-0.3 cm/s in permeability and 0.075 - 0.85mm for *AOS*. The explanation for this wide range in physical properties lies in the manufacturing process.

Geotextiles are generally made from synthetic fibers rather than natural fibers. The synthetic materials, or polymers, are made in chemical processing plants from the polymerization of thermoplastics. Geotextiles are commonly made from the polymers of polypropylene (PP), polyester (PET), polyamide (nylon), or polyethylene (PE). There are no significant differences in the physical properties of these polymers, such as specific gravity (0.9 - 1.3), melting temperature (135^0C- 260^0C) and water absorption (0.0 - 2.0%); hence the polymer type has little effect on the pore-size distribution of geotextiles.

There are four main fiber types which are used to manufacture woven geotextiles: monofilament, multifilament, slit-film and fibrillated fibers. Monofilament fibers are single fibers that are manufactured from circular and quite often oblong cross-section filaments. Their diameters are the same as the diameters of the holes in the spinneret, unless they are altered through a drawing or stretching process. Monofilament fibers may be hundreds or thousands of meters in length and because the monofilament is a single fiber, the pore structure of geotextiles made from them consists mostly of large inter-fiber pores. The distribution of these pores is influenced by the diameter of the fibers, the spacing of the fibers and the type of weave. Multifilament fibers are formed from yarns which consist of many fibers. The diameters of the fibers depend on the number of monofilament fibers used, and how they are combined to form a yarn. Like the monofilament fiber, the multifilament fiber may also be hundreds or thousands of meters in length. A multifilament yarn may be formed by twisting fibers together to form one continuous strand. Multifilament geotextiles have two characteristic pore sizes (bimodal), large inter-fiber pores, like those found in monofilament geotextiles, and small intra-fiber pores, which are found between the individual monofilaments of the multifilament fibers. Slit-film fibers are made from continuously extruded flat tapes that are cut into narrow strips by knives or air jets. Slit-film fibers may be twisted and spun into slit-film yarns. Slit-film geotextiles are also bimodal in nature, as are multifilament geotextiles. Fibrillated fibers are made from extruded films, where short, discontinuous cuts have been made down their length. Fibrillated geotextiles are also bimodal in nature. The fiber type has an overall effect on the pore structure of a woven geotextile.

There are also different fiber types used to manufacture nonwoven geotextiles: continuous filaments; and staple fibers. Both fiber types are made from continuously extruded circular cross-section filaments. The only difference between the fiber types is their length. Continuous filaments are fibers of extreme length and staple fibers are very short fibers (in the range of 25-100 mm long). Staple fibers may be twisted and spun into yarns. The continuous filaments tend to have more order within the cross-section as opposed to the staple fibers, which are random throughout the geotextile. Staple fibers generally provide a much tighter pore structure than continuous filaments [2].

The mode of operation of a geotextile in any application is defined by six discrete functions: separation, filtration, drainage, reinforcement, sealing and protection. Depending on the application the geotextile performs one or more of these functions simultaneously. In the most common reinforcement application in the context of soil, the geotextile interacts with soil through frictional and/or adhesion forces to resist tensile or shear forces. To provide reinforcement, a geotextile must have sufficient strength and embedment length to resist the tensile forces generated, and the strength must be developed at sufficiently small strains (i.e. high modulus) to prevent excessive movement of the soil - geotextile reinforced structure [3]. To reinforce embankments and retaining structures, a woven geotextile is recommended because it can provide high strength at small strains.

III. EXPERIMENTAL INVESTIGATION

The materials used in the study were local soil, nonwoven geotextile and ordinary tap water. In order to conduct sliding shear testing, Geotextile was glued on wooden block having 6cm x 6cm plan area. Wooden block was just fitting in lower half of standard shear box. Inner plan area of shear box used in the study was also 6cm x 6cm.

Experimental soil was collected from Birla Institute of Technology & Science, Pilani campus. It was collected from ground surface using core cutter technique. Its specific gravity was found to be 2.577. Table 1 shows particle size distribution of experimental soil, all of which was passing through 4.75mm sieve.

Table -1 Particle Size Distribution of Experimental Soil

Particle Size	2.36mm	1.18mm	600µ	300µ	150µ	75µ	Pan
% Finer	97.4	92.8	91.6	67.2	34.0	2.4	0

Sliding shear testing of nonwoven geotextile reinforced experimental soil was conducted at 0%, 5%, 8.78% (in-situ) & 15% water contents. Results have been summarized in Tables 2 & 3. They have also been plotted in Figures 1 & 2. Equation for straight line of best fit through experimentally obtained data points is also shown in Figures 1 & 2.

Table -2 Test Results of Nonwoven Geotextile Reinforced Soil (0% & 5% Water Content)

Normal stress (kg/cm^2)	Failure shear stress (kg/cm^2) (0% water content)	Failure shear stress (kg/cm^2) (5% water content)
0.0494	0.0798	0.0835
0.0991	0.14	0.1473
0.1389	0.2037	0.1719
0.2083	0.2394	0.2394

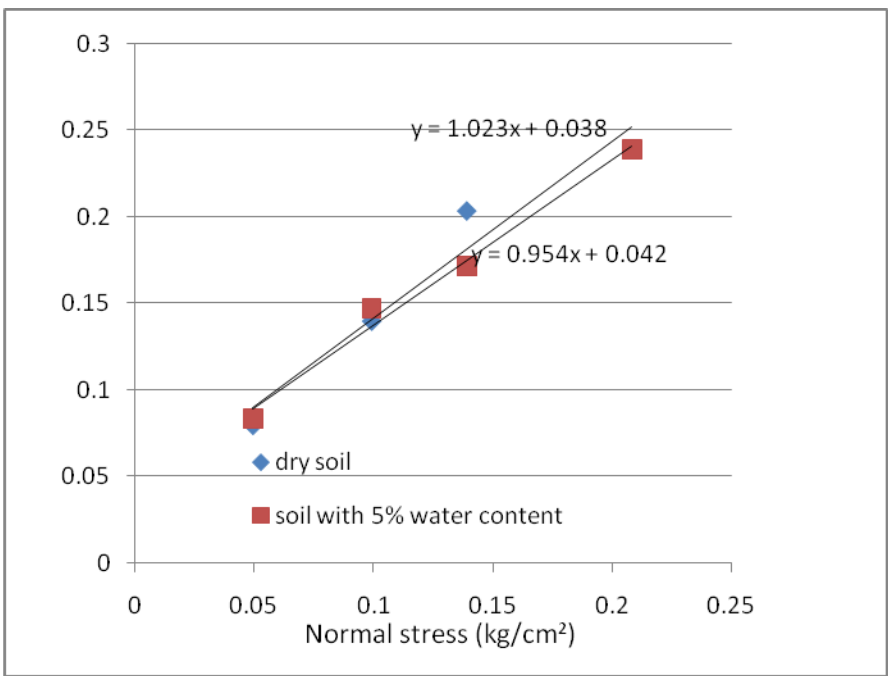

Figure 1. Test results on nonwoven geotextile reinforced soil (0% & 5% water content)

Table -3 Test Results of Nonwoven Geotextile Reinforced Soil (8.78% & 15% Water Content)

Normal stress (kg/cm^2)	Failure shear stress (kg/cm^2) (8.78% water content)	Failure shear stress (kg/cm^2) (15% water content)
0.0494	0.1044	0.1166
0.0991	0.1473	0.1473
0.1389	0.1657	0.1719
0.2083	0.2578	0.2271

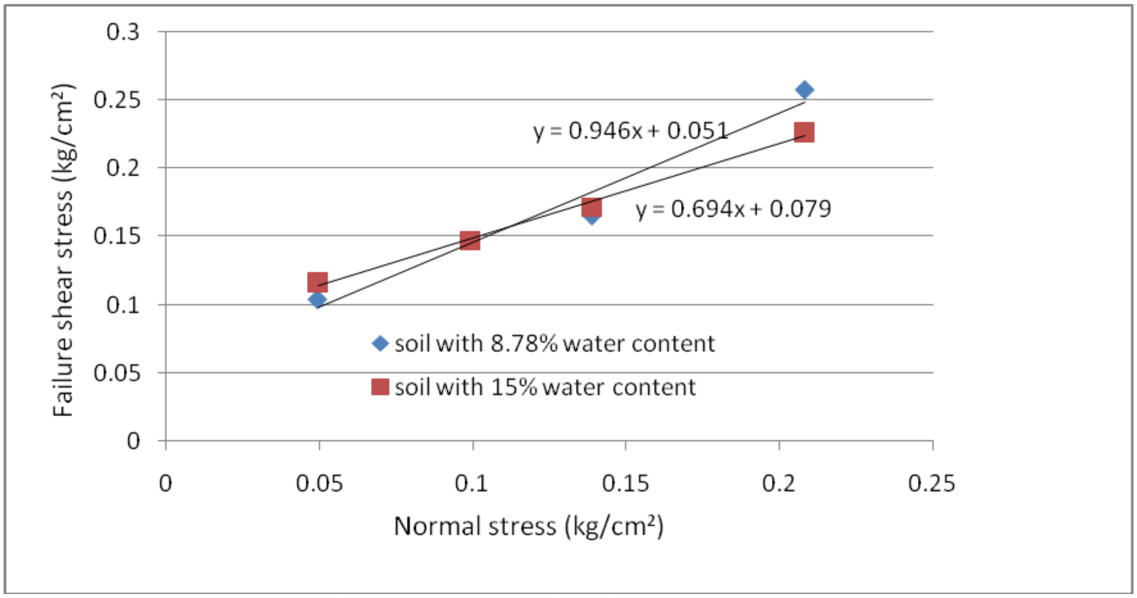

Figure 2. Test results on nonwoven geotextile reinforced soil (8.78% & 15% water content)

Adhesion and interface friction angle variation between experimental soil and nonwoven geotextile (with water content) has been shown in Table 4. These variations have also been plotted in Figures 3 & 4 respectively.

Table -4 Adhesion & Interface Friction Angle Values at Tested Water Contents

Tested water content	Adhesion (kg/cm^2)	Interface friction angle (deg.)
0%	**0.038**	**45.65**
5%	**0.042**	**43.65**
8.78% (in-situ)	**0.051**	**43.41**
15%	**0.079**	**34.76**

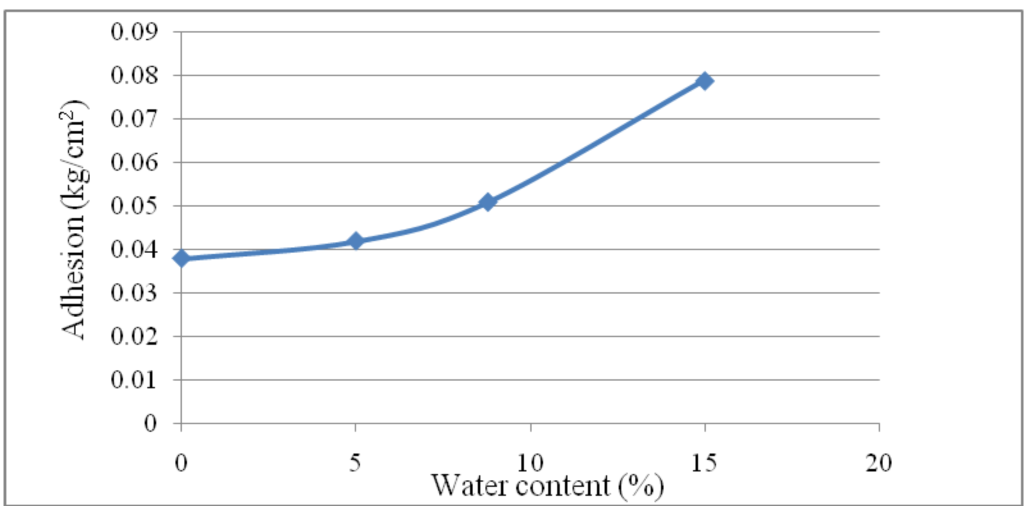

Figure 3. Adhesion variation with water content

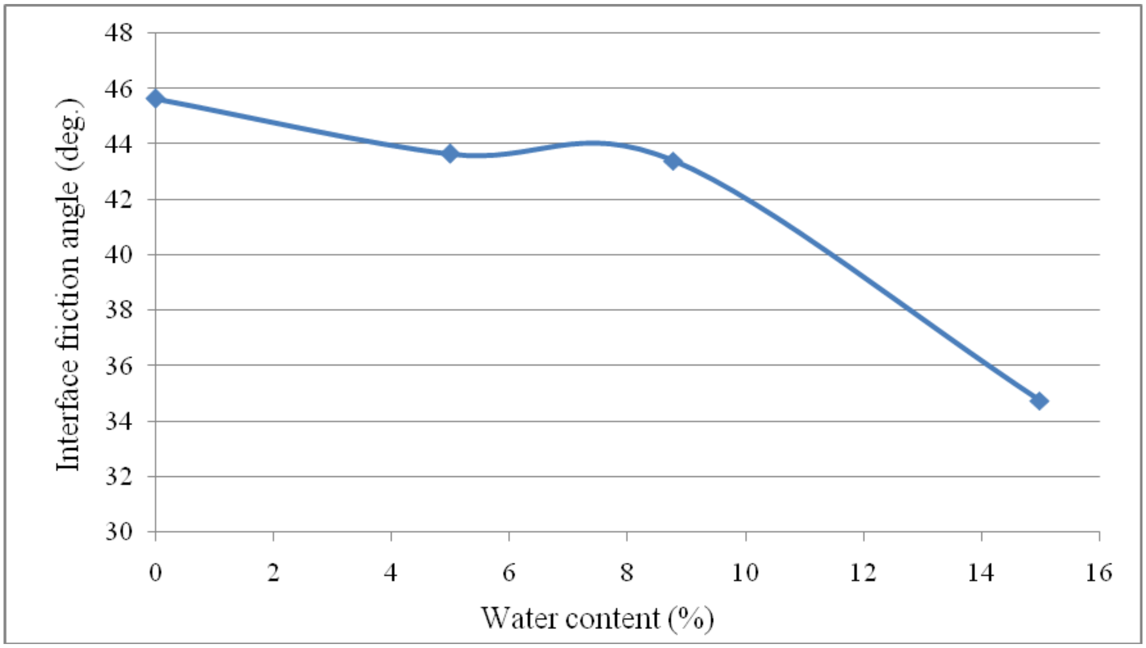

Figure 4. Interface friction angle variation with water content

IV. RESULTS AND DISCUSSION

In general, nonwoven geotextiles retain more soil fines than do woven geotextiles. The structure of mechanically bonded needle-punched fabric helps nonwoven geotextile to decrease the internal fabric clogging potential. The nonwoven geotextiles have very good permeability characteristics. They should be strongly considered where seepage flows are a concern. Nonwoven geotextiles have rougher surface than woven geotextiles. Therefore, the bond between the soil and nonwoven geotextile offers more resistance to sliding along the plane of contact. Higher interface friction angle between the two is expected, while using nonwoven geotextile as reinforcing material in soil.

Adhesion between soil and geotextiles may exist due to the interlocking of the materials at the interface [7]. The adhesion is most apparent in nonwoven geotextiles.

In-situ experimental soil (at in-situ water content) has negligible cohesion. Its angle of internal friction is around 28^0. These are obtained from direct shear testing under conditions similar to the one reported in present study. Present experimental study shows that the same experimental soil, when reinforced with nonwoven geotextile had adhesion value of 0.051 kg/cm^2 and interface friction angle value of 43.41^0. Consequently, there will be substantial shear strength gain if in-situ experimental soil is reinforced with nonwoven geotextile in appropriate geotechnical applications.

When water content in experimental soil sample was increased from 0% to 15%, adhesion between soil and nonwoven geotextile was found to increase from 0.038 kg/cm^2 to 0.079 kg/cm^2. This indicates increased interlocking of soil and nonwoven geotextile materials at the interface in aforementioned water content range.

The friction of reinforced soil with nonwoven geotextile is higher than unreinforced soil because reinforcement works in a manner that when it is placed in soil, bond is developed through frictional contact between the soil particles and the planar surface areas of reinforcement [4]. Thus, the frictional resistance is higher compared to unreinforced soil. Similar trend of varitation was observed between in-situ experimental soil and nonwoven geotextile also in the present experimental study.

When water content in experimental soil sample was increased from 0% to 15%, interface friction angle between soil and nonwoven geotextile was found to decrease from 45.65^0 to 34.76^0. This indicates increased lubricating effect of water with water content increase between soil and nonwoven geotextile materials at the interface in aforementioned water content range.

V. CONCLUSIONS

The interface friction angle and adhesion between nonwoven geotextile and soil are important variables for geotextile reinforced structure design and analysis. Results of present study show that nonwoven geotextile can effectively be used as reinforcing agent in local in-situ soil as it leads to substantial friction between geotextile and in-situ soil at the interface compared to unreinforced conditions. Although small, nonzero value of adhesion is also induced at the interface. Adhesion as well as interface friction angle was found to change with water content in present study in the range of water content studied. Hence as per geotechnical design requirement, required amount of water can be maintained in nonwoven geotextile reinforced local soil to get desired shear strength in it.

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