A study on interfacial frictional characteristics of rock flour with geotextiles

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A STUDY OF INTERFACIAL FRICTIONAL CHARACTERISTICS OF ROCK FLOUR WITH GEOTEXTILES

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ABSTRACT: Interfacial friction angle developed by fill material with reinforcing material place a vital role in the design and performance of any reinforced soil structures. Frictional fills (clean graded sands) are preferred over cohesive frictional fills in construction of reinforced soil structures such as reinforced earth retaining walls and reinforced soil beds since they exhibit higher frictional strength with reinforcements. The cost of reinforced earth construction can be reduced significantly by using an alternate cost effective material as fill that can interact with reinforcement through friction. The present work is intended to assess the potential of rock flour, a waste material available at rock crushing plants for use as fill material in the construction of reinforced soil structures. Extensive laboratory investigations are to be carried out on rock flour sample collected from various quarries to evaluate engineering properties and frictional characteristics of the material with synthetic geo fabrics. Discussion is made on the test results with regard to the utilization of rock flour as fill material in various reinforced soil structures.

INTRODUCTION:

Reinforced earth technique is now gaining popularity in construction of various civil engineering structures. The construction of any reinforced structures involves use of soil or fills material, reinforcing material and facing, if necessary. The success of technology mainly depends on the type of fill material and its interaction with reinforcing material used (Vidal, 1969; Sridharan and Hans Raj singh, 1988; Koemer, 1990). Granular soils (sands) are preferred over silts and clays in the construction of reinforced soil structures as they exhibit higher values of friction coefficients with reinforcing materials and does not show considerable decrease in friction coefficient in presence of moisture (Potyondy, 1961; Sridharan and Hans Raj Singh, 1988).

The frictional fills also called granular fills are defined as good quality, well graded, non-corrosive cohesion less material possessing good frictional characteristics. It is suggested that the effective angle of internal friction should not be less than 25 degrees (Jones 1985; Koerner, 1990). The gradation specifications of frictional fills for use in reinforced earth constructions are as that of coarse grained soils with percentage of fines less than 10 and uniformity coefficient greater than 5 (Jones, 1985). It is advantageous if some locally available granular waste material is found suitable for use as fill material in reinforced earth construction. The present work is aimed at exploring the possibility of using waste material generated at rock crushing plants, namely rock flour as fill material with synthetic reinforcement through quantitative studies on rock flour.

EXPERIMENTAL PROGRAM

Materials used:

1. Geotextiles
2. Rock Flour
3. Sand

Geotextiles: form the largest marketable material among geo synthetics. They are porous flexible fabrics manufactured from polymeric materials such as polypropylene, PVC, polyester, polyethylene and polyamide. They are supplied by manufacturer in the form of rolled sheets of various lengths and widths.

Rock flour: also called stone dust, is generated during processing of coarse aggregates from rock at rock crushing plants and is available as a waste material. The rock flour is granular material like sand with a larger amount of angular particles and it also consists of small fraction of fines. Rock Flour used in the present study is collected from a rock crushing plant near Warangal in Andhra Pradesh.

Quantification of Rock Flour The rock flour is produced in the state of Andhra Pradesh of India was used in the study. The quantity of rock flour was estimated by gathering information from local granite crushing plants. The volume of rock flour produced is about 20% of volume of rock being crushed. The volume of rock crushed at a plant depends on plant capacity. The amount of rock flour produced from a crushing plant in an average is about 6.0m^3 out of every 30m^3 of volume of rock crushed .The annual production of rock flour in the state of Andhra Pradesh is estimated at 245 Lac kN from about 400 crushing plants in developing country like India, a lot of highway projects are being taken up with exclusively use hot mix plants consequently, it results in production of rock flour.

Sand:used in the present study is collected from local stream near warangal

Table 1 Properties of soil

Slno	Property	Sand	Rock flour
1	Gravel (%) Sand (%) Silt (%) Clay (%)	10 88 02 00	0.6 96.8 2.0 0.6
2	Atterberg limits	Non-plastic	Non-plastic
3	Is soil type	SM	SP
4	OMC(%)	16.0	14.0
5	MDD(kN/m3)	18.3	20.8

S.no	Geotexile type	Property
1.	Woven geotextile (PD 381)	Material: Polypropylene Thickness: 0.096 mm under 1 kPa Grab strength 18kN/m Mass/unit area 160(g/m^2) Impact resistance 08(mm)
2.	Non- woven geotextile (Fibertex G-100)	Material: Polypropylene Thickness: 0.423 mm under 1 kPa Grab strength 16.5kN/m Mass/unit area 295(g/m^2) Impact resistance 10(mm)

Table 2 Properties of Geotextiles

METHODOLOGY

The frictional characteristics of sand and rock flour with Geotextiles are determined from Large direct shear box test and the same was compared with Modified pullout apparatus.

Large Direct Shear test Apparatus

The large direct shear machine used in this study consists of an upper box and lower box of size 300 mm long, 300 mm wide. Because the upper and lower boxes are of same size, an area correction is necessary during stress calculations of geo-synthetic–soil interface tests. The samples with dimensions of 30 cm x 30 cm in area and 8.5 cm in height were used in direct shear tests.

Testing: Once the preparation of sample was over, the testing was carried out in large direct shearmachine. For each case, three samples were tested for three different normal stresses. The normal stresses applied to the samples were 75kPa, 150kPa and 300kPa. No consolidation was allowed for the upland soil samples prior to shearing. The shear rate selected for all the tests was 1.586 mm / min.

Figure 1 *Large Direct Shear Test Apparatus*

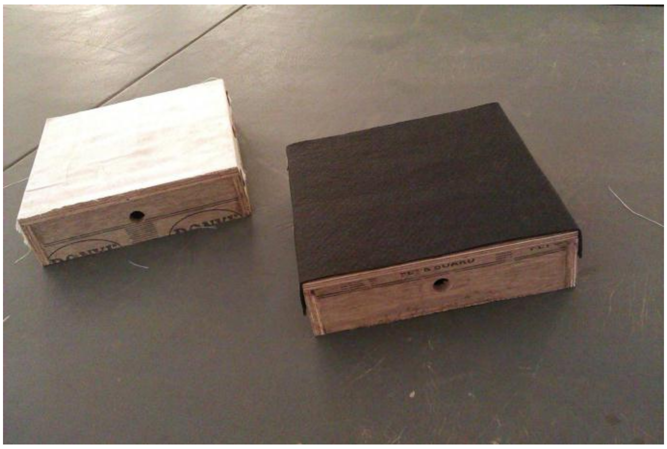

Figure 2 *Geotextiles nailed to wooden box*

Pull Out test Apparatus

The pullout tests were carried out using a specially fabricated pullout testing apparatus (Fig.3.2), with the deformation rate of 4.5mm/min. The extended geotextile was fixed to the clamping device with nut and bolt arrangement. This clamping device was connected to the tension load cell of 100kN capacity and further to the pullout unit. The dial gauge of 100mm extension was attached to the frame using a magnetic base. The pullout load was applied manually with the deformation rate of 4.5mm/min till the maximum load was recorded. The load recorded is shown digitally in load indicator.

Figure 3 Modified Pullout Apparatus

Sample Preparation:

The following procedure was used to prepare the samples with geotextiles,

1. The pullout box was filled with soil sample upto bottom of the sleeve opening to a known maximum density.
2. On that compacted layer, geosynthetic was placed throughout the length of the box, and that geosynthetic was hanged out through the sleeve opening. (Fig)
3. Later on this geosynthetic again a soil layer of 6 in. height was compacted.
4. Now the top plate was fixed and with the jack loading device, the normal stress was applied. This normal load is noted with the help of proving ring of capacity 100kN.
5. After all this setup, the pullout force is applied either by motorized equipment or by manual method at a constant rate of strain of 8mm/min, through the experiment.
6. The pullout force is applied till the maximum force is recorded in the load indicator.
7. The displacement of geosynthetics is measured by dial extensometer of 100mm length with a magnetic base fixed to the frame of the apparatus.
8. Finally the test is stopped at a failure point of geotextile by noting the corresponding load and deformation values.

Figure 4 Embedment of Geotextile into pullout box

Results and Discussions

Direct Shear Test Results

Soil-soil (SAND)

The failure envelopes derived from the direct shear tests on sand are shown in Figure 5.1. The value of peak friction angle observed at maximum density of 16.8kN/m3 is 35º. The peak shear stress values were obtained at different normal stresses of (75kpa, 150kpa and 300kpa).

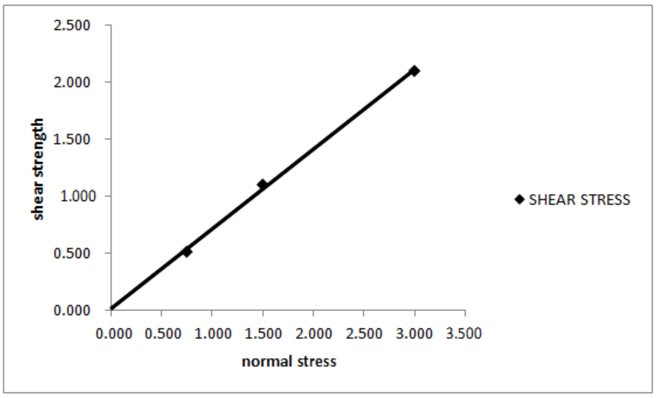

Figure 5.1 Normal stress versus shear strength for sand alone

Sand–geosynthetics

It was observed that The non-woven geotextile has slight increase in interfacial friction angle **27^0 to 29.5^0** when compared to the woven geotextile. This can be attributed to the fact that the thickness of non-woven is more than woven, and aperture size of woven geotextile is much less when compared to woven geotextile

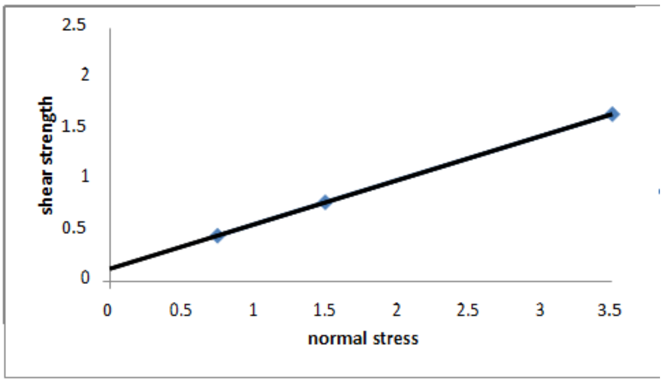

Figure 5.2 Normal stress versus shear strength for sand and woven geotextile

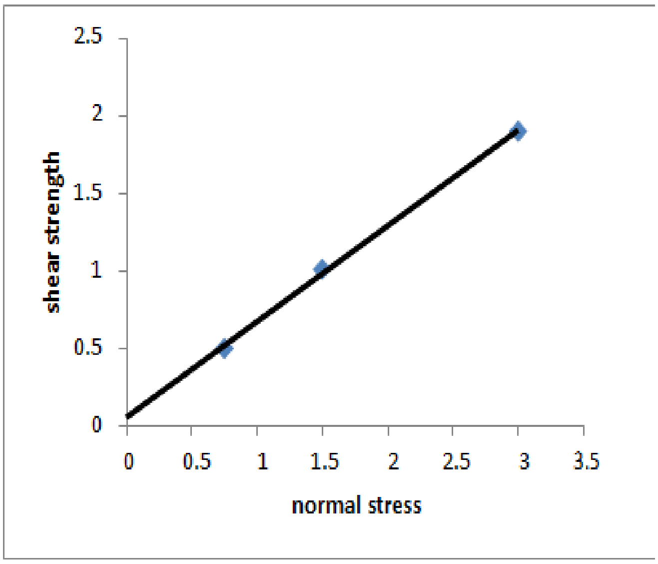

Figure 5.3 Normal stress versus shear strength for sand and non-woven geotextile

Soil-soil (rock flour)

The failure envelopes derived from the direct shear tests on Rock Flour are shown in Figure 5.4. The value of peak friction angle observed at maximum density of 20.08kN/m^3 is 47º. The peak shear stress values were obtained at different normal stresses of (75kpa, 150kpa and 300kpa).

Rock flour – geo-synthetics

It was observed that the non-woven geotextile has slight increase in interfacial friction angle **30.3^0 to 35^0** when compared to the woven geotextile.

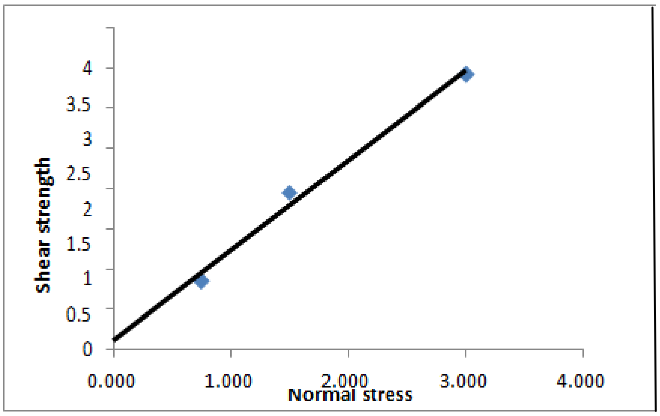

Figure 5.4 Normal stress versus shear strength for Rock Flour alone

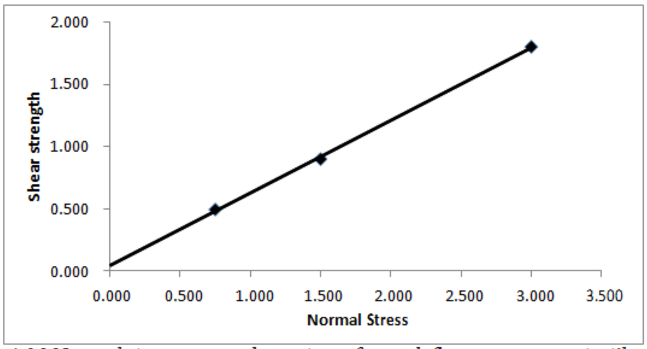

Figure 5.5 Normal stress versus shear strength for Rock Flour and woven geotextile

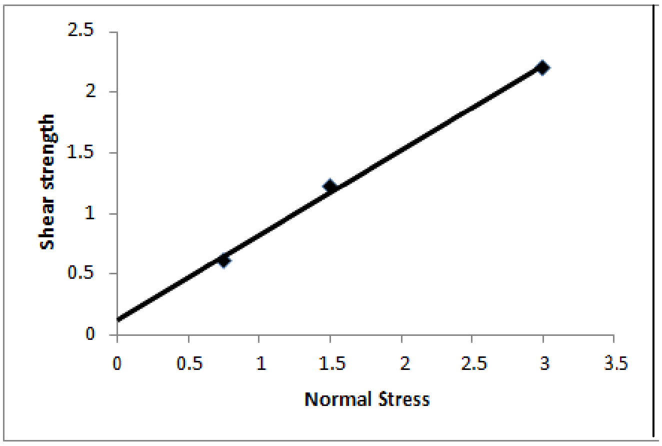

Figure 5.6 Normal stress versus shear strength for Rock Flour and Non- woven geotextile

From the above results it was observed that the interfacial angle was more for non- woven geotextile than that of woven geotextile. It was also observed that interface friction angle was more for rock flour compared to sand.

Table 3. Friction angle of Direct shear test for the test soil and soil/geosynthetics

Slno	Description	Sand	RockFlour
1	Angle of Internal Friction	**35^{0}**	**47^{0}**
2	Interfacial Friction b/w Woven textile and test soil	**27^{0}**	**30.5^{0}**
3	Interfacial Friction b/w Non-Woven textile and test soil	**29.5^{0}**	**35^{0}**

Pullout Test Results

An interaction coefficient C_i can be determined based upon the following equation. However,the value of C_i is function of soil type and test parameter specific.

$$C_i = \frac{P}{2WL\,(\sigma_n \, tan\emptyset)}$$

Where

P = maximum pullout resistance

W = width of the reinforcement (m)

L = length of the embedded portion of the reinforcement (m)

σ_n = normal total stress applied to the soil; (kN/m^2) and

$\emptyset$ = total stress friction angle of the soil.

For different normal stresses he pullout interaction coefficients varied from 0.380 to 0.800 for sand- woven geotextile. The interaction coefficients varied from 0.470 to 0.870 for sand and Non-woven geotextile. While for rock flour and woven geotextiles varied from 0.310 to 0.615. The interaction coefficients varied from 0.360 to 0.760 for rock flour and Non-woven geotextile.

Table 4.Summary of pullout test interaction coefficients (Ci) with soil/geosynthetics

Test Soil Type	37.0kN/m2	111.0kN/m^2
Sand-Woven	0.797	0.386
Sand-Non woven	0.870	0.476
Rock flour-woven	0.612	0.314
Rock Flour Non-woven	0.757	0.356

From the above results it is observed that the pullout co-efficient decreases as normal stress are increased. Simultaneously the pullout force is increased. As per the literature studies if an pullout interaction co-efficient C_i between **0.5** and **1.0** it indicates a good bond between the soil and reinforcement. Poor bonds or breakage of the geo-synthetic corresponds to **C_i < 0.5** (Tatlisoz et al.). Increasing the normal stress generally causes a decrease in interaction co-efficient as a result of increased progressive failure.

CONCLUSIONS

The following conclusions are drawn based on the present study for different soil – geo-synthetic combinations.

1. The range of specific gravity of sand lies between 2.6 to 3.2. The specific gravity of rock flour is 2.64. Other Index properties of rock flour indicate that the Rock flour can be treated as the best alternative to the sand as a backfill material as the Rock flour meeting all the standards of back fills.
2. Zero cohesion obtained for rock flour through large scale direct shear test represents pure frictional material. The angle of internal friction of rock flour (47^0) is more than the angle of internal friction of sand (35^0). Higher angle of internal friction indicates higher resistance against shear.
3. Grab tensile strength of woven & non-woven geo textiles are 18KN/m and 16.5KN/m respectively indicate that woven Geotextiles are stronger than non-woven geo textiles.
4. More interfacial friction angles between non-woven Geo textiles and back fill material (sand & rock flour) than the internal facial friction angles between woven Geo ten tiles and back fill indicate more interlocking between back fill particles and non-woven geo textiles.
5. More interfacial friction angles between rock flour and geotextiles (both woven and nonwoven) indicate that the rock flour particles are more angular than sand particles and they provide more strength to reinforcing elements.
6. The stress strain behavior of sand with woven geo textiles in pull out test under the normal stresses 37 KN/m^2 & 111 KN/ m^2 indicate homogeneity and arrived at maximum shear strength at 75mm displacement. Whereas the stress strain behavior of rock flour with woven geo textiles in pull out test indicate non homogeneity because the woven geo textiles under 37.0 KN/m^2 normal stress exhibited ductile behavior due to interlacement resistance of warp and weft yarn.

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