International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 11, November-2014

An Experimental Study on Interfacial Properties of Rock Flour and Design of Reinforced Soil Bed

C Ravi Kumar Reddy[1] , G Anugna Sai[2] , V Ratna Priya[3] , C H Hema Venkata Sekhar[4]
[1]Professor, Civil Engineering Department, K L University, Vaddeswaram-522502, Guntur, A. P
[234]PG Scholars, Civil Engineering Department, K L University, Vaddeswaram-522502, Guntur, A. P

***Abstract*— The design of Reinforced Soil Constructions such as Reinforced Earth Retaining walls, Reinforced Soil Beds, Reinforced Embankments is greatly influenced by the friction coefficient of reinforcing material and fill material. Granular or Frictional soils such as Coarse sand and moorum are preferred as fill material due to their good frictional and drainage characteristics. Due to increased construction activity, the conventional construction materials such as sand and Moorum are becoming scarce and expensive. Hence, for economizing the reinforced soil constructions, alternate low cost materials are to be explored for used as fill material. In the present work, an attempt has been made to assess suitability of rock flour for use as fill material, in the construction of reinforced soil structures.**

Rock flour samples from two different sources have been used in the study and extensive laboratory investigations have been carried out on the samples to establish engineering properties. The properties of parent rock of rock flour samples have been studied. Two types of Geo textiles (one woven and the other non woven) have been used in the study. The physical and mechanical properties of the woven and non woven geo textiles are established. The interaction of rock flour with woven and non woven Geo textiles has been studied from modified shear box tests. The interfacial shear parameters of rock flour with Geo textiles have been assessed in both dry and wet conditions. The rock flour yielded high values of friction coefficient with Geo textiles even in wet condition (f > 0.95in dry condition and f > 0.84 in wet condition for woven Geo textiles and f > 1in dry condition and f > 0.81 for nonwoven geo textiles) and hence it is promising to use in reinforced soil constructions.

Keywords—Reinforced soil bed;rock flour; interfacial property; experimental study;geotextiles

I. INTRODUCTION

Reinforced technique is now going popularity in construction of various civil engineering structures. The constructions of any reinforced soil structures involves use of soil or fill material, reinforcing material and facing, if necessary. The success of technology is mainly depends on the type of fill material and its interaction with reinforcing material used. Granular soils are preferred over clays and silts in construction of reinforced soil structures as they exhibit higher values of friction coefficients with reinforcing materials and do not show considerable decrease in the value of frictional coefficient in presence of moisture. Cohesive frictional soils are preferred in the construction of reinforced earthen embankments and dams. Cohesive frictional soils are more commonly available than the granular soils at places of construction. The frictional fills are also called as granular fills, are defined as good quality, well-graded, non-corrosive cohesion less material possessing good frictional characteristics. It is advantageous if some locally available granular waste material is found suitable for use as fill material in reinforced earth construction. The study shows that the strength of the soil bed can be improved by providing sufficient reinforcement. The geo synthetics are considered as reinforcement. The bearing capacity increase due to the use of a geo synthetic layer has been expressed in terms of a non dimensional bearing capacity ratio (BCR). The study shows that the BCR could be improved up to 1.8 times when reinforcement is suitably located relative to the footing. The horizontal reinforcement is found to be more effective in improving the bearing capacity as compared to the vertical reinforcement. **Sahu et al. (2003)** have experimented with crushed stone waste as fine aggregate in concrete. **CNVS Reddy and MVReddy (2007)** have conducted experimental study on use of rock flour and insulator ceramic scrap in concrete. **GT Rao and Andal (1996)** conducted a study on behaviour of concrete with stone sand replacing river sand. **Hussian and Perry (1978)** have conducted analysis of rubber membrane strip reinforced earth wall. **Shankar and Ali (2001)** have evaluated engineering properties of Rock Flour. **Potyondy (1961)** has studied skin friction between various soils and construction materials. **Sridhran and Singh (1988)** have studied the effect of soil parameters on friction coefficient in reinforced earth.

II. EXPERIMANTAL INVESTIGATION

A. *Experimental studies for rock flour*

1) Grain Size Analysis: The test is performed to determine the percentages of different grain sizes contained within the rock flour. The sieve analysis is performed to determine the distribution of coarser, finer and larger sized particles. The Grain size distribution is carried out by conducting Sieve Analysis, according to IS: 2270- part III-1980.

2) Specific Gravity: Specific gravity is the ratio of the mass of unit volume of the rock flour at a standard temperature to the mass of the same volume of gas free distilled water at a standard temperature. The Specific Gravity test is carried out on the rock flour samples by using Density bottle and according to IS: 2270- part III-1980.

3) Compaction Test: The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given rock flour type will become most dense and achieve its maximum dry density. IS light compaction test is conducted as per IS: 2720-part VII and IS heavy compaction test is conducted as per IS: 2720-part VIII on the different rock flour samples.

4) Direct Shear Test: A direct shear test is a laboratory or field test used to measure the shear strength properties of rock flour. Direct shear test is performed accordance with 2-1960

5) Permeability: It is the measure of the soils ability to permit water to flow through its pores or voids. Permeability test is conducted as per IS: 11209-1985 on different rock flour samples.

6) Density of Stone: Density of Stone is calculated by taking a piece of woven dried stone. Its dry weight measured and it is dipped to the water taken in 1000ml jar and the displaced amount of the water is noted and density is calculated.

7) Water Absorption Capacity: Water absorption capacity of the stone is calculated by taking the a piece of stone, it is dried in woven for 24 hours, its dry weight is noted and it is submerged in water for 24 hours, its wet weight is taken, difference in weights are calculated and water absorption capacity is calculated.

8) Free swell: Free Swell Index is the increase in volume of a soil, without any external constraints, on submergence in water.

9) Liquid limit: The liquid limit (LL) is often conceptually defined as the water content at which the behavior of a clayey soil changes from plastic to liquid. Actually, clayey soil does have very small shear strength at the liquid limit and the strength decreases as water content increases; the transition from plastic to liquid behavior occurs over a range of water content.

10) Plastic limit: The plastic limit is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The procedure is defined in ASTM standard D 4318. If the soil is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded and the test repeated. As the moisture content fails due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch). A soil is considered non-plastic if a thread cannot be rolled out down to 3.2 mm at any moisture.

B. Properties of Woven and non woven Geo textiles

Extensive laboratory investigations are carried out to obtain properties of Woven and Non Woven Geo textiles. The details of tests are given below.

1) Mass Per Unit Area: Mass per unit area of the woven and non woven Geo textiles are calculated by taking the Geo textile specimen in regular size. Mass per unit area of the woven and non woven Geo textiles are calculated by measuring mass and area of the specimen.

2) Thickness: Thickness of Woven and Non Woven Geo textiles is measured as the distance between the upper and lower surface of the fabric, measured at a specific pressure (2.0kPa). ASTM D 1777 stipulates that the thickness is to be measured to an accuracy of at least 0.001in.The thickness of commonly used Geo textiles range from 10 to 300 mils.

3) Compressibility: Compressibility of a fabric is its thickness at varying applied normal pressures. For most Geo textiles the compressibility is relatively low. For non woven needle-punched or bulky resin-bonded fabrics, however compressibility is very important.

4) Grab Tensile Strength: Tensile Strength is the most important property of the Geo textiles. This test is an index test used to determine the tensile strength of Geo textiles using grab method under specified test conditions. The basic idea of the test is to place the fabric within a set of clamps or jaws, place this assembly in a testing machine, and stretch the fabric until failure occurs. Fabric failures are generally easy to identify. During the extension process, it is customary to measure both load and deformation in such a way that a stress – versus – strain curve can be generated.

C. Interfacial Shear Parameters of rock flour with Woven and Non Woven Geo textiles

Modified shear test: Modified Direct Shear Tests are conducted on the rock flour in OMC and MDD condition and also in wet Condition to evaluate the shear parameters cohesion and the angle of interfacial friction with Woven and Non Woven Geo textiles. During the test a wooden piece is placed as a rigid material in the lower half of the shear box and the Geo textile is placed on it. In the upper half of the shear box, rock flour is placed by compacting at OMC and MDD condition. The Interfacial Shear parameters obtained are tabulated in Table 4.1. Failure envelops of different samples with woven Geo textiles are shown in the Figures 4.2 and 4.3 and with non woven Geo textiles are shown in Figures 4.4 and 4.5.

III. RESULTS AND DISCUSSIONS

A. Properties of rock flour

TABLE I. ROCK FLOUR PROPERTIS

S.No	*Engineering Property*	*Sample 1*	*Sample 2*
1	Specific Gravity	2.77	2.70
2	Grain Size Analysis		
	(a) Gravel Size (%)	9.1	14.2
	(b) Sand Size (%)	81.9	70.4
	(c) Fine (%)	9.0	14.4
	(d) Coefficient of Uniformity	25.60	17.14
	(e) Coefficient of Curvature	0.671	0.933
	(f) IS Classification	SP-SM	SP-SM
3	Maximum Dry Unit Weight(kN/m^3)		
	(a) IS Light Compaction	19.9	21.1
	(b) IS Heavy Compaction	21.4	23.6
4	Shear Strength Parameters		
	(a) Dry Condition		
	Cohesion	0	0
	Angle of Internal Friction	48º	47º
	(b) Wet Condition		
	Cohesion	0	0
	Angle of Internal Friction	43º	41º
5	Coefficient of Permeability (cm/sec)	6.724×10^{-3}	4.9×10^{-3}
6	Density of Stone (g/cc)	2.6	2.53
7	Water Absorption of Stone (%)	0.96	0.92

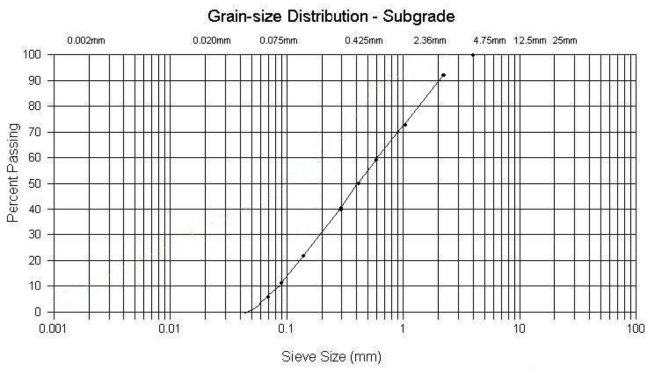

Fig. 1. Sieve analysis of sample1

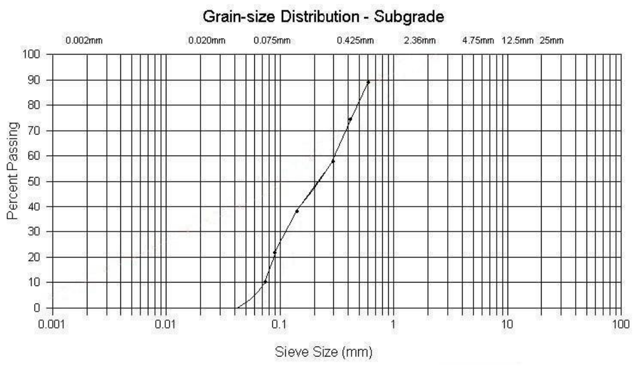

Fig. 2. Sieve analysis of sample2

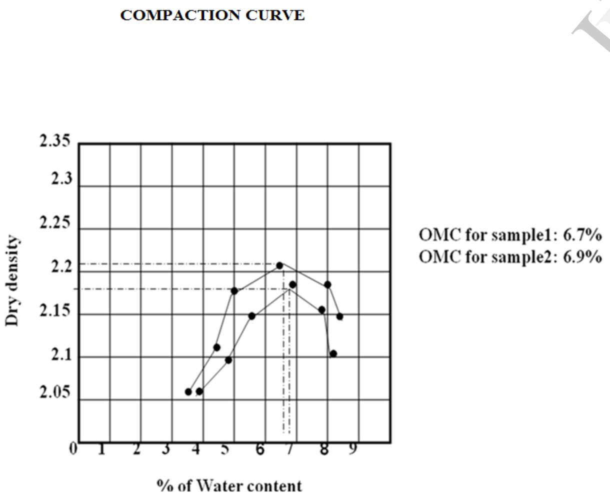

Fig. 3. Compaction curves

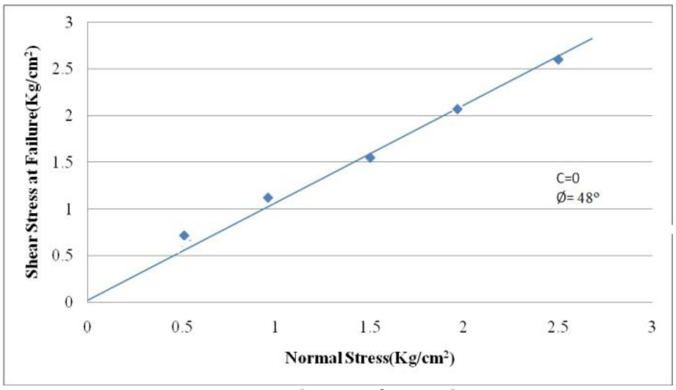

Fig. 4. Shear test for sample1

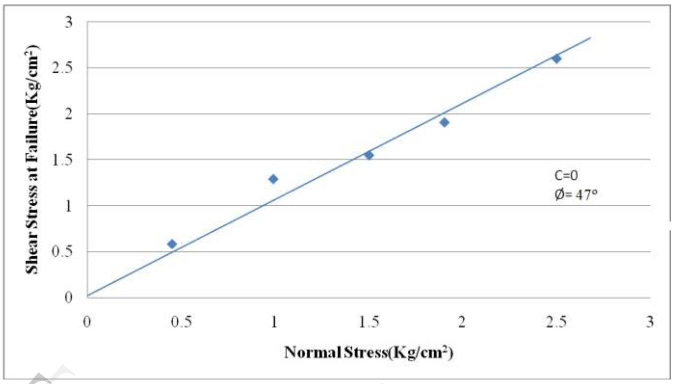

Fig. 5. Shear test for sample2

B. Properties of black cotton soil

TABLE II. BLACK COTTON SOIL PROPERTIS

S.No	Engineering Property	Sample
1	Specific Gravity	2.6
2	Grain Size Analysis	
	(a) IS Classification	CL
	(b) Coefficient of Uniformity (Cu)	8
	(c) Coefficient of Curvature (Cc)	0.18
3	Maximum Dry Unit Weight(kN/m^3)	
	(c) IS Light Compaction	19
	(d) IS Heavy Compaction	21
4	Liquid limit (%)	32
5	Plastic limit (%)	30
6	Shear Strength Parameters	
	(c) Dry Condition	
	Cohesion	0
	Angle of Internal Friction	36º
	(d) Wet Condition	
	Cohesion	0
	Angle of Internal Friction	35º

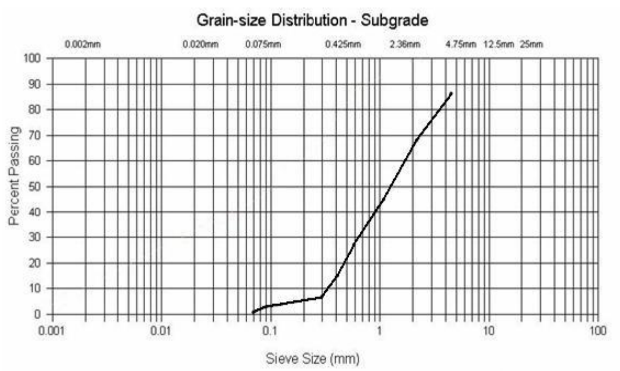

Fig. 6. Sieve analysis of Black cotton soil

C. Properties of geotextile

TABLE III. GEOTEXTILE PROPERTIS

S.No	Property	Woven Geotextile	Nonwoven Geotextile
1	Mass per unit Area(g/m^2)	136	249
2	Thickness (mm)	0.276	1.335
3	Compressibility (mm/Kpa)	0.01	0.06
4	Grab Tensile Strength(KN)	1.6	1.3

D. Interaction of rock flour with geotextile

1) Shear parameters of rock flour sample1with woven and nonwoven geotextiles:

TABLE IV. INTERFACIAL SHEAR PARAMETERS OF SAMPLE1

Interfacial Shear Parameters	Woven Geo textiles		Non Woven Geo textiles	
	Dry Condition	Wet Condition	Dry Condition	Wet Condition
Adhesion	0	0	0	0
Angle of Interfacial Friction	45°	43°	46°	39°

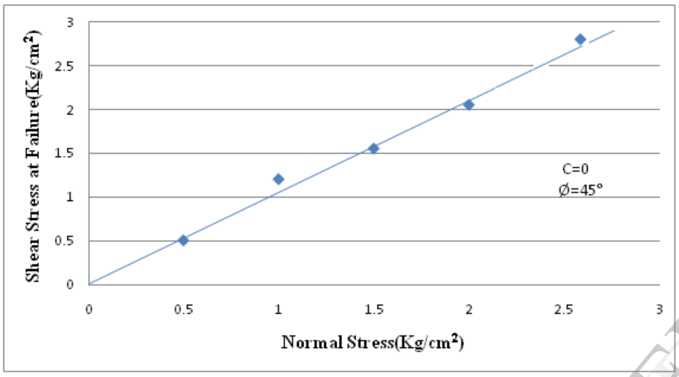

Fig. 7. Failure envelop of rock flour with woven Geotextile in dry condition

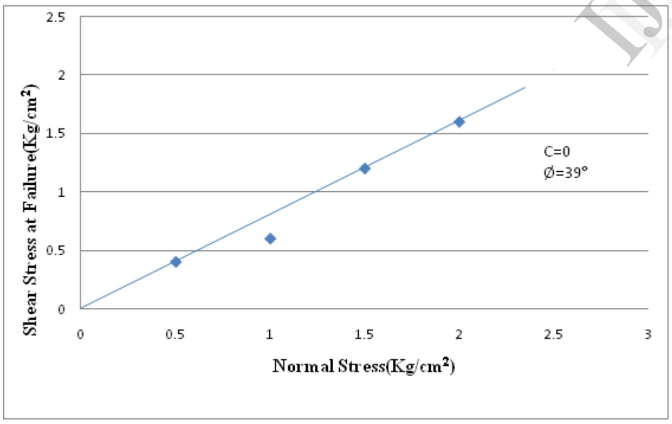

Fig. 8. Failure envelop of rock flour with nonwoven Geotextile in wet condition

2) Shear parameters of rock flour sample2with woven and nonwoven geotextiles:

TABLE V. INTERFACIAL SHEAR PARAMETERS OF SAMPLE2

Interfacial Shear Parameters	Woven Geo textile		Non Woven Geo textile	
	Dry Condition	Wet Condition	Dry Condition	Wet Condition
Adhesion	0	0	0	0
Angle of Interfacial Friction	44°	40°	46°	39°

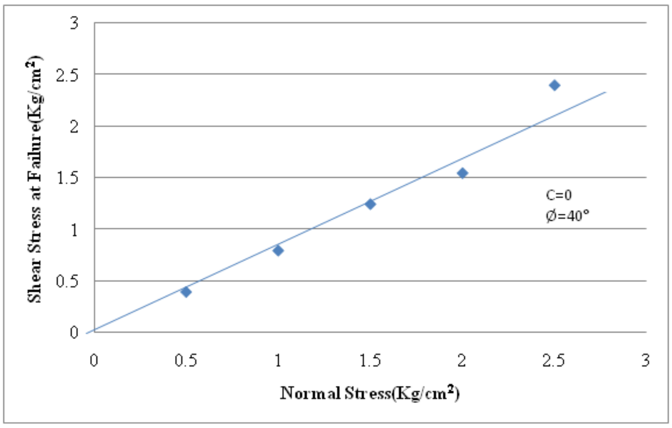

Fig. 9. Failure envelop of rock flour with woven Geotextile in wet condition

3) Shear parameters of rock flour sample2with woven and nonwoven geotextiles:

TABLE VI. FRICTIONAL COEFFICIENT OF ROCK FLOUR WITH GEOTEXTILE

Rock Flour Samples	Frictional Coefficient			
	Woven Geo textiles		Non woven Geo textiles	
	Dry Condition	Wet Condition	Dry Condition	Wet Condition
Rock Flour Sample 1	1	0.932	1.035	0.809
Rock Flour Sample 2	0.965	0.839	1.035	0.809

E. Design of reinforced soil bed

Design of reinforced soil beds have been carried out by using black cotton soil and rock flour as back fill materials. The results have been summarized and presented.

TABLE VII. BLACK COTTON SOIL AS BACK FILL

Determination	**Sheet reinforcement**	**Strip reinforcement**	**Grid reinforcement**
Safe bearing capacity (q)	32 T/m²	32 T/m²	32 T/m²
Allowable bearing capacity	19.77 T/m^2	19.77 T/m^2	19.77 T/m^2
Net ultimate bearing capacity	15.77T/m²	15.77T/m²	15.77T/m²
Net safe bearing capacity	6.308 T/m^2	6.308 T/m^2	6.308 T/m^2
Net allowable bearing capacity	10.3 T/m^2	10.3 T/m^2	10.3 T/m^2
BCR	3.10	3.10	3.10
Developed tie force	9 T/m^2	9 T/m^2	9 T/m^2
Tie frictional resistance	32	26.8	36
Allowable soil tie friction coefficient	0.2	0.16	0.24
Tie frictional resistance	9.45 T/m^2	8.36T/m^2	11.9 T/m^2
The maximum required length (L)	4.9m	7.1m	2.8m
Length of layer 2	4.5m	6.7m	2.4m
Length of layer 3	4.5m	6.7m	2.4m
Length of layer 4	4.5m	6.7m	2.4m
Length of layer 5	4.6m	6.8m	2.5m
Thickness of the reinforcement	6.56mm	6.56mm	6.56mm

TABLE VIII. ROCK FLOUR AS BACK FILL

Determination	Sheet reinforcement	Strip reinforcement	Grid reinforcement
Safe bearing capacity (q)	32 T/m²	32 T/m²	32 T/m²
Allowable bearing capacity	24.73 T/m^2	24.73 T/m^2	24.73 T/m^2
Net ultimate bearing capacity	20.88 T/m^2	20.88 T/m^2	20.88 T/m^2
Net safe bearing capacity	8.35 T/m^2	8.35 T/m^2	8.35 T/m^2
Net allowable bearing capacity	12.05 T/m^2	12.05 T/m^2	12.05 T/m^2
BCR	2.6	2.6	2.6
Developed tie force	7.98 T/m^2	7.98 T/m^2	7.98 T/m^2
Tie frictional resistance	32	26.8	36
Allowable soil tie friction coefficient	0.2	0.16	0.24
Tie frictional resistance	9.6 T/m^2	7.69 T/m^2	11.5 T/m^2
The maximum required length (L)	3.9m	6.7m	1.9m
Length of layer 2	3.5m	6.3m	1.5m
Length of layer 3	3.5m	6.3m	1.5m
Length of layer 4	3.5m	6.3m	1.5m
Length of layer 5	3.6m	6.4m	1.6m
Thickness of the reinforcement	8.81mm	8.81mm	8.81mm

F. Summary of results

1) Summary on Work Carried Out on Rock Flour

Engineering properties of rock flour indicate that the rock flour samples contain more percentage of sand. Based on gradation and plasticity characteristics it is classified as poorly graded silty sand (SP-SM) as per ISSCS (Indian Standard Soil Classification System). The rock flour samples exhibited good frictional characteristics in OMC and MDD condition(value of Ø for sample 1 is 48° and for sample 2 is 47°) and even in wet condition also the interfacial friction angles are high(value of Ø for sample 1 is 43° and for sample 2 is 41°). Rock flour specimens have normally good drainage (k > 4.9×10^{-3}cm/s). Hence it can be concluded that rock flour is a coarse grained material with good frictional and drainage characteristics. Rock flour samples used for study satisfy the requirements of the good fill material.

2) Summary of Work Carried out on Geo textiles

The results indicate that the woven Geo textiles (0.276mm) are thin compared to non woven Geo textiles (1.335mm). From the test results it can be seen that the woven Geo textiles have less compressibility compared to non woven Geo textiles.

3) Summary of Work Carried Out on Modified Shear Test

The test results shown in Table 4.1, indicates that rock flour sample (1) exhibited higher values of interfacial friction angles with woven (value of Ø in dry condition is 45° and in wet condition is 43°) and non woven Geo textiles (value of Ø in dry condition is 46° and in wet condition is 39°) in OMC and MDD condition and also in wet condition. Table 4.2, indicates that rock flour sample (2) also exhibited higher values of interfacial friction angles with woven (value of Ø in dry condition is 44^o and in wet condition is 40^o) and non woven Geo textiles (value of Ø in dry condition is 46° and in wet condition is 39°) in dry and wet condition. Woven Geo textiles exhibited high interfacial frictional angles in wet condition compared to the non woven Geo textiles because of high thickness and compressibility of non woven Geo textiles.

IV. CONCLUSIONS

- From the investigated data it can be concluded that the rock flour is coarse grained material with good frictional (Ø=39° in wet condition) and Drainage (k>4.9×10-3cm/s) characteristics.
- From the case studies it is observed that the rock flour is economical than the black cotton soil
- It can be noted from the experimental study that the Rock flour satisfies the requirements of frictional fill as it can be used in construction of Reinforced Soil Structures. Higher value of angle of internal friction is due to parent rock, Basalt
- From the experimental results (Modified Box shear test) Rock flour mobilizes high friction coefficient with Geo synthetic material than the black cotton soil
- The frictional coefficient mobilized by rock flour with woven Geotextiles is relatively more than that of non woven Geo textiles.
- Hence Rock flour can be effectively utilized as fill material in construction of Reinforced Earth Structures such as Reinforced Earth Retaining Wall Reinforced Soil Bed, and Reinforced Embankments

REFERENCES

[1] A.K.Sahu, S.Kumar and A.K.Sachin, "Crushed Stone Waste as Fine Aggregate for Concrete", Indian Concrete Journal, January 2003.

[2] C.N.V.S.Reddy and M.V.Reddy, "An Experimental Study on Use of Rock Flour and Insulator Ceramic Scrap in Concrete", IE (I) Journal-CV, Vol.88, August 2007.

[3] G.T.Rao and T. Andal, "A Study of Behaviour of Concrete with Stone Sand Replacing River Sand", National Conference on Alternate Construction Materials in Civil Engineering", Hamirpur, PP.196-201, 1996.

[4] Hussian. A and Perry.E.B, "Analysis of Rubber Membrane Strip Reinforced Earth Wall. Proceedings of Symposium on Soil Reinforcing and Stabilizing Techniques", Sydney, 1978.

[5] N.B. Shankar and Md. Ali, "Engineering Properties of Rock Flour", National Conference on Cement and Building Materials from Industrial Waste, PP. 167-172, July 1992

[6] Potyondy.J.G, "Skin Friction Between Various Soils and Construction Materials", Geotechniques,Vol II,No.4,PP.339-353, 1961.

[7] Sridhran.A and Hansan Raj Singh, "The Effect of Soil Parameters on Friction Coefficient in Reinforced earth". Indian Geotechnical Journal, Vol. 18, No.4, 1988.