Potential of rock flour for use in reinforced soil construction

POTENTIAL OF ROCK FLOUR FOR USE IN REINFORCED SOIL CONSTRUCTION

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ABSTRACT: Interfacial friction angle developed by a fill material with reinforcing material plays 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 paper 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 were carried out on rock flour samples collected from various quarries to evaluate engineering properties and frictional characteristics of the material with synthetic geofabrics. Detailed discussion is made on the test results and conclusions are drawn regarding the utilization of rock flour as fill material in various reinforced soil constructions.

INTRODUCTION

Reinforced earth technique is now gaining popularity in construction of various civil engineering structures. The construction of any reinforced soil structures involves use of soil or fill material, reinforcing material and facing, if necessary. The success of the technology mainly depends on the type of fill material and its interaction with reinforcing material used (Vidal, 1969; Sridharan and Hans Raj Singh, 1988; Koerner, 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 the value of friction coefficient in presence of moisture (Potyondy, 1961; Sridharan and Hans Raj Singh, 1988). 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, also called granular fills are defined as good quality, well-graded, non-corrosive cohesionless material possessing good frictional characteristics. It is suggested that effective angle of internal friction should not be less than 25^0(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 and qualitative studies on rock flour.

The investigations on soil-geofabric system indicate that the mobilized friction parameters of synthetic fabrics are effected by surface texture, thickness of fabric as well as type, density and moisture content of soils (Makiuchi and Miyamori, 1988). It has been reported that the mobilised friction angle for the geofabrics ranges from 0.75 to 0.90 times the friction angle of soils. Studies on geotextile-soil friction evaluation (Venkatappa Rao and Pandey, 1988) revealed that the pullout tests gave higher values of friction angle than that obtained from modified shear box tests. So the values of friction angle determined from modified shear box tests can be used in the design of reinforced soil structures, though the values are conservative, but lead to a safe design. So in the present study, modified shear box tests (Hussaini and Perry, 1978) were conducted to study the interfacial friction angles of rock flour with synthetic geofabrics. The test involved filling the upper half of shear box with fill material and lower half with some other materials like wood to support reinforcing fabric so as to cause shearing between fill material and reinforcing fabric during testing. The shearing of the specimens was done similarly to conventional box shear testing at different normal pressures.

ROCK FLOUR

Rock flour, also called stone dust, is generated during processing of coarse aggregates from rock at rock crushing plants and is available as waste material. The rock flour is a granular material like sand with a larger amount of angular particle. Rock flour is a stable material under varying moisture conditions since it contains the rock minerals such as quartz, feldspar and silica. At present, rock flour is used in basement filling of buildings, mechanical stabilization of subbase and base courses and to improve roughness of bituminous surface course.

Quantification of Rock Flour

The rock flour 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 percent 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 on an average is about 6.0 m^3 out of every 30 m^3 of volume of rock crushed per day. 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 which

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exclusively use hot mix plants. Consequently, it results in production of large volume of rock flour.

Engineering Properties of Rock Flour

Samples of rock flour were collected from rock crushing plants located at and around Warangal. Extensive laboratory investigations were carried out to obtain its engineering properties. As the rock flour is a granular material, its maximum dry unit weight was determined using the Indian Standard (I.S.) light and heavy compaction tests (equivalent to standard and modified proctor compaction tests of ASTM) and also from vibrating technique. The minimum dry unit weight was hand filling rock flour into the compaction mould in dry condition. The values of angle of internal friction and CBR of the rock flour were evaluated in dry and wet conditions at its maximum dry unit weight corresponding to the I.S. light and heavy compaction conditions. The coefficient of permeability determined from constant head permeability tests. The strength envelopes of rock flour in light and heavy compaction conditions obtained from direct shear tests are presented in Figs. 1 and 2. Laboratory studies were also conducted to study the capillary rise in rock flour in its loosest and densest forms obtained from light and heavy compaction conditions. The average values of engineering properties of rock flour obtained from the laboratory investigations are presented in Table 1.

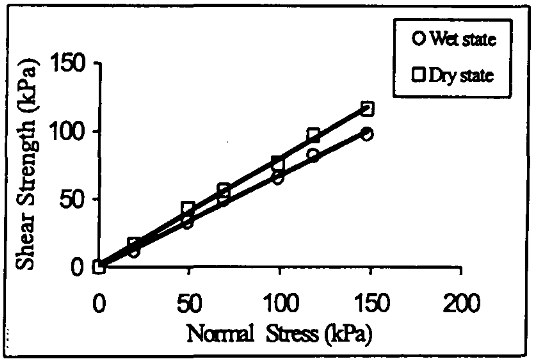

Fig. 1 Strength envelope of rock flour in light compaction condition

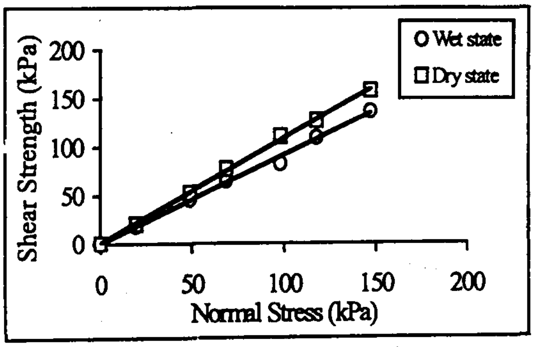

Fig. 2 Strength envelope of rock flour in heavy compaction condition

Table 1 Engineering Properties of Rock Flour

S. No.	Engineering Property	Value
1.	Specific Gravity	2.62
2.	Grain Size Analysis	
	a) Gravel size (%)	01
	b) Sand size (%)	90
	c) Fines (%)	09
	d) Coefficient of uniformity	8.6
	e) Coefficient of curvature	2.2
3.	Minimum Dry Unit Weight (kN/m^3)	13.7
4.	Maximum Dry Unit Weight (kN/m^3)	
	a) Light Compaction	17.2
	b) Heavy Compaction	18.6
	c) Under vibrations	18.8
5.	Coefficient of Permeability (m/s)	
	a) Densest state	5.3×10^{-5}
	b) Loosest state	3.8×10^{-4}
6.	Shear Strength Parameters	
	a) Cohesion (kPa)	0.00
	b) Angle of Internal Friction	
	I.S Light Compaction	
	i) Dry Condition	39^0
	ii) Wet condition	36^0
	I.S Heavy Compaction	
	i) Dry Condition	47^0
	ii) Wet condition	45^0
7.	CBR Value (%)	
	I.S Light Compaction	
	a) Dry Condition	28
	b) Wet condition	26
	I.S Heavy Compaction	
	a) Dry Condition	48
	b) Wet condition	46
8.	Capillary Rise (m)	
	a) Loosest state	0.10
	b) Densest state	
	i) Light compacted	0.16
	ii) Heavy compacted	0.22

Table 2 Properties of Geotextiles

Property	Woven Geotextile	Non-Woven Geotextile
Type	GWF 26-130	Terram B 30
Specific surface	190 g/m^2	300 g/m^2
Grab tensile strength	1.04 kN	1.30 kN

REINFORCING MATERIAL

In the laboratory investigation, woven and nonwoven geotextiles were used as reinforcing material with rock flour. The properties of geotextiles are given in Table 2.

FRICTIONAL CHARACTERISTICS OF ROCK FLOUR WITH GEOTEXTILES

The frictional characteristics of rock flour with woven and nonwoven geotextiles were determined from modified shear box tests. In the shear box, the geotextile layer was placed on the wooden block in lower half and the rock flour was filled in the upper half at its maximum dry unit weight. The test specimens were sheared at different normal pressures in dry and wet conditions to get the corresponding shear strengths. The angle of interfacial friction (ϕ_μ) was obtained by plotting the strength envelopes. The test specimens were prepared at maximum dry unit weight corresponding to light and heavy compaction conditions and tested to determine the values of interfacial friction angle. The strength envelopes of rock flour with woven and nonwoven geotextiles are as shown in Figures 3, 4, 5 and 6. The frictional characteristics of rock flour with the synthetic fabrics are presented in Table 3.

Table 3 Frictional characteristics of rock flour with geotextiles

S. No.	Reinforcing Material with Rock Flour	Interfacial Friction Angle	
		Light Compaction	Heavy Compaction
1.	Woven Geotextile		
	a) Dry condition	35°	45°
	b) Wet condition	32°	42°
2.	Nonwoven Geotextile		
	a) Dry condition	35°	42°
	b) Wet condition	33°	40°

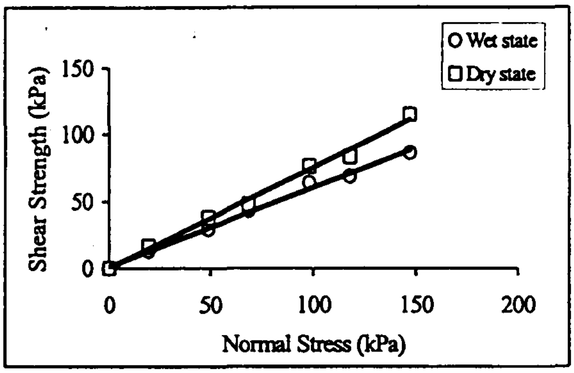

Fig. 3 Strength envelope of rock flour with woven geotextile in light compaction condition

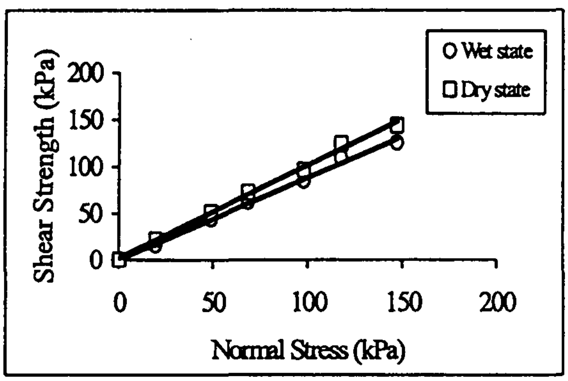

Fig. 4 Strength envelope of rock flour with woven geotextile in heavy compaction condition

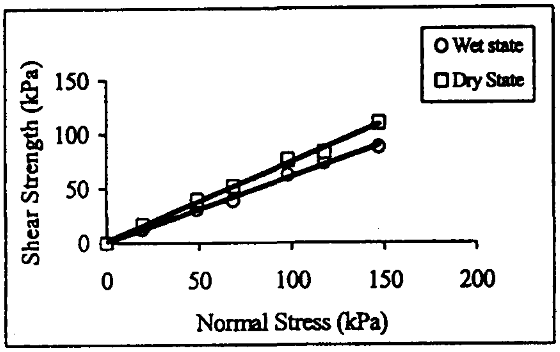

Fig. 5 Strength envelope of rock flour with nonwoven geotextile in light compaction condition

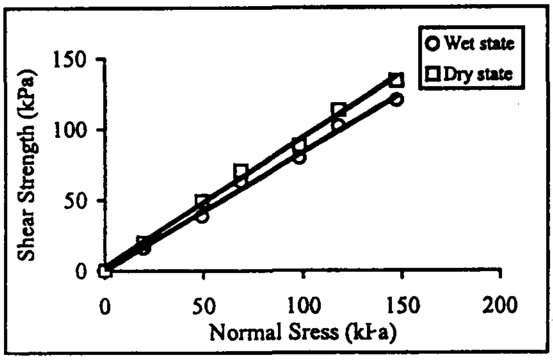

Fig. 6 Strength envelope of rock flour with nonwoven geotextile in heavy compaction condition

DISCUSSIONS

The grain size distribution of rock flour and its angle of internal friction in wet condition presented in Table 1 indicate that it satisfies the requirements of frictional fill for use in reinforced soil constructions. It can be also noticed from this table that it has high values of internal frictional angles even under light compaction conditions. This is very much beneficial because the frictional characteristics are ensured even if the dry unit weight values reduce due to dilation effects. The minimum value of coefficient of permeability of rock flour in densest possible state ($k = 5.3 \times 10^{-5}$ m/s) infers the free draining nature of the material.

The interfacial friction angle of rock flour with synthetic geotextiles presented in Table 3 reflects the interaction of the material with the fabrics. The mobilised interfacial friction angles are about 85 to 90 percent of angle of internal friction of the rock flour, which is higher and reliable in comparison to sand. The strength envelopes of rock flour indicate uniform interfacial friction angle at all normal stress values. It may be attributed to the roughness and better interlocking of the rock flour particles. The CBR values of rock flour presented in the Table 1 obtained for the rock flour specimens in the laboratory are high. Being an unbound material, it should not be directly used in design and construction of flexible pavements.

The Indian Roads Congress (IRC 37- 1999) recommends the use of 230 mm thick granular (sand) layer above expansive soil subgrades to serve as capillary cut-off and subgrade intrusion barrier. As the capillary rise in rock flour material is 160 to 220 mm, it may be used as capillary cut-off by providing 250 mm thick layer above clayey subgrades. The geofabric-encapsulated rock flour may still perform better as subgrade intrusion barrier and also as subbase course. However the strength of geofabric encapsulated rock flour depends on the type and properties of the geotextile used and is to be evaluated from laboratory or field testing.

CONCLUSIONS

Rock flour can be advantageously used in the construction of reinforced soil construction such as reinforced earth retaining walls, reinforced soil beds and reinforced flexible pavements as fill material due to its stability, free draining nature and good frictional characteristics with synthetic reinforcement. Rock flour exhibits higher value of interfacial friction angle in comparison with coarse graded sand. Apart from improving the quality of reinforced soil construction, the construction cost can be reduced since rock flour is available at low cost. Geotextile encapsulated rock flour may also be evaluated for use as subbase course material because it appears promising in terms of strength, drainage and frictional characteristics.

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