

POTENTIAL OF ROCK FLOUR FOR USE AS FILL MATERIAL IN REINFORCED SOIL STRUCTURES

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ABSTRACT

The fly over constructions have seen a revolutionary change ever since reinforced earth walls have emerged and replaced the conventional retaining walls. The approach sections of fly over's are now being connected with reinforced earth retaining walls due to fast constructions, low cost and better seismic resistance. The major component of the reinforced earth retaining wall is frictional fill and so cost of the fill influences cost of the wall. The construction cost of reinforced earth walls can be significantly reduced if alternate cost effective materials are used in place of conventional fill material, i.e. sand and gravelly soils. The process of assessing any alternate cost effective material such as a waste, it is essential to have knowledge on requirements of fill for use in reinforced soil structures and methods of evaluation of frictional characteristics of the fill with reinforcing materials. So in the present work besides explaining concept of reinforced earth, requirements of fill material to be satisfactory for using in reinforced soil constructions and tests for evaluation of interfacial frictional parameters of fill and reinforcement have been reviewed. In the present study rock flour, waste material produced from granite rock crushing plant is assessed for its suitability as fill material in reinforced soil constructions. The study is extended to study the interfacial friction characteristics of rock flour with synthetic geotextiles from modified direct shear tests. The results have been compared with respect to river sand and rock flour of Leptynite origin. The results of study indicated better interaction in comparison to river sand and rock flour of Leptynite origin. Rock flour of granite origin mobilized friction coefficients of 0.84 & 0.79 in OMC & MDD condition and 0.79 & 0.75 in wet condition with woven and non woven geotextiles respectively.

Key Words: *Fly Over, Leptynite, OMC, MDD, Granite*

1.1 GENERAL

Reinforced earth technique has gained much popularity in construction of various civil engineering structures. The construction of any reinforced soil structure involves use of soil or fill material, reinforcing material and facing. The success of the technology mainly depends on the type of fill material

and its interaction with the reinforcing material that is being used. Granular soils are preferred in construction of reinforced soil structures over clays and silts as they exhibit higher values of friction coefficients with reinforcing materials and do not show considerable reduction in the friction

coefficient value in presence of moisture. The frictional fills, called as granular fills, are defined as good quality, well-graded, non-corrosive cohesionless material possessing good frictional characteristics. It is advantageous and economical if some locally available granular waste material is found suitable for use as fill material in reinforced earth construction.

1.2 REINFORCED SOIL STRUCTURES

The reinforced soil structures are reinforced earth retaining wall, reinforced embankments and reinforced soil beds.

1.2.1 Reinforced Earth Retaining Wall

Soil is an abundant construction material which has compressive strength and

negligible or no tensile strength. To overcome this weakness, the soil can be reinforced with materials with high tensile strength. The basic principle of earth reinforcement is the generation of frictional resisting force between the back fill soil and the reinforcing element. The frictional force is directly dependent on normal effective stress and mobilized angle of internal friction between the soil and reinforcement. For walls reinforced with longitudinal reinforcement, the anchorage strength, or pullout resistance, is a result of the shear strength along the interfaces between the reinforcement and backfill soil along the longitudinal reinforcement. Reinforced earth retaining wall is composed of back fill soil, facing (skin) and reinforcing element. The reinforcing element can be geotextile, metal strips rods, bars, etc.

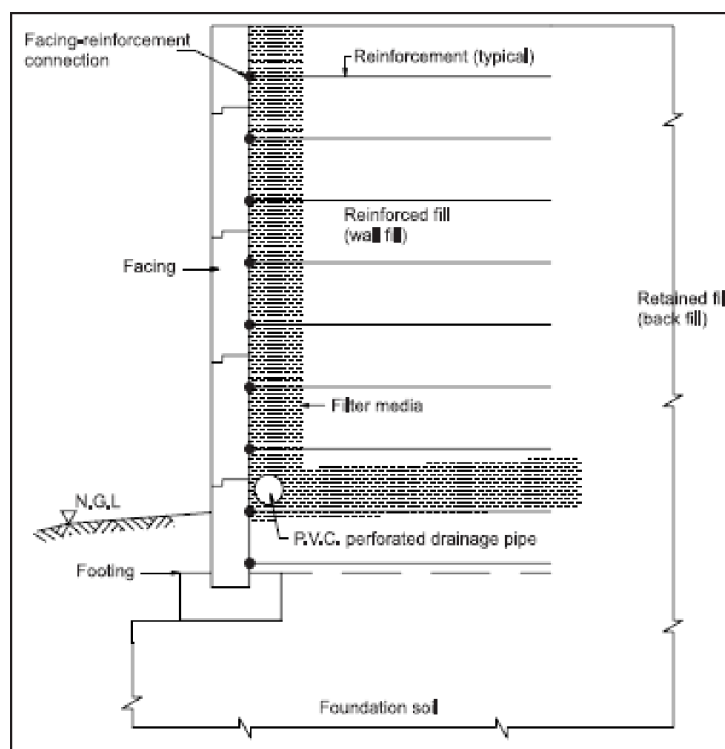


Figure 1.1 Cross Section of a Reinforced Earth Retaining Wall

1.2.2 Reinforced Embankment

Soft soils usually occur in estuarine or marshy areas. They exhibit considerable volume changes upon loading, and are associated with poor shear strength. If the foundation soil for an embankment is too soft to support both the dead and live loads on the embankment, some type of treatment on it is necessary. Methods such as excavation and replacement, stabilization with preloading and the use of prefabricated wide drains have been used traditionally. However, in recent years the use of reinforcement techniques to improve embankment stability has become very popular owing to a number of successful applications of this technique. Holtz (1994) indicated that reinforcement at the basal level in the form of geotextile, steel or precast concrete blocks or automobile tire casings/chipped tires significantly improves the embankment stability, and this aspect was demonstrated by a number of case studies carried out in Sweden and Denmark for both highway and railway embankments. The use of geosynthetics to improve the performance of embankments on soft soil is a very effective form of reinforced soil technique. BS 8006 (1995) divides the applications into two categories.

- (i) Use of reinforcement to control initial stability of embankment. The reinforcement is used as
 - (a) basal reinforcement beneath embankment,
 - (b) basal reinforcement with vertical drains, and
 - (c) basal mattress reinforcement
- (ii) Use of reinforcement to control both stability and settlement of embankment. Nowadays applications are growing in number owing to the requirement of construction of high speed railway embankments on soft soil, where deformation requirements are critical.

1.2.3 Reinforced Soil Beds

A reinforced soil bed is a composite material composed of stiffer materials called reinforcement embedded in the soil bed. Reinforcement inclusion in a soil bed results in a significant improvement in the bearing capacity and in reduced settlements. Using reinforced soil beds below foundations in weak soil deposits, the foundations are designed bearing capacity up to 3 to 4 times safe bearing capacity of native soil. The stiffness and load carrying capacity of reinforced soil beds depends on the characteristics of fill material.

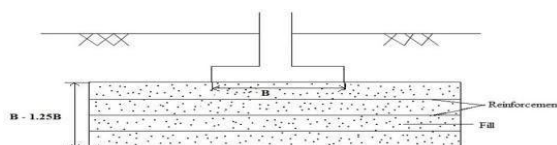


Figure 1.2 Cross Section of Reinforced Soil Bed

1.3 MATERIALS FOR REINFORCED SOIL STRUCTURES

The rock flour is good frictional characteristics and available of rock flour is more in the state of Andhra Pradesh. The cost of rock flour is low so it can

advantageously used as fill material in reinforced soil structures.

1.3.1 Fill Material

The introduction of reinforcement improves the shear strength of soil and hence any type of soil can be theoretically used. However, the fill material selection is done based on the purpose of reinforced earth construction. For construction of Reinforced Earth Retaining walls, cohesionless soils are used. The advantages being stability, free draining and relatively non-corrosiveness to reinforcing elements. In case of construction of embankments, cohesive and cohesive frictional soils can be used advantageously, where there is no necessity to keep wall vertical. Indigenous and waste material can be also tried as fill material if it suits to the requirement and will be economical where the available soil is not meeting requirement of fill.

Generally fill material is classified into three types as listed below.

- ☐ Cohesionless Fill
- ☐ Cohesive –Frictional Fill
- ☐ Cohesive Fill

Cohesionless Fill

It is also called as frictional fill or granular fill. It can be defined as good quality, well graded, non-corrosive material, possessing good angle of internal friction. Normally crushed rock, river sand and gravel come under this category. The requirements of the material are:

- The angle of internal friction, $\Phi > 25^\circ$

- Percentage of fines < 15
- $C_u > 5$ and $C_c = 1$ to 3

In case of metallic reinforcement,

- Chloride ion content < 0.05 (%)
- Total sulphates < 0.5 (%)

Cohesive – Frictional Fill

It can be defined as a material with percentage fines greater than 15. The Cohesive – frictional fill is more easily available than frictional fill, the specifications for selection a soil as cohesive – frictional fill are as follows.

It should not contain clay percentage in excess of 10 otherwise there will not be free drainage in the material

- $W_L \leq 45\%$, $W_P \leq 20\%$
- The angle of internal friction, $\Phi < 20^\circ$
- Moisture content to be used for satisfactory condition of workability and placement should be in the range of 6 to 10%.

Cohesive Fill

These are soils with medium to high plasticity. The cohesive fills are unsuitable for construction of reinforced earth retaining structures, because

- The bond between reinforcing element and soil is poor.
- The bond further decreases when pore water pressures increase.
- Cohesive soils are more aggressive and hence the durability of reinforcing material cannot be assured.

- They are susceptible to frost action and additional earth pressure may be generated.
- However cohesive soils (Non-expansion clays) can be successfully used in case of embankment structures with geo-fabrics and geo grids.

1.3.2 Reinforcement Material

A number of materials have been successfully used as reinforcement such as steel, geofabrics, geogrids, aluminum, glass fiber, wood and rubber. The polypropylene

1.3.3 Facing if Necessary

Facing is required for vertical structures such as reinforced earth retaining walls. The facing prevents erosion and enables a suitable architectural treatment to be provided to the structure. The following can be used as facing.

Concrete Precast slab: They are most common form of facings for retaining structures. It is relatively inexpensive.

Brick Masonry: suitable for small structures and they are durable. Geo fabrics: since geotextiles are flexible and light, they have been used successfully for facings. However they should be protected against vandalism and attack of rodents.

1.4 FILL MATERIALS IN USE FROM INDUSTRIAL WASTES

Some industrial wastes are used as fill materials in reinforced soil structures other than rock flour such as fly ash, bottom ash, pond ash and zinc slag.

based synthetic fabrics and grids are being used in developed countries .The reinforcement may be in the form of strips, grids, sheet materials, rope and other combinations. The requirements of reinforcement are

- (i) Strength
- (ii) Durability
- (iii) High adhesion/friction with soil
- (iv) Economy
- (v) High modulus of elasticity
- (vi) Less hardness

Galvanized steel facing: It can be easily transported, shaped and erected. The appearance may not be pleasing and durability is doubtful.

Gabions: Gabions are wire baskets filled with rock. Gabions are 1m height, 1m in width and 2 to 4m long. The baskets are made of 2 to 3m diameter wire with openings from 60 to 100 mm. They may be galvanized or coated (PVC) for protection against corrosion. The filling material should be durable rock or river cobbles, having size larger than mesh size but not larger than half the depth of individual basket. A filter layer, geotextile may be placed between Gabions and back fill to avoid soil particles from being washed out through rock fill by seepage or wave action.

1.4.1 Fly Ash is a finely divided residue resulting from the combustion of powdered bituminous coal or sub bituminous coal (lignite) and transported by fuel gases of boilers fired by pulverized coal or lignite. Fly ash is highly fine grained non-plastic material. The fly ash has low permeability

and low soaked CBR value. Hence it is not suitable for use in structural layers of pavements. However, due to rich silica content, it may be considered as pozzolanic material in preparation of lime stabilized soil sub-bases/bases of flexible pavements. Fly ash is a valuable bulk fill material and large quantities of fly ash can be used in embankments.

1.4.2 Bottom Ash is the ash collected at the bottom of boiler furnace, characterized by better geo- technical properties.

Bottom ash is well graded coarse grained non-plastic material. The bottom ash has reasonably good permeability and good frictional characteristics. Hence bottom ash is suitable for use as fill material in reinforced soil constructions, back fills behind retaining walls, basements and as filter material in base lining system of landfills, construction of embankments etc. Bottom ash and pond ash have been used as structural fill materials for the construction of highway embankments and/or the backfilling of abutments, retaining walls, or trenches.

1.4.3 Pond Ash is the mixture of fly ash and bottom ash together with water to form

1.5 AIM AND OBJECTIVES OF THE STUDY

The present work is aimed at evaluation of potential of rock flour for use in reinforced soil structures. To achieve the aim, work has been planned with the following objectives:

Objectives:

- To procure rock flour for study from a quarry located in Kurnool.

slurry, which is pumped to the ash pond area. In ash pond area, ash gets settled and excess water is decanted. This deposited ash is called pond ash. Pond ash is well graded coarse grained non-plastic material. The pond ash has reasonably good permeability and good frictional characteristics. Hence pond ash is suitable for use as fill material in reinforced soil constructions. This is used as filling materials including in the construction of roads & embankments.

1.4.4 Zinc Slag a ferrosilicate slag also referred as ISF (Imperial Smelting Furnace) slag, is a by-product generated during the primary smelting of zinc ore in a form of blast furnace. It is a granulated, glassy material and has the appearance of dark coloured sand. It typically has a particle size distribution between coarse and fine sand. Zinc slag is well graded coarse grained material. It is a granular material with little amount of fines possesses good frictional and reasonable drainage characteristics. Hence it can be advantageously used in construction of embankments. Further the material develops good bond with reinforcing materials.

- To study the Geology of parent rock of procured rock flour sample.
- To establish the engineering properties of rock flour under study.
- To determine properties of Woven and Non-woven geotextiles selected for study.
- To determine the interfacial shear parameters of rock flour with Woven and Non-woven geotextiles

by conducting modified Direct Shear tests.

- To study the effect of saturation on friction coefficient of rock flour and the geotextile.

METHODOLOGY

In the present chapter, the methodology adopted for the work has been explained. The tests proposed for characteristics of rock flour and Geosynthetics under study are mentioned. A flow chart is presented for better understanding of the methodology of the work.

2 CHARACTERISTICS OF MATERIALS

2.1 Rock Flour

The rock flour for the study has been collected from a quarry located at Kurnool. The quantity of rock flour present in the state of Andhra Pradesh is estimated by gathering information from quarries located across the state.

Extensive laboratory investigations namely grain size analysis, atterberg limit tests, I.S heavy compaction test, direct shear test, permeability and CBR tests are proposed to characteristics the rock flour. The effect of saturation of shear parameters is also included in the study.

2.2 Geotextiles

Woven and non woven Geotextiles selected for the study has been characteristics by performing tests on physical properties and mechanical properties, particularly strengths. The tests include determination of

weight, thickness, compressibility and wide width tension test.

3 ASSESSMENT OF ROCK FLOUR AS FILL MATERIAL IN REINFORCED SOIL CONSTRUCTIONS

Based on the established engineering properties of rock flour its suitability for use as fill in reinforced soil constructions by compares its properties to requirements of fill material given below.

Requirements of Frictional Fill (Jones, 1985)

- the angle of internal friction, $\phi > 25^\circ$
- percentage of fines < 15
- $C_u > 5$ and $C_e = 1$ to 3

In case of metallic reinforcement,

- Chloride ion content < 0.05 (%)
- Total sulphates < 0.5 (%)

4 DETERMINATION OF FRICTION COEFFICIENT OF ROCK FLOUR WITH GEOTEXTILES

After evaluation of rock flour for its suitability as fill material, modified shear box tests are proposed for determinations of friction coefficient. The procedure is suggested by Hussaini and Perry is used for the modified direct shear tests. The tests are planned as specimens prepared at OMC & MDD and saturated conditions. The tests are

conducted using woven and non woven geotextiles.

5 PROPERTIES OF PARENT ROCK

The toughness and frictional characteristics of rock flour depends on parent rock. Hence, it is proposed to study the geology of parent rock and it is proposed to compare the results obtained for rock flour under study to

rock flour of other parent rocks available from previous works.

Finally the results of the study are summarized and potential of rock flour for use as fill material in reinforced soil structures has been highlighted.

CONCLUSIONS

From the extensive laboratory studies carried out on rock flour and interaction studies of rock flour with woven and non woven geotextiles, the following conclusions have been drawn.

1. The equivalent IS classification symbol for rock flour under study is well graded sand.
2. The rock flour is coarse grained material with more sand size particles with good frictional and drainage characteristics ($k = 2.4 \times 10^{-3}$ cm/s).
3. Rock flour has higher value angle of internal friction ($\phi_{wet} = 41^\circ$) compared to coarse sand.
4. Rock flour satisfies the requirements of frictional fill used in construction of reinforced soil structures.
5. Rock flour mobilizes 88 to 93 % of angle of internal friction as interfacial friction angle with geotextiles.
6. The frictional coefficient mobilized by rock flour with woven geotextile is relatively more than that of non-woven geotextile.
7. The friction coefficient reduced by 7.0 percent from OMC and MDD state to wet condition in respect of a woven geotextiles where as the friction coefficient reduced by 3.5 percentage from OMC and MDD state to wet Condition in case of non woven geotextiles. This is attributed to higher thickness, more water retaining ability and compressibility of non woven geotextiles.
8. The rock flour of granite origin mobilized higher frictional characteristics (about 15%) compared to rock flour of Leptynite origin.
9. The friction coefficients mobilized by rock flour with geotextiles is higher than that mobilized by sand (about 10 - 20%).
10. Apart from improving the quality of reinforced soil construction, the construction cost can be reduced since rock flour is available at low cost.

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