# Study of Triaxial Behavior of Geotextile Reinforced Marginal Soil Without and with Cement Modification for Subgrade Construction of Pavements

**Mr. Pandu Kurre, Dr. M. Kumar, Dr. G. V. Praveen, Dr. M. Heeralal**

*Abstract*— **It has been observed at several instances that pavement performance is greatly affected by the usage of poor quality of soil subgrade which causes severe damage and distress. With the growing tendency to utilize marginal soils, there arises the need to understand the fundamental behavior of the materials in order to make suitable amendments in design parameters, especially in the subgrade construction of pavements. This paper presents the shear strength behavior of geotextile reinforced marginal soil without and with cement modification and compares its performance with that of conventional soil subgrade (gravel). The cement modified reinforced marginal soil has shown significant improvement in shear strength parameters both under un-drained and drained conditions. Further, the study revealed that the cement modified marginal soil has become non-plastic with its performance close to that of gravel subgrade. The mechanisms of geotextile reinforced soil in mobilizing the shear strength parameters are observed to be relevant even for cement modified marginal soil.**

*Index Terms*— **Marginal soil; Cement modification; Geotextile reinforcement; Shear strength**

## I. INTRODUCTION

In view of the scarcity for suitable backfill soils at several project sites, there is a growing tendency to utilize locally available marginal soils in the pavement construction (Glendinning et al. 2005; Won and Kim, 2007). Some investigators have also studied the shear strength behaviour of reinforced cohesive soils (Swami Saran, 2006), though there exists numerous studies carried out on conventional soils (Haeri et al. 2000; Latha and Murthy, 2006). It is unanimously felt that the cohesive soils and other marginal soils suffer from poor drainage and the consequent low shear strength parameters. Failures of pavement structures made of cohesive backfills were also reported by various investigators (Koerner, 2000; Goel, 2006; Yoo and Jung, 2006). Despite these problems, several investigators favours the use of marginal soils with suitable amendments to the material (Swami Saran, 2006).

Even few investigators have attempted to use cement modified backfill soils in the geosynthetic reinforced soil (Watanabe et al. 2002; Aoki et al. 2003; Lawson, 2003) to improve their stability under earthquake loading.

**Mr. Pandu Kurre,** Research Scholar, in Civil Engineering, University College of Engineering, Osmania University, Hyderabad

**Dr. M. Kumar,** Prof. in Civil Engineering, University College of Engineering, Osmania University, Hyderabad

**Dr. G. V. Praveen,** Prof. in Civil Engineering, S. R Engineering College, Warangal

**Dr. M. Heeralal,** Assoc. Prof. in Civil Engineering, National Institute of Technology, Warangal

Mechanically stabilized earth (MSE) has gained its wide acceptance for variety of applications such as road and railway embankments, earth dams, hill roads, abutments and retaining walls, spillways, area foundations and land scaping to name a few in civil engineering practice (Koerner, 2000; Wartman et al. 2006). Since its inception in France by Henri Vidal (1969), several investigators have attempted to understand the basic mechanisms of MSE and broadly arrived at a common understanding of shear strength parameters based on rupture and slippage failures through extensive triaxial testing (Swami Saran et al. 1992; Latha and Murthy, 2006). However, there exists still varied opinion among researchers regarding the basic mechanisms, especially with the use of different backfill materials and a wide variety of reinforcing materials (Haeri et al. 2000; Yoo and Jung, 2006; Latha and Murthy, 2006).

In the present work, locally available marginal soil was stabilized using cement to overcome the ill-effects of its plasticity and a detailed laboratory testing was carried out on fabric reinforced marginal soil samples without and with cement content to understand the shear strength mechanisms through large triaxial tests. These results were compared with those obtained from reinforced gravel samples.

## II. MATERIALS AND METHODOLOGY

The present investigation is undertaken to understand the shear strength behaviour of reinforced marginal soil without and with cement modification for which the following materials and methodology were adopted.

### 2.1 Materials

Gravel/Murrum: Gravels are coarse grained soils with particle size under 2.36 mm with little or no fines contributing to cohesion of materials. Murrum is the product of decomposition and weathering of the pavement rock. Visually these are similar to gravel except presence of higher content of fines.

Marginal soil: Locally available marginal soil was used to simulate the marginal backfill soil. The properties of marginal soil were determined as per Bureau of Indian Standards (SP 36-Part 1): 1987). Gravel (9%); Sand (52%); Silt (24%); Clay (15%); Liquid limit, wl (37%); Plastic limit, wp (20%); Unified soil classification (SC); Optimum moisture content (16%); maximum dry density (1.78); Shear strength parameters: UU conditioncu(53kPa); $\phi$ u(160); CD condition c' (11 kPa);$\phi$' (300); Coefficient of permeability, k (7.62 × 10 –5cm/sec).

Cement: Ordinary Portland cement of 53 grade is used to modify the marginal soil.

Soil–cement: The marginal soil–cement mixes with different cement contents were tested for their Atterberg limits and UCS values as given in Table 1.

Table 1. The properties of plain and cement modified marginal soil

| Property | Cement content in Marginal Soil | | | | | |
|---|---|---|---|---|---|---|
| | 0% | 2% | 3% | 4% | 5% | 10% |
| Atterberg Limits (Immediately after adding the cement) | | | | | | |
| Liquid Limit, wl (%) | 37 | 36 | 36 | 34 | 34 | NP |
| Plastic Limit, wp (%) | 20 | 19 | 19 | 18 | 20 | |
| Atterberg Limits (At 3 days curing period) Liquid Limit, wl (%) Plastic Limit, wp (%) | --- | NP | NP | NP | NP | NP |
| Unconfined Compressive Strength (kPa) (At 3 days curing period) | 76 | 275 | 359 | 508 | 669 | 1275 |

From this Table, it can be seen that the soil has become non-plastic (NP) at 2% cement content and for the subsequent shear strength studies 3, 5 and 10% cement contents by dry weight of soil were used.

Geotextiles

Fibertex G–100, a non woven geotextile was used as reinforcing materials and its properties are given in Table 2. The properties were determined as per the standard procedures (Mandal and Divshikar, 2002). This fabric was so chosen to distinguish the failure mechanisms of fabric reinforced cement modified marginal soil.

Table 2. Properties of Geotextile

| Property | Fibertex G–100 (non-woven) |
|---|---|
| Weight | 100 g/m2 |
| Thickness at 2 kPa | 0.6 mm |
| Wide width tensile strength | 4.0 kN/m |
| In-plane permeability | 0.13 m/sec |
| Apparent opening size, O95% | 110 micron |

## 2.2. Sample Preparation

The shear strength tests were carried out on 100 mm diameter and 200 mm height soil samples. It is evident that, larger size samples could depict and gives picture of the failure mechanisms properly (Powrie, 2002). The samples were prepared with the help of a split mould by means of static compaction. For this, the required dry weight of soil corresponding to maximum dry density for each sample was taken and the calculated saturated moisture content was added to it. In case of reinforced samples, the wet soil was divided into equal parts (so as to embed the Fibertex G–100 reinforcing layer in the middle of height of the specimen) and pressed to the required thickness between geotextile (Fibertex G–100) layers under a compression testing machine.

The fabric reinforcement (Fibertex G–100) was chosen with low tensile strength to replicate failure mechanism in accurate manner. The diameter of geotextile reinforcing layers is kept slightly less than the diameter of mould and the geotextile disc was placed horizontally in soil samples. The geotextile reinforcing layer placed at the middle of the height of specimen and its position and placement in soil sample is shown in Fig.1.

In case of cement modified marginal soil samples, 3% cement by dry weight of soil was thoroughly mixed until a mixture of uniform color/texture was obtained. After adding water content equal to optimum moisture content of the plain soil, the resulted soil–cement mixture was used for sample preparation. The required wet weight of sample was compacted using a compression testing machine and the Fibertex G–100 fabric layer was placed as per the configuration. These cement modified marginal soil samples were kept in polythene bags and placed in desiccators for 24 hours and then moisture cured by immersing them in water tubs (perforating the polythene bags) for 7 days of curing period before testing.

The reinforced marginal soil samples were prepared using the split mould as per the reinforcing layer configuration by static compaction. For these samples, no cement modification was adopted.

## 3.1. Testing Procedure

The unreinforced and reinforced marginal soil samples without and with cement modification were tested both in undrained and drained triaxial testing conditions. The reinforced gravel samples were tested only under drained triaxial condition. These tests were aimed at understanding the shear strength behaviour of reinforced marginal soil without and with cement modification and to compare its performance with that of reinforced gravel samples.

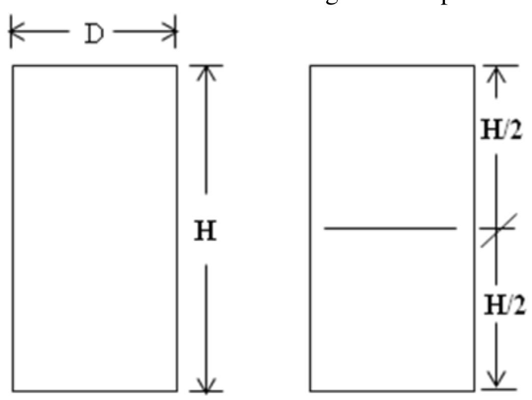


Fig.4.1. 100 mm diameter (D) and 200 mm height (H) soil samples with geotextile reinforcing layer configuration.

3.2. Large Triaxial Tests

Laboratory undrained and drained triaxial compression tests were performed to investigate the stress–strain characteristics and shear strength of unreinforced and reinforced marginal soil samples without and with cement modification. Also the triaxial tests were performed on plain and reinforced marginal soil samples without cement modification. The tests were carried out in a large triaxial cell. The test sample was placed on the pedestal with filter papers on both the sides and a split filter paper was wrapped around the sample to facilitate its saturation or drainage. Then the sample was enclosed by a thin rubber membrane with the help of membrane stretcher (Plate 1).

Plate 1. Soil specimen preparation and test set up for triaxial testing.

The membrane was sealed using 'O' rings at the top and bottom to a loading pad of triaxial cell and it was filled with water. Then it was placed on the pedestal of a compression testing machine and the sample was sheared under the intended cell pressure at a strain rate of 1.20 mm/min for undrained condition and 0.01 mm/min for drained condition. The axial deformation of the sample was measured using a dial gauge with least count of 0.01 mm and the load was recorded using a 5 ton capacity proving ring (Plate 2).

Plate 2. Large triaxial test–Experimental set up

Few repetitions were made under drained condition whenever it was felt necessary during the investigation; especially for 3% cement content with single layer of geotextile (Fibertex G–100) reinforcement. Triaxial tests have been done without and with admixing of cement, with reinforcement.

## III. Results and Discussion

3.1. Stress–strain behavior

In order to characterize the marginal soil without/with cement modification or with/without geotextile reinforcement, shear strength tests (large triaxial tests) were carried out.

3.1.1. Triaxial Tests (UU Condition)

For the test samples as used in triaxial tests, typical stress–strain patterns for Fibertex G–100 fabric reinforced marginal soil without/with cement modification for $\sigma3$ = 150 kPa are shown in Fig. 2 under undrained condition. As can be observed from these stress–strain patterns, there is only a nominal increase in strength by the provision of reinforcement under this test condition.

It can be observed from this figure that the improvement in strength of virgin soil upon reinforcement under undrained condition (Fig. 2) is significantly lower than that in drained condition (Fig. 3). Hence, the low permeable marginal soil with higher plasticity cannot be used in subgrade soil unless elaborate drainage arrangements are made to ensure proper soil–reinforcement interaction.

The fabric layers were observed to be subjected to sliding without any signs of rupture in plain soil. The comparative stress–strain curves of different test samples of marginal soil under triaxial loading (UU condition) for confining stress of 150 kPa at 7 days curing period are shown in Fig. 2. It can be observed from this figure that even 3% cement modified marginal soil has shown an increase in deviator stress by 3 times compared to plain soil and the failed samples were observed to be non–plastic.

In case of cement modified and fabric reinforced samples, Fibertex G–100 fabric layer was observed to be partly stretched and partly slided in tested samples and the fabric layer was ruptured. The significant strength gain of cement modified samples without and with fabric reinforcement even under undrained condition could be attributed to their increased stiffness with non-plastic nature as elucidated by the observation of failed samples.

3.1.2. Triaxial Tests (CD Condition)

The stress–strain patterns of marginal soil samples under drained condition indicate that there is a distinct influence of cement modification and fabric reinforcement on the deviator stress (Fig. 3).

The specimens have shown gradual failure with increased strain level compared to soil–cement alone indicating more of its ductile nature. The non–woven geotextile layer, Fibertex G–100 was partly stretched and partly slided and was subjected to rupture failure as in the case of undrained test condition (Plate 3). The descending order of strength gain is observed for Fibertex G–100 geotextile reinforced modified marginal soil sample followed by modified marginal soil samples and plain marginal soil samples.

Plate.3. Rupture failure of fabric reinforcement

As the stress–strain patterns are almost similar for different sample conditions, only representative plots are presented to avoid repetition. From these trends, it is understood that the effective mobilization of peak deviator stress of fabric reinforced and cement modified marginal soil depends on full drainage condition.

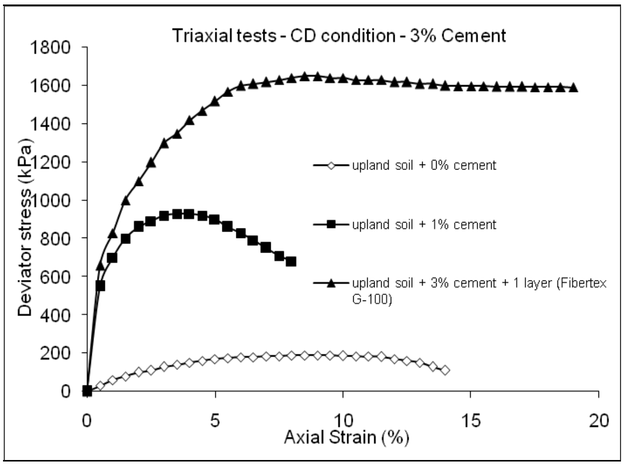


Fig. 3. Stress–strain curves of reinforced and 3% cement modified marginal soil under drained condition at 7 days curing for σ3 = 150 kPa.

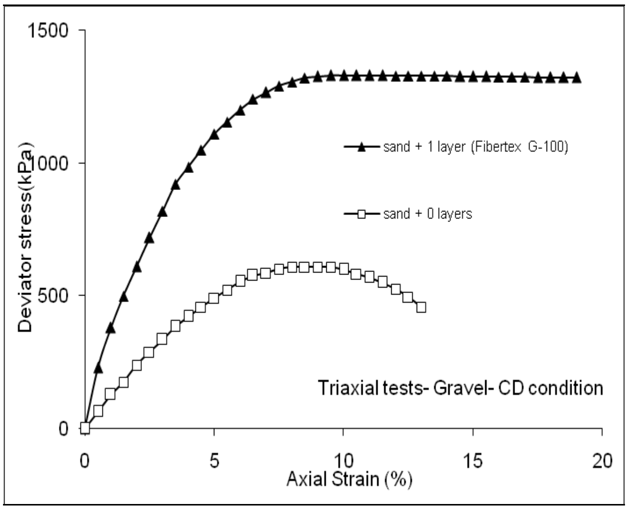


Fig.4. Stress–strain curves from triaxial tests on reinforced gravel under drained condition.

This can be supported by the fact that the peak deviator stress under drained condition is almost twice that in undrained condition. Further, the higher strength gain by soil–cement from fabric reinforcement at greater curing periods could be reflected in triaxial tests under drained condition, whereas in triaxial undrained tests it could not be distinctly measured due to premature failure of soil–cement as observed from failed samples. It can also be observed that the stress–strain patterns of cement modified marginal soil samples are close to those for reinforced gravel samples (Fig. 4).

From above discussion, it can be understood that the cement modified marginal soil with its non–plastic nature and improved stiffness could be used along with reinforcement as subgrade soil for flexible pavement construction, especially when the fabric reinforcement that facilitates internal drainage. The fabric reinforced marginal soil upon cement modification could ensure proper soil–reinforcement interaction resulting in higher shear strength parameters due to its nullified plasticity with added cement. The shear strength parameters of cement modified geotextile reinforced marginal soil are almost similar to those obtained for gravel. This could be supported by the non-plastic nature of cement modified marginal soil coupled with enhanced internal drainage provided by fabric reinforcement.

The failed samples have shown a mixed failure of stretching coupled with slippage and Fibertex G–100 (non–woven) geotextile, predominantly rupture failure is observed in all the drained test conditions. The reinforced samples of both the marginal soil and gravel have shown progressive failure as against the post peak yielding of plain soil samples. The suggested cement modification of marginal soil is similar to conventional soil–cement and hence, the cost considerations are also similar.

## IV. CONCLUSIONS

The fabric reinforced marginal soil upon cement modification could ensure proper soil–reinforcement interaction resulting in higher shear strength parameters due to its nullified plasticity with added cementation. The shear strength parameters of cement modified reinforced marginal soil are almost similar to those obtained for gravel. This could be supported by the non-plastic nature of cement modified marginal soil coupled with enhanced internal drainage provided by fabric reinforcement. In case of Fibertex G–100 (non-woven) geotextile, predominantly rupture failure is observed in all the drained test conditions. The reinforced samples of both the marginal soil and sand have shown progressive failure as against the post peak yielding of plain soil samples. With increasing stiffness of cement modified marginal soil at higher cement contents, the cohesion component is considerably increased with nominal variation in the angle of internal friction.

## V. REFERENCES

[1] Glendinning, S., Jones, C. J. F.P., and Pugh, R.C. “Reinforced soil using cohesive fill and electro kinetic geosynthetics.” International Journal of Geomechanics, ASCE,2005, Vol.5, No.2, 138-146.
[2] Goel, R. “Mechanically stabilized earth walls and reinforced soil slopes: Indian scenario- a comprehensive review.” Journal of the Indian Roads Congress,2006, Vol. 67, No.1, 51-78.

[3] Haeri, S.M., Noorzad, R., and Oskoorouchi, A.M. "Effect of geotextile reinforcement on the mechanical behaviour of sand." Geotextiles and Geomembranes, Elsevier, 2000, No.18, 385-402.

[4] Kim, S. K., and Lee, E.S. "Use of decomposed granite soils as backfill for reinforced earth structures." Proceedings of International Symposium on Earth Reinforcement,1996, A.A. Balkema, 1996, Vol.1, 51-56.

[5] Koerner, R.M. "Emerging and future developments of selected geosynthetic applications." Journal of Geotechnical and Geoenvironmental Engineering, 2000, Vol.126, No.4, 293-306.

[6] Latha, G.M., and Murthy, V.S. "Investigations on sand reinforced with different geosynthetics." Geotechnical Testing Journal, 2006, Vol.29, No.6, 474-481.

[7] Lawson, C.R. "Combined technology in Earth reinforcement." Proceedings of12th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering,2003, Singapore, 1-17.

[8] Mandal, J.N., and Divshikar, D.G. "A Guide to Geotextiles Testing." New Age International (P) Publishers, New Delhi, ISBN: 81-224-1396-X. 2002.

[9] Swami Saran. "Reinforced soil and its engineering applications."2006, I.K. International Pvt. Ltd, New Delhi, India.

[10] Wartman, J., Rondinel-Oviedo, E.A., and Rodriguez-Marek, A. "Performance and analysis of Mechanically Stabilized Earth walls in the Tec Oman, Mexico Earthquake." Journal of Performance of Constructed Facilities, ASCE, 2006,Vol.20, No.3, 287-299.

[11] Won, M.S., and Kim, Y.S. "Internal deformation behaviour of geosynthetic-reinforced soil walls." Geotextiles and Geomembranes, Elsevier,2007, No.25, 10-22.

[12] Yoo, C., and Jung, H.Y. "Case history of geosynthetic reinforced segmental retaining wall failure." Journal of Geotechnical and Geoenvironmental Engineering,ASCE,2006, Vol.132, No.12, 1538-1548