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Behaviour of Geosynthetic Reinforced Soil Using Different Testing Conditions

1st Kavya Verma
Department of Civil Engineering,
Galgotias College of Engineering & Technology
(Dr. APJ Abdul Kalam Technical University, Lucknow, U.P) Greater Noida, India

2nd Nitin shri Yaduvanshan
Department of Civil Engineering,
Galgotias College of Engineering & Technology
(Dr. APJ Abdul Kalam Technical University, Lucknow, U.P) Greater Noida, India

3rd Vidhi Tyagi
Department of Civil Engineering,
Galgotias College of Engineering & Technology
(Dr. APJ Abdul Kalam Technical University, Lucknow, U.P) Greater Noida, India

4th Vishal Joshi
Department of Civil Engineering,
Galgotias College of Engineering & Technology
(Dr. APJ Abdul Kalam Technical University, Lucknow, U.P) Greater Noida, India

ABSTRACT: In this paper, efforts are made to investigate the behaviour of Geosynthetic Reinforced Soil (GRS) under various loading conditions for prediction of deformation characteristics of GRS mass by Soil-Geosynthetic Performance (SGP) test. This paper provides an overview of principles, materials, application, and benefits are associated with geosynthetic reinforcement. It improves soil bearing capacity, control erosion, and enhance overall stability. Geosynthetic materials including geotextiles, geogrids, and geocells are used for reinforcement, offering advantages such as tensile strength, flexibility, and resistance to environmental degradation.

1. INTRODUCTION

Soil is the cheapest construction material. It is relatively strong under compressive stress. Civil engineers have forced to improve site containing weak soil for the stable construction. Geosynthetic reinforcement is one of the extensively used method to improve the significant tensile stresses baring capacity, settlement of shallow foundation and also in field of geotechnical engineering.
According to ASTM D4439, a geosynthetic n-a planar product manufactured from polymeric material used with soi, rock earth or other geotechnical engineering relative materials.

Geosynthetics perform Five major functions like Separation, Reinforcement, Filtration, Drainage, and Containment.

Geosynthetics has two basic aims:

1. To perform better (e.g. with no deterioration of material or excessive leakage)
2. To be more economical than using traditional materials and solutions.

There are different types of geosynthetic used now a day are geotextiles, geogrid, geonets, geomembranes, geosynthetics clay liners, geo-pipe, geo-foam, and geo- composites.
The behaviour of GRS mass has been studied by using laboratory test such as Triaxial compression test (e.g. yang, Broms) and PLANE STRAIN

COMPRESSION TEST (e.g. Mc Gown et al., tatsuoka and Yamauchi, whittle et al., Boyle) Most of the test are of relatively small dimensions and can lead to misleading result.

A large-scale laboratory test known as the Soil Geosynthetic Performance (SGP) Test is developed by WU and Helwany (1996) to investigate the behaviour of GRS mass under plane strain conditions.

In this paper, a comparative study is made through Soil Geosynthetics Performance (SGP) experiments and laboratory test like Conventional triaxial compression test for soil, in-isolation load extension test for geosynthetics, direct shear test for soil geosynthetics interfaces.

The test was conducted to examine the behaviour of different soil, geosynthetics and soil-geosynthetics interfaces subject to monotonic loading and unloading-reloading cycle(s).

2. MATERIAL USED IN STUDY

A. Soil

Two types of granular soil were used in this study that is River Sand and a Road Base Soil. The river sand was chosen because of its well-define properties. The road base soil was granular material that is commonly used as backfill for GRS retaining wall. The specific gravity of sand is 2.65. the maximum and minimum unit weights are 17.65 kN/m^3 and 15.34 kN/m^3 respectively. The road base soil used in this study was dark brown, silty sand. It has 12% of fine particles. The plasticity index and liquid index were 6% and 27% respectively. The maximum dry density was 18.75 KN/m^3 with optimum water content of 14.2%.

B. Geosynthetic

Two types of geosynthetics, woven polypropylene geotextile and non-woven heat bonded propylene geotextile, were used in this study. Woven geotextile represents a strong reinforcement material, where non-woven geotextile represents a weak reinforcement material.

3. LABORATORY TEST OF SOIL

A. Conventional Triaxial Compression Test

This test was done to examine the behaviour of soil subjected to unloading reloading cycles. In this test, the triaxial chamber was placed on CTM machine and the confining pressure was applied and the volume change occurred during shear was measured by monitoring the volume change. Here, the river sand specimen and the road base soil specimen was prepared at a dry unit density of 16.85 kN/m^3 and 17.8 kN/m^3 respectively.

Test Result:

Maximum deviator stress generally found at the failure state of the specimen. In the results of the monotonic-loading CTC tests. The deviator stress increased with the axial strain until failure occurred. The River Sand initially contracted during shear and started to dilate at axial strains less than 0.8%. Similar to the sand, the Road Base soil at lower confining pressures contracted initially and dilated after it reached certain axial strains. the results of the monotonic-loading CTC tests. The deviator stress increased with the axial strain until failure occurred. The river sand initially contracted during shear and started to dilate at axial strains less than 0.8%. Similar to the sand, the road base soil at lower confining pressures contracted initially and dilated after it reached certain axial strains.

4. LABORATORY TEST FOR GEOSYNTHETIC

A. In Isolation Load Extension Test

In the LE test, a geosynthetic specimen was subjected to uniaxial tensile force without soil confinement. In this test of geosynthetics, the specimen is subjected to a uniform stress-deformation condition and can be considered independent of the specimen dimensions. The in-isolation load-extension tests were conducted in both strain-controlled and stress-controlled modes of loading.

Test Result:

To describe the load-deformation behaviour of the geosynthetics, an ultimate tensile load (ULT) is defined. The tensile load versus axial strain relationships of the monotonic loading LE tests of Non-Woven Heat-Bonded Polypropylene and Woven Polypropylene Geotextile is as follows

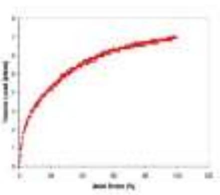

Figure 4.1: Tensile load versus axial strain relationship of non-woven heat-bonded polypropylene

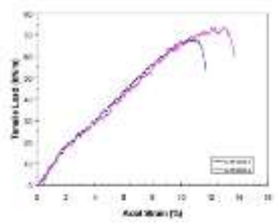

Figure 4.2: Tensile load versus axial strain relationship of woven polypropylene geotextile

The results of the stress-controlled and strain-controlled parts of Non-Woven Heat-Bonded Polypropylene are:

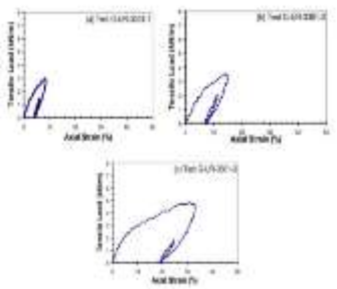

Figure 4.3: Stress-controlled part

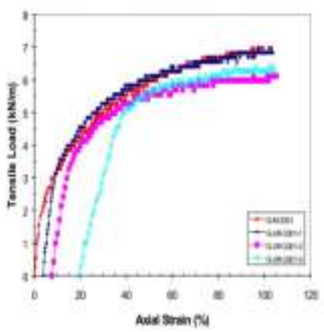

Figure 4.4: Strain controlled part

The results of stress-controlled and strain-controlled portions of the woven polypropylene geotextile are:

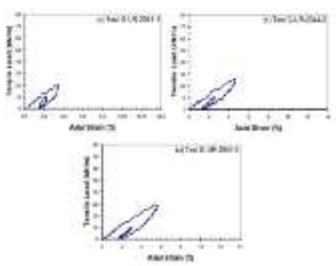

Figure 4.5: Stress controlled Part

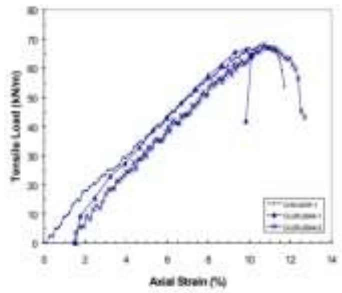

Figure 4.6: Strain controlled part

The specimen was loaded up to a preloading level in the stress-controlled section at a loading rate of 1.75 kN/m per minute, then it was emptied, reloaded, and reloaded to 2 kN/m for non-woven heat-bonded polypropylene and 10 kN/m for woven polypropylene geotextile, and finally it was unloaded again. After that, the specimen was loaded monotonically at a strain rate of 10% per minute (strain-controlled portion) until failure happened. From the results of the stress-controlled part, it is seen that the load-strain relationships of the primary loading, unloading, and reloading was non-linear. The geosynthetic surface positioned at 0.1 mm above the horizontal surface of the lower shear box. The soil was placed in the upper shear box.

The irrecoverable strain of the stress-controlled component served as the starting point for the load-strain curve in the strain-controlled part. As soon as the tensile load approached the preloading load level, the reloading curve's slope changed dramatically. Once the tensile load surpassed the preloading load threshold, the load-strain curve approximated the monotonic loading curve.

5. LABORATORARY TEST FOR GEOSYNTHETIC INTERFACE

A. Direct Shear Test For Soil Geosynthetics Interface

The DS test apparatus consisted of a pair of 60-mm by 60-mm by 20-mm deep shear boxes with a displacement-controlled loading system. The rate of shear displacement was 0.4 mm per minute. The unloading and reloading paths of the DS test were manually controlled by reversal of the upper box displacement. For the specimen, a geosynthetic with dimensions of 60 mm x 60 mm was firmly glued to the top surface of a rigid wooden block.

The wooden block with the geosynthetic specimen was placed inside the lower shear box. The thickness of the wooden block was modified several times to have the Test result: The relationships of shear stress versus horizontal displacement and vertical displacement versus horizontal displacement of the interface tests were plotted. Failure state was defined as the peak shear stress.

In the DS test results of the Road Base Soil-Woven Polypropylene Geotextile interface, the shear stress increased in a non-linear manner with increasing horizontal displacement. The unloading-reloading part of the curve was approximately linear. From the vertical displacement-horizontal displacement plots, the River Sand-Woven Polypropylene Geotextile specimen initially contracted and then dilated. Upon unloading, the specimen contracted. During reloading, the specimen exhibited similar volume change behaviour as in the preloading path. The specimen contracted and dilated until failure. In the Road Base Soil-Woven Polypropylene Geotextile specimen, contraction behaviour prevailed in the preloading and unloading-reloading paths.

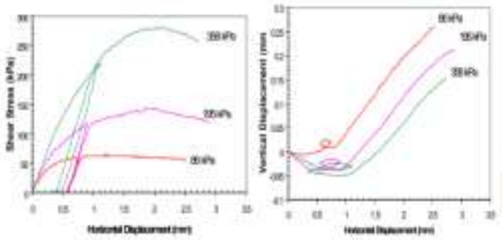

Figure 5.1: DS result of Sand-Woven Polypropylene geotextile interface.

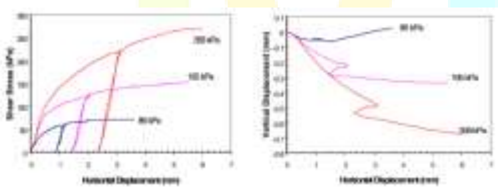

Figure 5.2: Results of Tests DS-UR-(RB+2044)-1, 2, and 3.

6. M ETHADOLOGY

A. Problem Statement:

A geosynthetic reinforced soil (GRS) containing horizontally placed layers of geosynthetic reinforcement. when subjected to vertical load, a GRS mass typically exhibits higher stiffness and higher load carrying capacity than soil without reinforcement. The geosynthetic reinforcement restrains deformation of the GRS mass along axial direction of reinforcement because of soil geosynthetic interactions.

B. Research Objectives:

1. Conducting laboratory tests to examine the behaviour of different soil, geosynthetics and soil-geosynthetics interfaces subject to unloading-reloading cycle.
2. Develop a revise SGP test apparatus so that GRS mass can be investigated with improved precision.

C. Experiment Apparatus Configurations:

The modified SGP test apparatus was manufactured by the Turner-Fairbank Highway Research Centre of the Federal Highway Administration. SGP Test apparatus with a specimen on the MTS-810 loading apparatus.

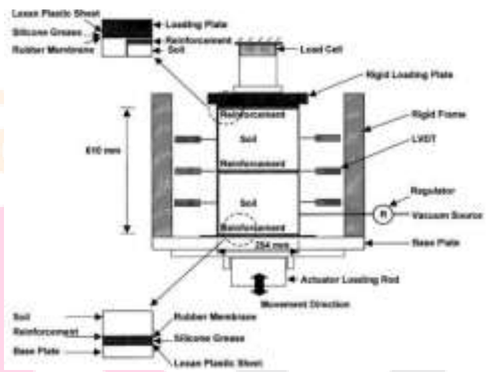

Figure 6.1: Schematic Diagram of Modified SPG Test Apparatus

In modified SGP test, a generic GRS mass was placed inside a rigid container of dimensions 400 mm by 250 mm by 250 mm. Dimensions of specimen were 300 mm high, 150 mm wide, and 250 mm deep.
The test specimen comprised a soil with three layers of reinforcement at bottom, mid-hight, and top.

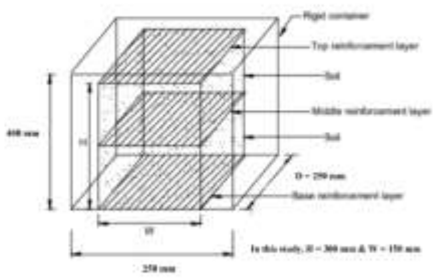

Figure 6.2: Specimen Dimensions of Modified SGP Test.

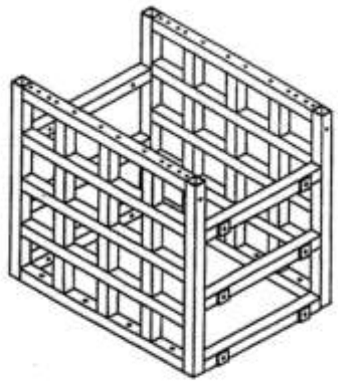

Figure 6.3: Rigid Container of Modified SGP Test Apparatus.

D. Specimen Preparation And Test Procedure

1. River Sand Specimen

The sand was inside the SGP test apparatus at constant density 16.85 KN/m3 and lubricate the base. silicone grease the sidewall and inner surface of moveable rigid panel. Place the rubber membrane bag in cuboid space of apparatus and also remove the air bubbles trapped between the rubber membrane and contacted surface. Place the bottom reinforcement layer and large carboard with 250 mm by 250 mm rectangular slot on top of apparatus. Rise the hopper filled with the sand to prescribe drop height and start dispersing the sand with a pendulum motion of hopper. Move the hopper up incrementally to maintain a constant hight of pluviation.

Place the top reinforcement layer on top of the soil specimen. Remove the hopper and cardboard. Fold the rubber membrane bag to cover the top surface of specimen and then seal the rubber membrane connection. Place SGP apparatus on fork lift and move it to the testing area and place it in CTM loading machine. then remove vacuum pressure and horizontal removable panels. Place rigid loading plate and start applying the vertical load and record the performance of the test specimen.

2. Road Base Soil Specimen

Lubricate the base and silicone grease the sidewall. Install moveable panel and place rubber membrane over lubricated base and sidewall area. remove air bubbles then place bottom reinforcement layer. Start compacting the road base soil in 25 mm thick lift then place middle reinforcement layer at mid height and continue compacting. Place the rigid loading plate at the top of specimen. Glue 25mm plastic pieces on the unrestrained surface of specimen at 152 mm, 305 mm, and 458 mm from the specimen base. apply a vertical seating load of 3.5 kPa on specimen set initial value for all instruments. Start applying the vertical load and also record the performance of test specimen.

7. TEST RESULT AND CONCLUSION

A. Test Results

The test results show that at the same vertical load, the GRS mass experienced less vertical and horizontal displacement then soil mass. (Figure 7.1) shows plot of vertical and horizontal displacement Vs the vertical load of the road base soil mass without reinforcement and with woven polypropylene geotextile reinforcement. (Figure 7.2) shows plot of vertical and horizontal displacement versus the vertical load of river sand mass without reinforcement with non-woven heat-bonded polypropylene geotextile reinforcement and with woven polypropylene geotextile reinforcement.

The GRS masses also had higher failure load. In figure 7.2 the initial vertical stiffness of GRS mass with non-woven heat-bonded polypropylene was smaller than that of sand.

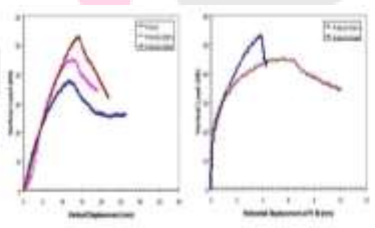

Figure 7.1: Vertical Load Versus Displacement of Road Base Soil

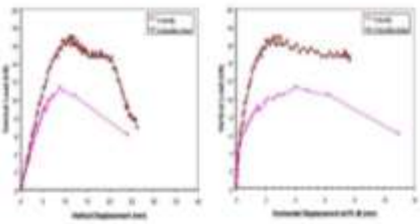

Figure 7.2: Vertical Load Versus Displacement of River Sand

At small displacement the soil and GRS masses showed almost identical deformation responses. Under a vertical load the GRS mass deformed in both vertical and horizontal directions. In road base soil mass without reinforcement, the required vertical and horizontal deformation were 2.0 mm and 0.5 mm respectively depend on stiffness of soil, reinforcement, and interface.

The road base soil showed largest horizontal movement at point at least at point T. for GRS mass point at, T, and B showed comparable horizontal displacement. The smaller horizontal displacement occurs at point M.

Two type of failure mode, a diagonal shear failure and a wedge-type shear failure, were observed in these GRS tests (Figure 7.4).

The first failure occurred in sand and road base soil masses and sand masses with weak reinforcement. The ruptured location was approximately the intersection of shear plane and the middle reinforcement layer.

Second failure occurred in GRS mass with a strong reinforcement. it ruptured in the lower part of the specimen without reinforcement.

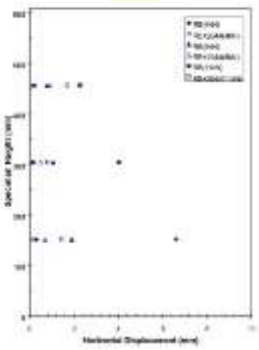

Figure 7.3: Horizontal displacement of point T, M, and B at 4 kN, 8 kN, and 11kN vertical load

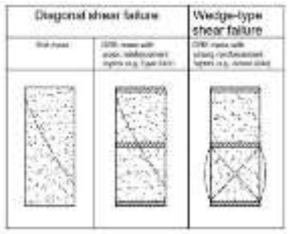

Figure 7.4: Two failure modes in SGP test.

The vertical stress distribution of specimen with and without reinforcement are almost identical, whereas the horizontal stress distribution and shear stress distribution are distinctly different. figure 7.5, 7.6, and 7.7 showed the vertical, horizontal, and shear stress distribution at a vertical load at 6 kN. The shear stress in specimen without reinforcement was nearly zero and it's occurred near the reinforcement in specimen with reinforcement. To quantify the reinforcing effect, a minor principal stress ratio introduced it is a direct indication of increasing in the minor principal stresses resulting from the reinforcement. Figure shows a distribution of minor principal stress ratio of about 1.4 to 1.5 occurred near reinforcement and reduce with the distance from the reinforcement location.

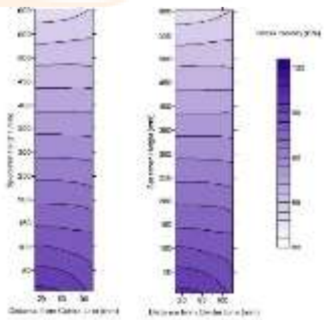

Figure 7.5: Vertical stress distribution at 6-kN vertical load of test P-M-RB and P-M-(RB+2044)

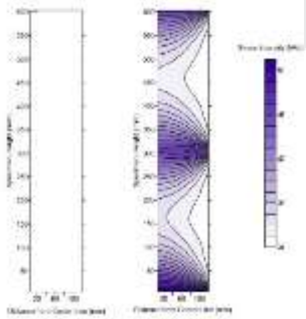

Figure 7.6: Horizontal stresss distriution at 6-KN vertical load of tests P-M-RB and P-M-(RB+2044)

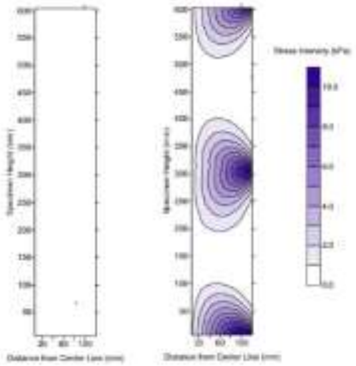

Figure 7.7: Shear stresss distriution at 6-KN vertical load of tests P-M-RB and P-M-(RB+2044)

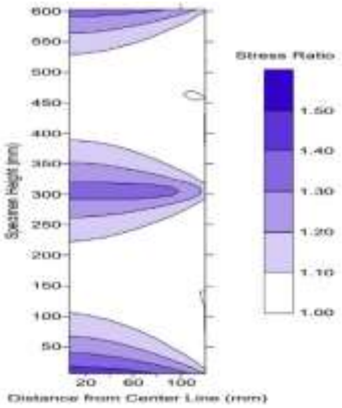

Figure 7.8: Distriution of minor principal stress ratio at 6-KN vertical load of tests P-M-RB and P-M-(RB+2044)

B. CONCLUSTION

1. Due to the reinforcing effect imposed by the reinforcement, a soil mass with reinforcement had higher strength and stiffness about 30% higher than without reinforcement.
2. Some vertical and horizontal deformation were required to mobilize the reinforcing effect. For the Road base soil mass with or without reinforcement, the required vertical and horizontal displacements to fully mobilize the reinforcing effect were 2.0 mm and 0.5 mm, respectively.

8. ACKNOWLEDGEMENT

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