ABSTRACT

Evaluation Studies on flexible pavement system were carried out by using the different reinforcement materials in the flyash subbase courses laid on expansive soil subgrades. It was observed from the laboratory test results of direct shear and CBR, that the optimum percentage of waste plastics is equal to 0.4% for flyash materials. Cyclic load tests were carried out in the field by placing a circular metal plate on model flexible pavements. It is observed that the maximum load carrying capacity associated with less value of rebound deflection is obtained for geogrid reinforced stretch followed by bitumen coated bamboo mesh and waste plastics reinforced stretch in the flexible pavement system laid on expansive subgrades.

1. INTRODUCTION

Reinforced earth technique has been gaining popularity in the field of civil engineering due to its highly versatile and flexible nature. It has been used in the construction of retaining walls, embankments, earth dams, foundation beds for heavy structures on soft grounds, viaduct bridges and other applications Vidal (1968); Hausmannn (1990); Rao (1995). With the advent of geosynthetics in civil engineering, reinforced earth technique has taken a new turn in its era. The practice of reinforced earth technique became easy and simple with geosynthetics. Inspite of its wide use in various engineering practices, its application in the construction of pavements is very much limited Prasada Raju, (2001). However, geosynthetic layer has been used as a separator at the subgrade – pavement interface Al-Qadi and Bhutta (1999); Brandon et al (1996) to prevent the entry of pavement materials into the subgrade or subgrade material into the pavement materials.

Reinforcement of soils with natural and synthetic fibres is potentially an effective technique for increasing soil strength. The growing interest in utilizing waste materials in civil engineering applications has opened the possibility of constructing reinforced soil structure with unconventional backfills, such as waste plastics and waste tire shreds. The results of direct shear tests performed on sand specimens by Gray and Ohashi (1983) indicated increased shear strength and ductility, and reduced post peak strength loss due to the inclusion of discrete fibers. The study also indicated that shear strength is directly proportional to fiber area ratio and length of fiber up to certain limit. These results were supported by number of researchers using consolidated drained triaxial tests like Gray and Al-Refai (1986); Gray and Maher (1989); Ranjan et al. (1996); Michaowski and Cermak (2003); Jadhao and Nagarnaik (2008).The addition of fibers increases the CBR, ultimate strength, stiffness and resistance to liquefaction, shear modulus and damping of reinforced the sand by Temel and Omer (2005). The results of compaction tests for a silty, clay soil specimen reinforced with fibers indicate that increasing the volume of fibers in the soil generally causes a modest increase in the maximum dry unit weight, and a slight decrease in the optimum moisture.
content by Fletcher and Humphries (1991). Research of different types of reinforcement and materials has been conducted by several investigators. However, the amount of information available on reinforcement is still limited.

In the present investigation, Direct shear and CBR tests were conducted in the laboratory for flyash materials with different percentages of waste plastics to obtain optimum percentage of reinforcement material. An attempt is made to study the performance of reinforced flyash subbase layer with different materials, such as Geogrid, Bitumen Coated Bamboo Mesh and Waste Plastics in model flexible pavement construction laid on expansive soil subgrades. Cyclic load tests were carried out by placing a circular metal plate directly on the flexible pavement laid on expansive soil subgrades. Keeping in view the high cost of geogrid, other materials like bamboo mesh and waste plastics were also tried for their use as reinforcing materials.

2. EXPERIMENTAL STUDY

Materials Used

The following materials are used in this study.

Soil
Expansive soil collected from Godilanka near Amalapuram was used for this investigation as a subgrade material. The soil properties are \( W_L = 75\% \), \( W_p = 35\% \), \( W_S = 12\% \), I.S. Classification=CH (Clay of high compressibility), OMC=23\%, MDD=15.69 kN/m\(^3\), Differential free swell=150\%, Soaked CBR=2.0\%; Permeability = 1.5 \( \times 10^{-7} \) cm/sec.

Gravel
Gravel collected from Dwarapudi, near Rajahmundry was used as subbase course. The soil properties are \( W_L = 38\% \), \( W_p = 20\% \), OMC=13\%, MDD=18.05 kN/m\(^3\), Soaked CBR=8.0\%, Permeability = 1.2 \( \times 10^{-1} \) cm/sec.

Flyash
The flyash collected from Vijayawada thermal power station, Vijayawada was used as a subbase course in this work. The properties of flyash are MDD=13.24 kN/m\(^3\), OMC=24\%, Soaked CBR=4.0\%, Permeability (cm/sec) = 0.5 \( \times 10^{-6} \).

Geogrid
Netlon CE 121 Geogrid with a peak tensile strength of 7.68kN/m and aperture size of 8mm \( \times \) 6mm was used.

Bamboo Mesh
Bamboo Mesh of thickness 1mm with a peak tensile strength of 26.32kN/m coated with 80/100 grade bitumen was used.

Waste Plastics Strips
Waste plastic strips having a size of 12 mm \( \times \) 6 mm and a thickness of 0.5 mm is used in this study (Fig.1)

3. LABORATORY EXPERIMENTATION

Direct Shear and CBR Tests

The direct shear and CBR tests were conducted as per IS: 2720 (part XIII, 1986) and IS: 2720 (part-XVI, 1979), in the laboratory, by using different percentages of waste plastics mixed with flyash materials uniformly with dry weight of soil and compacted to maximum dry density and optimum moisture content of flyash material with a view to find the optimum percentage of waste plastics.

4. FIELD EXPERIMENTATION

In this study four alternative test tracks (Geogrid reinforced subbase, Bitumen coated bamboo mesh reinforced subbase, waste plastics reinforced subbase and untreated subbase) were prepared on expansive soil subgrade with flyash subbase materials separately, as shown in Fig. 1 and the details of which are presented in the following sections.

Preparation of Test Stretches

Tests track each of size 3m long and 1.5m wide was excavated to an average depth of 0.8m as shown in Fig. 1. Out of which 0.5m was for laying subgrade, 0.15m was for laying subbase and 0.15m for laying base course. The expansive soil was spread in the field, allowed for drying sufficiently and then pulverized to small pieces with wooden rammers. In the prepared test pit, the pulverized expansive soil was mixed with water at OMC and was laid in the excavated pit in 10 layers, each layer of 0.05 m compacted thickness, amount to a total thickness of 0.5 m. On the prepared subgrade flyash subbase material mixed with water content at OMC laid in 2 layers, each of 0.05m compacted thickness to a total thickness of 0.15m was laid. The reinforcement materials viz. Geogrid, Bitumen Coated Bamboo Mesh (BCBM) was kept above the first compacted layer of each pit. For the Waste Plastic reinforced stretch, the reinforcement materials (optimum percentage based on laboratory Shear and CBR) was mixed uniformly throughout the subbase material as shown in the Fig. 1. On the prepared subbase two layers of WBM-II each of 0.075m compacted thickness to a total thickness of 0.15m using crushed stone aggregate of size 45mm to 63mm with
murrum as binding material was laid. The compaction was done with the help of hand operated roller.

**Cyclic Load Testing**

Cyclic Plate load tests were carried out for different test stretches with different reinforcement materials viz. Geogrid, Bamboo mesh, Waste plastics, and unreinforced flyash stretch under normal tyre pressures using circular steel plate of diameter 0.3m. A loading frame was arranged centrally over the test track as shown in the Fig. 2. The loading frame was loaded with the help of sand bags. A steel base plate of 0.3m diameter was placed centrally over the test pit. Hydraulic Jack of capacity 100kN was placed over the plate attached to the loading frame with a loading cylinder. Three dial gauges with a least count of 0.01mm were placed on the metal flats to measure the settlements. A load of 5 kPa was applied as a seating load with the help of hydraulic jack and released. The load was applied in increments corresponding to tyre pressures of 500, 560, 630, 700 and 1000 kPa and each pressure increment was applied cyclically until there is insignificant increase in the settlement of the plate. These tests were carried out on the prepared expansive soil subgrade with three different reinforcement materials.

![Fig. 2: Experimental Set up for Conduct of Cyclic Plate Load Test](image)

5. **DISCUSSION ON TEST RESULTS**

Direct shear tests and CBR tests were conducted by using different percentages of waste plastics were mixed with flyash material for finding the optimum percentage. Cyclic load tests were conducted in the field on the flyash reinforced and un reinforced subbases laid on expansive soil subgrades.

**Direct Shear and C B R Test Results**

From the test results it is observed that flyash reinforced with waste plastics has given comparatively higher values of shear strength parameters in comparison with untreated flyash. From the direct shear test results ,it is observed that for flyash reinforced with waste plastics, the cohesion and angle of internal friction values are increased from 7.85 to 18.64 kN/m$^2$ and 33 to 40 respectively with 0.4% of waste plastics and there after decreased. It is also observed that flyash reinforced with waste plastic strips, soaked CBR values are increased from 4.0 to 10.81 for 0.40 % of waste plastics as shown in Fig. 3.

![Fig. 3: Strength Parameters for Flyash Reinforced with Different Percentages of Waste Plastic Strips](image)

**Load Test Results**

The cyclic load test results for the different alternatives were presented in the following sections.

**Pressure – Total Deformation Behavior on Expansive Soil Subgrade**

From the test results it is observed that the deformation attained equilibrium after six cycles of loading and unloading for all the pressure increments tried during the study. Higher deformations are recorded at higher load intensities as expected. From the pressure – total deformation curves shown in Fig. 4 for different test stretches the load carrying capacity is substantially increased for Geogrid reinforced stretch. For all the deformation levels geogrid reinforced stretch has shown better performance followed by bitumen coated bamboo mesh stretch and waste plastics stretches. At all load intensities the waste plastic reinforced stretch has shown higher deformation than other reinforcement materials.

![Fig. 4: Pressure-Total Deformation Curves for Different Pavement Stretches Laid on Expansive Soil Subgrade](image)

**Pressure-Elastic Deformation Behavior on Expansive Soil Subgrade**

It was observed that load carrying capacity was substantially increased for reinforced geogrid subbase for all the deformation levels which exhibits high load carrying capacity followed by other reinforcement materials as shown in the Fig.5. It can be observed that the elastic deformation values are decreased for geogrid reinforced stretch followed by bamboo mesh and waste plastics stretches.
Performance of Different Reinforcement Materials on Expansive Soil Subgrade

By providing reinforcement in subbase course the load carrying capacity has increased by 55%; 37% and 15% for geogrid, bitumen coated bamboo mesh and waste plastics respectively at saturated state of expansive soil subgrade laid on flyash subbase. From the cyclic load test results, the load carrying capacity is significantly increased and elastic deformations are decreased for the Geogrid reinforced stretch, BCBM reinforced stretch and waste plastics reinforced stretch respectively in flyash subbase laid on expansive soil subgrade at Saturation states. Higher deformations are recorded at higher load intensities as expected. It can be observed from the results, that the load carrying capacity has substantially increased for all the types of reinforcement materials at saturated states. Geogrid provide better interlocking with the soil particles thus ensuring adequate anchorage during loading. Relatively lower performance of bitumen coated bamboo could be attributed to its smooth surface to mobilize adequate friction. Waste plastics, which can lead to higher deflections compared to other reinforced materials tried in this investigation. However the geogrid scores over the other reinforcing material though relatively costly. The improvement in the load carrying capacity could be attributed to improved load dispersion through reinforced subbase on to the subgrade. This in-turn, results in lesser intensity of stresses getting transfer to subgrade, thus leading to lesser subgrade distress.

6. CONCLUSIONS

The optimum percentages of waste plastics from the direct shear and California bearing ratio tests for flyash materials is 0.4%.

The total and elastic deformation values of the flexible pavement system are decreased by the provision of the reinforcement viz., geogrid, bitumen coated bamboo mesh and waste plastics laid on expansive soil subgrades, in comparison with the conventional flexible pavement system.

The load carrying capacity of the flexible pavement system significantly increased for geogrid reinforced subbase stretch compared to other reinforced stretches on expansive soil subgrade.

REFERENCES


