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PERFORMANCE OF LOW COST MATERIAL IN THE PAVEMENT

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ABSTRACT

This paper investigates the performance of flexible pavement on expansive soil subgrade using flyash as subbase material course with different reinforcement materials like geogrid, bamboo mesh and waste plastics etc. Cyclic load tests were carried out in the field on the reinforced and unreinforced flexible pavements laid on expansive soil subgrades. It is observed that the maximum load carrying capacity associated with less value of rebound deflection is obtained for flyash reinforced subbase compared to unreinforced flyash subbase

1. INTRODUCTION

Civil and environmental engineering includes the analysis, design, construction and maintenance of structures and systems. All are built on, in, or with soil or rock. The properties and behavior of these materials have major influences on the success, economy, and safety of the work. Geoengineers play a vital role in these projects and are also concerned with virtually all aspects of environmental control, including waste disposal.

Many highway agencies, private organizations and researchers are doing extensive studies on waste materials and research projects concerning the feasibility and environmental suitability. The amount of wastes has increased year by year and the disposal becomes a serious problem. Particularly, recycling ratio of the plastic wastes in life and industry is very low and many of them have been reclaimed for the reason of unsuitable ones for incineration. It is necessary to utilize the wastes effectively with technical development in each field.

Expansive soils are known to cause damage mostly to light structures, such as residential dwellings and road pavements. The losses due to extensive damage to highways running over expansive soil subgrades are estimated to be in billions of dollars all over the world (Jones and Holtz, 1973; Steinberg, 1992). Various remedial measures like soil replacement (Snethen et al, 1979; Chen, 1988), prewetting (Bara, 1969; Subba Rao and Satyadas, 1980), moisture control (Mohan and Rao, 1965; Marienfeld and Baker, 1999), lime stabilization (Holtz and Gibbs, 1956; Thompson and Robnett, 1976; Bansal et al, 1996) have been practiced with varied degree of success. However, these technique suffer from certain limitations respect to their adaptability like longer time periods required for prewettting the highly plastic clays, (Felt,1953; Steinberg,1977), difficulty in constructing the ideal moisture barriers (Snethen et al,1979; Chen,1988), pulverization and mixing problems in case of lime stabilization (Holtz,1969; Ramana Murty,1998) and high cost for hauling suitable refill material for soil replacement (Snethen et al,1979; Chen,1988)etc.

In India there are about 82 thermal power plants, which are currently producing about 100 million tons of flyash per annum (Dhar, 2001). In order to utilize flyash in bulk quantities, ways and means are being explored all over the world to use it for construction of embankments and roads (Hausmann, 1990; Veerendra Singh et al, 1996; Boominathan and Ratna Kumar, 1996; Murthy, 1998). According to the latest MORHT specifications, several types of gravel are found to be unsuitable for road construction in view of higher finer fraction and excessive plasticity properties.

Reinforcement of soils with natural and synthetic fibres is potentially an effective technique for increasing soil strength. In recent years, this technique has been suggested for a variety of geotechnical applications ranging from retaining structures, earth embankments and footings to subgrade/subbase stabilization of pavements. The improvement of the engineering properties due to the inclusion of discrete fibres was determined to be a function of a variety of parameters including fibre type, fibre length, fibre content, orientation and soil properties. The introduction of randomly oriented fibres to a soil mass may also be considered similar to admixture stabilization. One of the primary advantages of randomly distributed fibres is the absence of potential planes of weakness that can develop parallel to oriented reinforcement (Maher and Woods, 1990).The optimum fiber content depends largely on the soil and fiber types (AlWahab and Al-Qurna, 1995. The results of direct shear tests performed on sand specimens (Gray and Ohashi.H, 1983) indicated increased shear strength, increased ductility and reduced post peak strength loss due to the inclusion of discrete fibers. The inclusion of discrete fibers increased both the cohesion and angle of internal friction of the specimens (Gray and Maher, 1989). The capability of synthetic fiber reinforcement for improving the behavior of sand has been demonstrated by Al-Refeai, 1991 using CBR tests, (Noorany and Uzdavines, 1989) using cyclic triaxial tests and (Maher and Woods, 1990) using resonant-column and torsional shear tests. These studies indicated that fiber inclusions increase the ultimate strength and stiffness, CBR, resistance to liquefaction and shear modulus and damping of reinforced sand. Full-scale experimental tests under traffic were performed by (Lindh and Eriksson, 1991) using synthetic fiber-reinforced sand in road pavements. The fiber reinforced sandy soil performed relatively high pressures and gave a stiffer response than that of non reinforced stratum and this strength was found increase continuously at a constant rate (Nilo C.Consoli et al., 2003).From the laboratory test results of (Prasad et al., 2008) direct shear and CBR, that the optimum percentage of waste plastics and waste tyre rubber is equal to 0.4% and 0.6% for flyash material. Research of different types of reinforcement and materials has been conducted by several investigators. However, the amount of information available on randomly oriented fiber reinforcement is still limited.

An attempt is made to study the performance of reinforced flyash subbase layer with different materials, such as Geogrid, Bitumen Coated Chicken Mesh, Bitumen Coated Bamboo Mesh, Waste Plastics and Waste Tyre Rubber 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 subgrades during wet season. Keeping in view the high cost of geogrid, other materials like bamboo mesh, waste plastics and waste tyre rubber were also tried for their use as reinforcing materials.

2. EXPERIMENTAL STUDY

2.1 Materials Used

The following materials were 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 %, Permeability (cm/sec) = 1.5×10^{-7}, Soaked CBR=2.0%.

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%, Permeability (cm/sec) = 0.5×10^{-6}, Soaked CBR=4.0%.

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%.

Geogrid: Netlon CE 121 Geogrid with a peak tensile strength of 7.68 kN/m and aperture size of 8 mm x 6 mm was used in this investigation.

Chicken Mesh : Chicken Mesh with peak tensile strength of 8.85 kN/m and aperture size of 2mm x 2mm coated with 80/100 grade bitumen was used as an alternative reinforcement material.

Bamboo Mesh*:* Bamboo Mesh of thickness 1mm with peak tensile strength of 26.32 kN/m coated with 80/100-grade bitumen was used as an alternative material.

Waste Plastics Chips*:* Waste plastics strips having a size of 12 mm x 6 mm and a thickness of 0.5 mm was used in this study as shown in Fig. 1.

Waste Tyre Rubber Chips: Waste Tyre Rubber chips passing through 4.75 mm sieve were used in this study, as an alternative reinforcement material as shown in Fig.2.

Road Metal*:* Road metal of size varying between 45-63mm was used for the base course.

Fig: 1 Waste plastic strips

Fig: 2 Waste Tyre Rubber Chips

Table 1 Chemical Composition of Flyash
(Courtesy: VTPS, Vijayawada)

Name of Chemical	Symbol	Range by % of Weight
Silica	SiO_2	61 to 64.29
Alumina	Al_2O_4	21.60 to 27.04
Ferric Oxide	Fe_2O_3	3.09 to 3.86
Titanium dioxide	TiO_2	1.25 to 1.69
Manganese Oxide	MnO	Up to 0.05
Calcium Oxide	CaO	1.02 to 3.39
Magnesium Oxide	MgO	0.5 to 1.58
Phosphorous	P	0.02 to 0.14
Sulphur Trioxide	SO_3	Up to 0.07
Potassium Oxide	K_2O	0.08 to 1.83

3. FIELD EXPERIMENTATION

3.1 Preparation of Test Stretches

In this study six alternative test tracks (Geogrid reinforced subbase, Bitumen coated Chicken mesh reinforced subbase, Bitumen coated bamboo mesh reinforced subbase, Waste plastics reinforced subbase, Waste Tyre Rubber reinforced subbase and Untreated subbase) were prepared on expansive soil subgrade with flyash subbase materials separately, as shown in Fig.3 and the details of which are presented in the following sections.

Tests track each of size 3m long and 1.5m wide was excavated to an average depth of 0.8m as shown in Fig. 4. Out of which 0.5m was for laying subgrade, 0.15m was for laying subbase and 0.15m for laying base course as shown in Fig.3.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 as shown in the Fig.5 . On the prepared subgrade flyash subbase material mixed with water content at OMC laid in 2 layers, each of 0.075m compacted thickness to a total thickness of 0.15m was laidas shown in the Fig.7. The reinforcement materials viz. Geogrid, Bitumen Coated Chicken Mesh (BCCM), Bitumen Coated Bamboo Mesh (BCBM) was kept above the first compacted layer of each pit as shown in the Fig.6. For the Waste Plastic/Waste Tyre Rubber reinforced stretchs, the reinforcement materials (optimum percentage based on laboratory Shear and CBR) was mixed uniformly throughout the subbase material. 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. A critical view of field stretches used for finding the best alternative reinforcement material in the flexible pavement system is shown in the Fig. 8.

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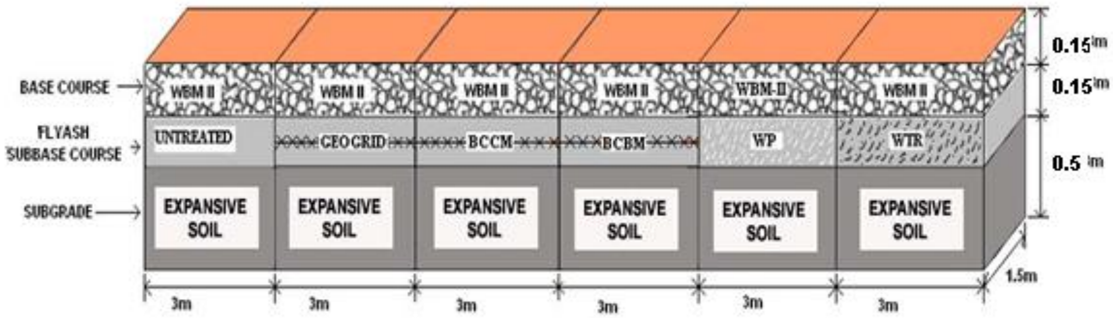

Fig.3 Preparation of Test Stretches

BCCM: Bitumen Coated Chicken Mesh WP: Waste Plastics
BCBM: Bitumen Coated Bamboo Mesh WTR: Waste Tyre Rubber

	
Fig.4 Excavated Model Pavement Stretch	Fig.5 Prepared Expansive Soil Subgrade in the Model Pavement

Fig.6 Placing of Reinforcement Material in the Subbase

Fig.7 Prepared Flyash Subbase

Fig.8 Prepared Model Flexible Pavement Stretch

Fig.9 Experimental set-up for conducting Cyclic Load Test

3.2 Cyclic Load Testing

Cyclic Plate load tests were carried out for different test stretches with different reinforcement materials viz. Geogrid, Chicken Mesh, Bamboo mesh, Waste plastics, Waste Tyre Rubber 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.9. 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 5kPa 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 five different reinforcement materials.

4. DISCUSSION ON TEST RESULTS

4.1 Load test results

The cyclic load test results for the different alternatives are presented in the following section.

Pressure – total deformation behaviour on expansive soil subgrades

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.10 for different test stretches the load carrying capacity is substantially increased for Geogrid reinforced subbase stretch. For all the deformation levels Geogrid reinforced stretch has shown better performance followed by BCCM, BCBM, WP and WTR stretches respectively. At all load intensities the waste tyre rubber reinforced stretch has shown higher deformation than other reinforced stretches.

Pressure-elastic deformation behaviour on expansive soil subgrades

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 BCCM, BCBM, WP and WTR stretches as shown in the Fig.11. It can be observed that the elastic deformation values are substantially decreased for Geogrid reinforced subbase stretch compared to other stretches.

4.2 Performance of Model Pavement Stretches Laid on Expansive Soil Subgrade

From the above studies flyash reinforced model flexible pavement has shown better performance compared to the unreinforced flyash model pavement.

Geogrid and chicken mesh provide better interlocking with the soil particles thus ensuring adequate anchorage during loading. Relatively lower performance of bitumen coated bamboo mesh could be attributed to its smooth surface to mobilize adequate friction. Waste plastics and waste tyre rubber are more elastic which can lead to higher deflections compared to other reinforced materials tried in this investigation.

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.

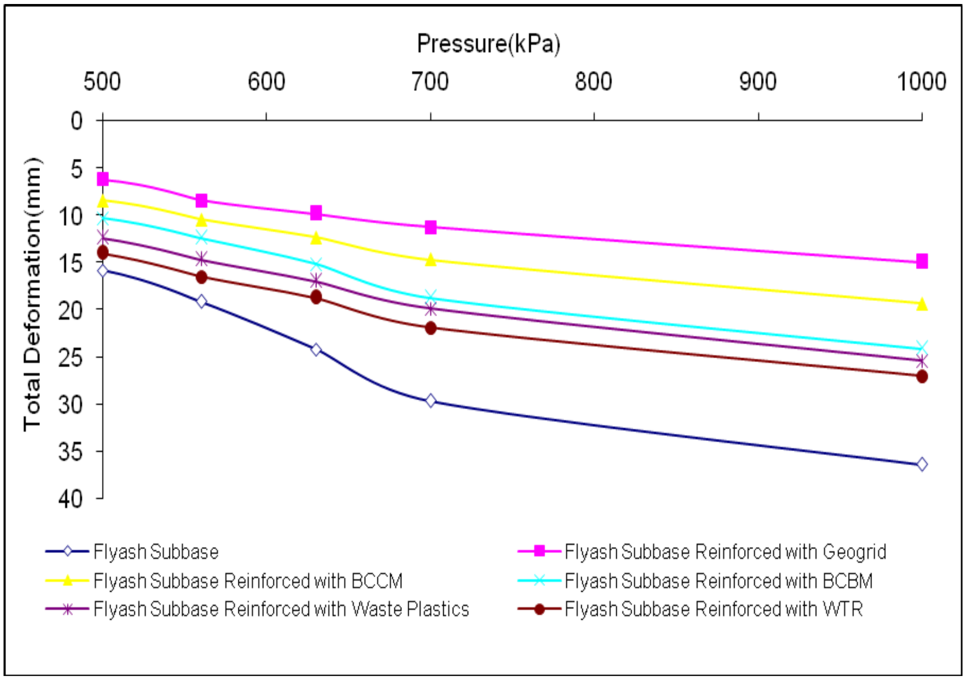

Fig: 10 Pressure vs Total Deformation values for Flyash Reinforced Subbases with Waste Plastics

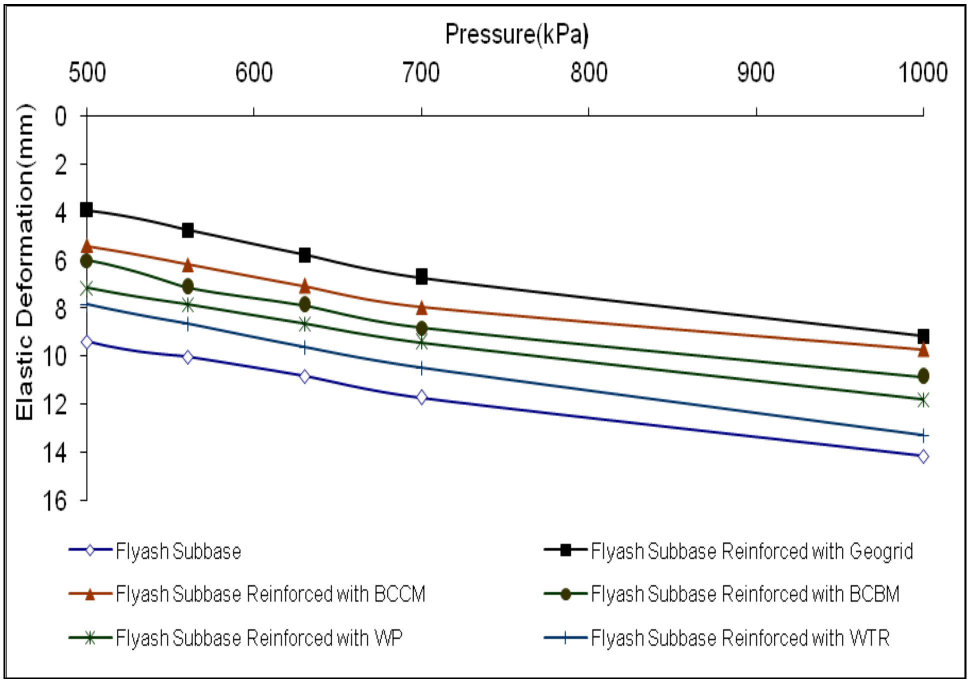

Fig: 11 Pressure vs. Elastic Deformation values for Flyash Reinforced Subbases with Waste Plastics

5. CONCLUSIONS

- The load carrying capacity of the model flexible pavement system is significantly increased by introducing reinforcement material in flyash subbases laid on expansive soil subgrade.
- The total and elastic deformation values of the flexible pavement system are decreased by the provision of the reinforcement viz: Geogrid, BCCM, BCBM, WP and WTR stretches in flyash subbases laid on expansive soil subgrade.

- The maximum load carrying capacity followed by less value of rebound deflection is obtained for Geogrid reinforced subbase stretch followed by other stretches laid in flyash subbase of the flexible pavement system.
- The improvement of the pavement performance is cognizable for the two reinforcement materials tried viz., geogrid and bitumen coated chicken mesh. Both geogrid and bitumen coated chicken mesh provide excellent interlocking of soil particles, thereby resulting in better performance compared with bitumen coated bamboo mesh, waste plastics and waste tyre rubber.

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