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UTILISATION OF WASTE PLASTICS IN FLEXIBLE PAVEMENT CONSTRUCTION LAID ON EXPANSIVE SOIL SUBGRADE

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ABSTRACT

This paper investigates the performance of model flexible pavement on expansive soil subgrade using gravel / flyash as subbase course with waste plastics as a reinforcing material. It was observed that from the laboratory test results of direct shear and CBR, the optimum percentage of waste plastics is equal to 0.3% and 0.4% for gravel and flyash materials. Cyclic load tests were carried out in the field on the reinforced and unreinforced model 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 gravel/flyash reinforced subbase compared to unreinforced gravel/flyash subbase.

INTRODUCTION

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 techniques 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 utilise 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 MORT specifications, several types of gravel are found to be unsuitable for road construction in view of higher finer fraction and excessive plasticity properties.

Many highway agencies, private organizations and researchers are doing extensive studies on waste materials and research projects concerning the feasibility, environmental suitability and performance of using recycled products in highway construction are in progress. 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.

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 (Gray and Ohashi, 1983). 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). Compaction tests conducted on sandy soil specimens reinforced with polypropylene/nylon fabric sheets resulted in specimens with less dense packing (Hoare, 1979). Reinforced uniformly graded sand specimens exhibited curvilinear-linear Mohr-Coulomb failure envelopes while reinforced well-graded, or angular, sand specimens exhibited bilinear failure envelopes (Gray and Maher, 1989). 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 using CBR tests (Al-Refeai, 1991), cyclic triaxial tests (Noorany and Uzdavines, 1989) and resonant-column and torsional shear tests (Maher and Woods, 1990). 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. Khaled Sobhan&Mehedy Mashnad, (2003), found that the use of fiber reinforcement significantly increased the postpeak load carrying capacity of the mix and thus the fracture energy. 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). 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.

In the present work an attempt is made to use waste plastics in gravel and flyash subbases in model flexible pavement laid on expansive soil subgrade to study the relative performance between the reinforced and unreinforced model flexible pavement. Direct shear and CBR tests were conducted in the laboratory for both gravel and flyash materials with different percentages of waste plastic strips to obtain optimum percentage of reinforcement material. The investigation was further extended by constructing model flexible pavements in the field with different subbases reinforced with optimum percentage of waste plastics and cyclic plate load tests were conducted on the model pavement during wet season.

EXPERIMENTAL STUDY

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 %, 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%, 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=18.05kN/m^3, Soaked CBR=8.0%.

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

Waste plastics: Waste plastic 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.

Fig: 1 Waste plastic strips

LABORATORY EXPERIMENTATION

Direct Shear Tests

Direct shear tests were conducted in the laboratory by using a standard direct shear testing machine as per IS: 2720 (part XIII, 1986). The required percentage of waste plastics was mixed uniformly with dry weight of soil and compacted to maximum dry density and optimum moisture content of natural material.

California Bearing Ratio (CBR) Tests

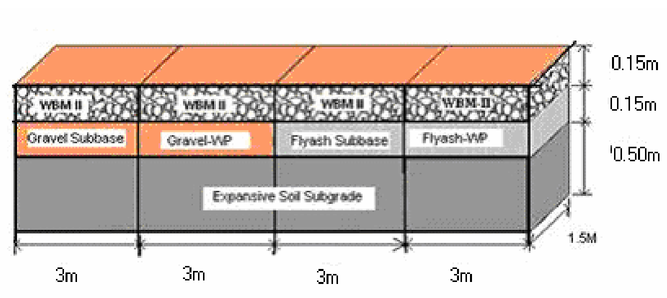
California Bearing Ratio tests were conducted in the laboratory for all the samples as per IS: 2720 (part VI, 1979).

FIELD EXPERIMENTATION

Preparation of Test Stretches

A test pit, each of size 3m long, 1.5m wide to an average depth of 0.8m was prepared as shown in the fig: 2. Out of which, 0.5m depth was for laying subgrade, 0.15m was subbase and 0.15m for basecourse,as shown in the fig.3. In the prepared test pit, the expansive soil mixed with water at OMC was laid in 10 layers such that each layer of 0.05m compacted thickness amount to a total thickness of 0.5m was laid in the excavated pit. On the prepared subgrade, gravel / flyash subbase material mixed with water content at OMC in 2 layers, each of 0.075m compacted thickness to a total thickness of 0.15m was laid. The waste plastic reinforcement material (optimum percentage based on laboratory 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.

Fig: 2 Excavated Pavement Stretch



(WP: Waste Plastics)

Fig.3 Preparation of Test Stretches

Cyclic Load Testing

Cyclic Plate load tests were carried out for different model pavements under normal tyre pressures using circular steel plate of diameter 0.3m. A loading frame was arranged centrally over the model pavement as shown in the Fig: 4. 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 1000kPa and each pressure increment was applied cyclically until there is insignificant increase in the settlement of the plate. These tests were carried out for all the four model flexible pavements as shown in the Fig: 3 during wet season.

Fig.4 Experimental set-up for conducting Cyclic Load Test

DISCUSSION ON TEST RESULTS

Laboratory Test Results

Direct shear tests and CBR tests were conducted by using different percentages of waste plastics mixed with gravel / flyash material for finding the optimum percentage of waste plastics.

Direct Shear Test Results: From the table:1, it is observed that, for gravel reinforced with waste plastics, the angle of internal friction values are increased from 36^0 to 44^0 with 0.3 % of waste plastics and thereafter decreased with further additions. The cohesion values are increased from 14.72 to 27.76 kN/m^2 with 0.3 % of waste plastics and thereafter decreased. It is also 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 33^0 to 40^0 respectively with 0.4% of waste plastics and there after decreased.

Table: 1 Strength Parameters for Gravel and Flyash Materials Reinforced with Waste Plastic Strips

% of Waste Plastics	Gravel			Flyash		
	C (kN/m^2)	Ø °	Soaked CBR (%)	C (kN/m^2)	Ø °	Soaked CBR (%)
0.0	14.72	36	8.0	7.85	33	4.0
0.1	18.93	37	9.37	9.64	34	5.98
0.2	23.64	40	13.34	12.65	36	7.41
0.3	**27.76**	**44**	**16.42**	16.70	38	8.91
0.4	27.65	43	15.23	**18.64**	**40**	**10.81**
0.5	26.29	42	14.12	17.66	38	9.47

California Bearing Ratio (CBR) Test Results: It is observed from table: 1, that for gravel / flyash reinforced with waste plastic strips, soaked CBR values are increased from 8.0 to 16.4 and 4.0 to 10.81 for 0.30 % and 0.40 % of waste plastics respectively.

From the results of direct shear and california bearing ratio tests, the optimum percentage of waste plastics for gravel and flyash materials are equal to 0.3% and 0.4% respectively.

CYCLIC LOAD TEST RESULTS

Four model flexible pavements were constructed in the field out of which two pavements were constructed with waste plastics reinforced in gravel and flyash subbases and the other two were unreinforced pavements so as to know the relative performance in the field. Cyclic plate load tests were conducted during wet season on all the four model flexible pavements and the results of which are discussed in the following section.

Pressure-Total Deformation Behavior on Gravel/Flyash Subbase Reinforced with Waste Plastics

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 test results as shown in Fig. 5 it is observed that load carrying capacity has substantially increased for waste plastics reinforced flexible pavement. At all the deformation levels gravel reinforced subbase shows better performance as compared to flyash reinforced subbase.

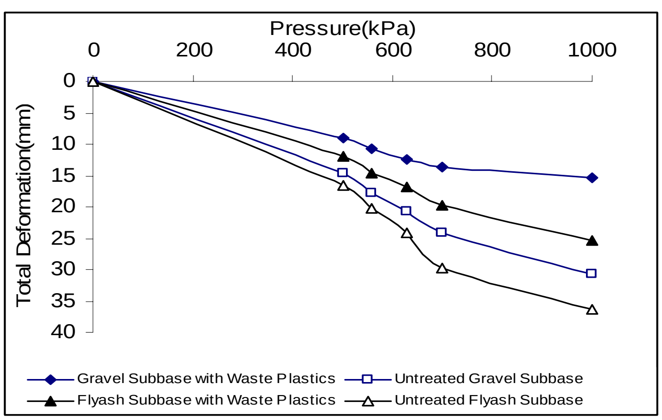


Fig: 5 Pressure vs Total Deformation values for Gravel and Flyash Reinforced Subbases with Waste Plastics

Pressure-Elastic Deformation Behavior on Gravel/Flyash Subbase Reinforced with Waste Plastics

From the pressure - elastic deformation curves as shown in the Fig: 6, for different stretches on expansive subgrade, it can be observed that the elastic deformations considerably decreased by the provision of reinforcement material in the subbase course. It was observed that load carrying capacity was substantially increased for reinforced gravel subbase for all the deformation levels which exhibits high load carrying capacity followed by reinforced flyash stretch.

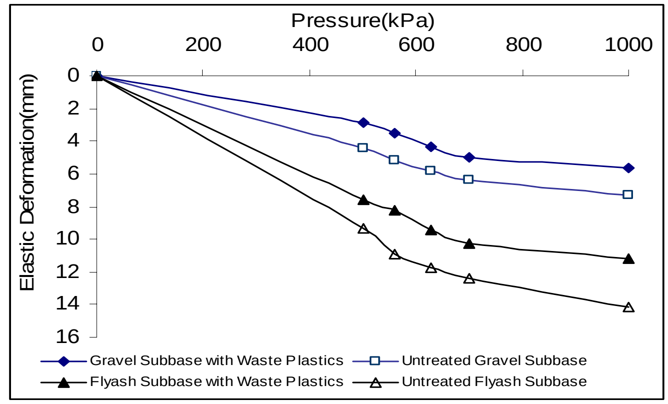


Fig: 6 Pressure vs Elastic Deformation values for Gravel and Flyash Reinforced Subbases with Waste Plastics

Performance of Model Pavement Stretches Laid on Expansive Soil Subgrade

From the above studies gravel reinforced model flexible pavement has shown better performance compared to the flyash reinforced model pavement. The load carrying capacity is maximum for waste plastics reinforced gravel subbase stretch, followed by waste plastics reinforced flyash subbase stretch. 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 sub grade distress.

CONCLUSIONS

From the result of direct shear tests and CBR test,s it is observed that for gravel and flyash materials, the optimum percentage of waste plastics are equal to 0.3% and 0.4 % of dry unit weight of soil respectively.

The load carrying capacity of the flexible pavement has significantly increased for both gravel and flyash subbases reinforced with optimum percentage of waste plastics laid on expansive soil subgrade.

At all the deformation levels, gravel reinforced with waste plastics in the model flexible pavement has shown better performance, compared to waste plastics reinforced flyash subbase.

The total and the elastic deformation values are decreased for reinforced waste plastics on both gravel and flyash subbases as compared to unreinforced subbases.

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