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Utilisation of Waste Materials in the Construction Of Roads

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Abstract:- Expansive soils are so widely spread that it becomes impossible to avoid them for highway construction to keep the network structure for mobility and accessibility. These soils are prevalent as large tracts in many parts of the world. Many highway agencies, private organizations and researchers are doing extensive studies on waste materials and research projects concerning the feasibility and environmental suitability. It is necessary to utilize the waste affectively with technical development in each field. Cyclic plate load tests were carried out on the tracks with optimum percentage of reinforcement materials like waste plastics and waste tyre rubber in gravel/flyash subbase laid on expansive subgrade. Test results show that maximum load carrying capacity associated with less value of rebound deflection is obtained for gravel/flyash reinforced subbase compared to unreinforced subbase.

Keywords:- Expansive Soil, Flyash, Gravel, CBR, Load Test, Reinforcement materials, Pavement.

I. INTRODUCTION

Soils which exhibit a peculiar alternate swell – shrink behaviour due to moisture fluctuation are known as expansive soils. These soils are generally found in poorly drained localities where there are marked wet and dry seasons. The clay minerals are formed through extensive physical and chemical weathering of parent material. Indian black cotton soils are formed by weathering of basalt and traps of Deccan plateau and the thickness of the layer is varying from 0.5m to more than 10m. DTA and X-ray diffraction pattern analysis [1-4] have shown that montmorillonite is the predominant clay mineral in the black cotton soil. The high percentage of clay content with predominant montmorillonite mineral is responsible for high volumetric changes during Wetting and drying and these volumetric changes causes huge damage to all civil engineering structures and pavements resting on them. The amount of wastes has increased year by year and the disposal becomes a serious problem. Particularly, recycling ratio of the wastes in life and industry is 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. Reinforced soil construction is an efficient and reliable technique for improving the strength and stability of soils. The technique is used in a variety of applications, ranging from retaining structures and embankments to subgrade stabilization beneath footings and pavements. [5] made an attempt to compare the quantity of the earth required for the subgrade with and without flyash and polypropylene fibers stabilization and for 1.5% of fiber and 15 % of flyash the thickness of the pavement is decreased by 60% and the 8610 m^3 of soil can be saved for one kilometer length of the road. By addition of the flyash and fiber to the expansive soils the CBR value is increased which can reduce the pavement thickness. [6], has conducted Cyclic plate load tests in the laboratory at OMC to study the relative performance between the reinforced and unreinforced subbases of model pavement system and the results were found that, flexible pavement reinforced with waste plastics and waste tyre rubber has shown better performance as compared to unreinforced subbase, at all deformation levels, flexible pavement system laid on sand subgrade has shown better performance when compared to expansive soil subgrade. [7] Conducted CBR and standard proctor tests in the laboratory for finding the optimum percentages of waste plastics, and quarry dust in soil sample. Based on the results the % of plastic waste increases the maximum dry density decreases, thereby decreasing the CBR value and increase in % of quarry dust increase of maximum dry density and CBR. [8] has conducted shear and CBR tests in the laboratory, observed from the results flyash materials reinforced with different percentages of waste plastics and coconut coir, the optimum percentages were equal to 0.3 % and 0.2 % respectively. The flyash material reinforced with waste plastics has shown better performance when compared to flyash reinforced coconut coir material. Waste plastics and coconut coir reinforced flyash materials has shown maximum improvement compared to unreinforced material. [9], shredded rubber from waste has been chosen as the reinforcement material and cement as binding agent which was randomly included into the soil at three different percentages of fibre content, i.e. 5% 10% and 15% by weight of soil. California bearing ratio and unconfined compression tests were conducted. The tests have clearly shown a significant improvement in the shear strength and bearing capacity parameters and low strength and high compressible soft clay soils were found to improve by addition of shredded rubber and cement. However the results are not conclusive with special reference to coir as a type of the reinforcement material for overcoming the problems of expansive soil. It is evident that not much work has been reported on the gravel/flyash subbases reinforced with tyre/plastics for its application to flexible pavements on expansive soil subgrades. In the present investigation an attempt is made to evaluate the performance of reinforced gravel/flyash subbase layer with different materials, such as waste plastics and waste tyre rubber in model flexible pavement construction 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.

II. MATERIALS USED

Details of various materials used during the laboratory experimentation are reported in the following section**.**

A. ***Expansive Soil:*** The subgrade soil used in this study was a typical expansive block cotton soil collected from Amalapuram, East Godavari District of Andhra Pradesh State, India. Based on these properties, this soil can be classified as inorganic clay of high compressibility (CH), according to IS: 1498-197016. The soil properties are W_L = 66%, W_P = 32%, W_S =12% OMC=23%, MDD = 15.69 kN/m^3, Differential Free Swell = 150 %, Soaked CBR = 2 %.

B. ***Gravel:*** Gravel satisfying MORTH specification was used as subbase material in this investigation. The properties of gravel used in subbase course are gravel = 60%; sand =30%; fines =10%; liquid limit = 20%; plastic limit = 14%; plasticity index = 6%; maximum dry density = 18.9 kN/m^3 and Optimum Moisture Content = 12%.

C. Flyash: The flyash collected from Vijayawada thermal power station, Vijayawada is used as a subbase course in this work. The properties of flyash are MDD = 13.24 kN/m^3, OMC = 24%, W_L = 28 %, Soaked CBR = 4 %.

D. ***Waste Plastic Strips:***

Waste plastic strips having a size of 12 mm × 6 mm and a thickness of 0.5 mm was used in this study (Fig. 1).

E. ***Waste Tyre Rubber Chips***

Waste Tyre Rubber chips passing through 4.75 mm sieve were used in this study (Fig. 2).

Fig.1 Waste Plastics

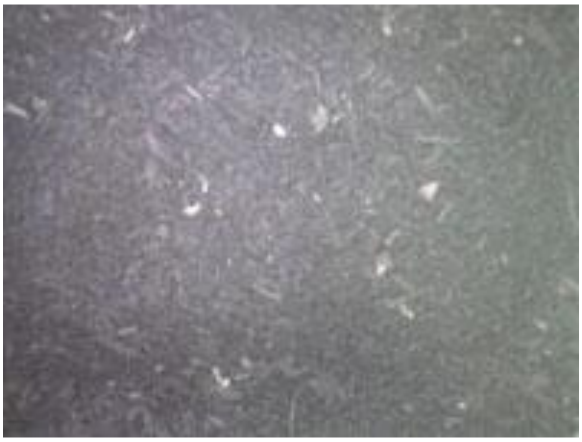

Fig.2 Waste Tyre Rubber

F. ***Road Metal:*** Road metal of size 20 mm conforming to WBM-III, satisfying the MORT Specifications is used as base course material.

III. LABORATORY EXPERIMENTATION

Various tests were carried out in the laboratory for finding the index and other important properties of the soils used during the study. Direct shear and CBR tests were conducted by using different percentages of waste plastics and waste tyre rubber mixed with gravel/flyash material for finding optimum percentage of reinforcement materials. The details of these tests are given in the following sections.

Index Properties: Standard procedures recommended in the respective I.S. Codes of practice [IS:2720 (Part-5)-1985; IS:2720 (Part-6)-1972],were followed while finding the Index properties viz. Liquid Limit, and Plastic Limit of the samples tried in this investigation.

Compaction Properties: Optimum moisture content and maximum dry density were determined according to I.S heavy compaction test (IS: 2720 (Part VIII).
Direct Shear Tests: The direct shear tests were conducted in the laboratory as per IS Code (IS: 2720 (Part-13)-1986) as shown in the Fig. 3. The required percentages of waste plastics + waste tyre rubber were mixed in gravel / flyash by dry unit weight uniformly. The water content corresponding to OMC of untreated soil was added to the soil in small increments and mixed by hand until uniform mixing of the strips was ensured. The soil was compacted to maximum dry density (MDD) of untreated soil.
***California Bearing Ratio** (CBR) **tests** :* Different samples were prepared in the similar lines for CBR test using gravel/flyash materials reinforced with waste plastics + waste tyre rubber. The CBR tests were conducted in the laboratory for all the samples as per I.S.Code (IS: 2720 (Part-16)-1979) as shown in the Fig. 4.

Fig:3 Direct Shear Test Apparatus

Fig:4 California Bearing Ratio Test Apparatus

Heave Measurements: The model flexible pavement system is saturated completely by pouring water above the base course. Heave readings are taken with the help of dial gauges at regular intervals for the expansive soil subgrade pavements as shown in the Fig: 7. These readings are measured until there is no significant change between consecutive readings observed.

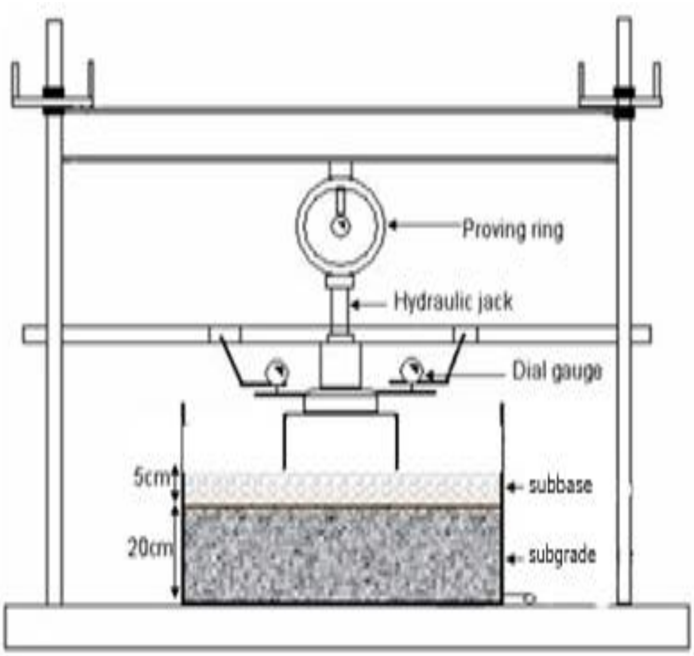

Fig: 5 Laboratory Experimental Set- Up for Conducting Cyclic Load Test

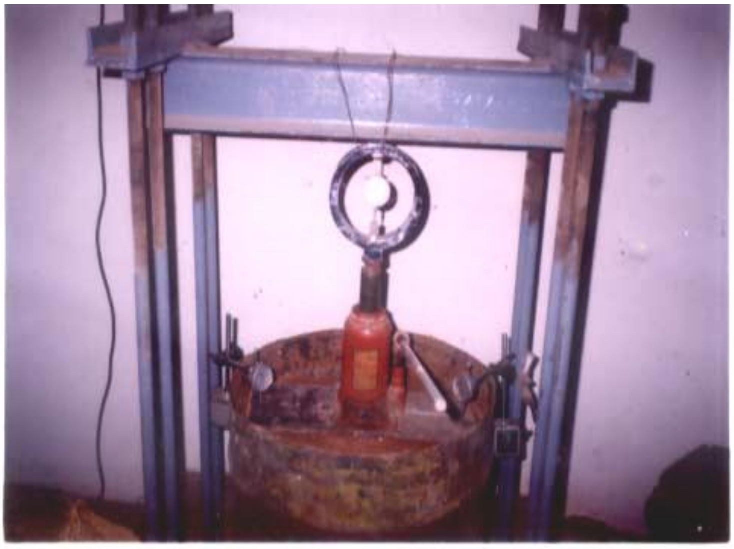

Fig. 6 Laboratory Cyclic Load Test Apparatus

Fig: 7 Heave Measurements in Laboratory

1. ***Loading-Unloading Test:*** Loading-unloading tests were carried out on model flexible pavement system after its complete saturation. The loading was done through a circular metal plate of 10 cm diameter placed at the centre of the model flexible pavement system. Dial gauges having least count 0.02 mm were arranged as shown in Fig 6. A hydraulic jack was placed on the loading plate and it was connected to the 5 tonne capacity proving ring. Loading-unloading tests were carried out for different pressure increments of 500,560, 630, 700 and 1000 kPa. At each pressure increment six cycles of loading and unloading were done until there was no significant change in deformation.

IV. LABORATORY TEST RESULTS

Based on the compaction test results of gravel and flyash as the percentage of reinforcing materials increases, the maximum dry density increases and optimum moisture content increases for gravel up to (0.2% of WP+2.0% of WTR), similarly for flyash up to (0.3% of WP+3.0% of WTR). Further addition of reinforcing material the maximum dry density decreases shown in figs. 8and 9.

The direct shear tests were conducted as per IS: 2720 (part XIII, 1986) in the laboratory for gravel and flyash materials with and without waste tyre rubber and waste plastics strips and the results are furnished figs.10 and 11. The Specimens are tested by using direct shear testing machine for gravel/flyash materials mixed with varying percentages of waste tyre rubber chips + waste plastics strips. Graphs drawn between normal stress and shear stress for each percentage, from these shear strength parameters such as Angle of internal friction and cohesion values are calculated.

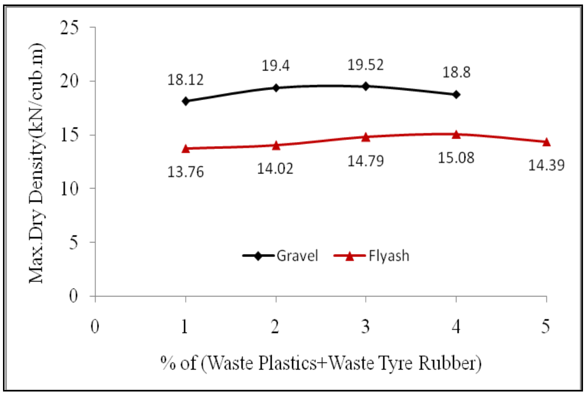

Fig: 8 Variation of Maximum Dry Density (MDD) for Gravel /Flyash Reinforced with Different Percentages of (WP+WTR)

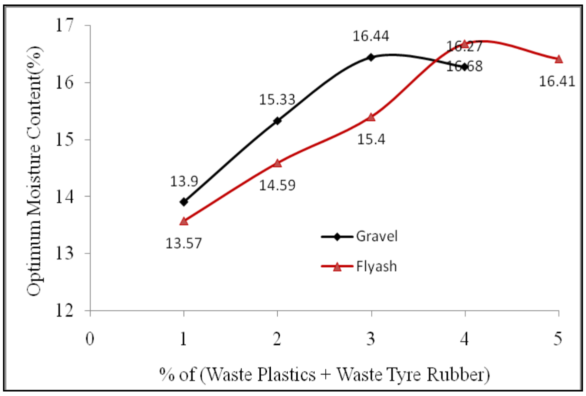

Fig: 9 Variation of Optimum Moisture Content for Gravel/Flyash Reinforced with Different Percentages of (WP+WTR)

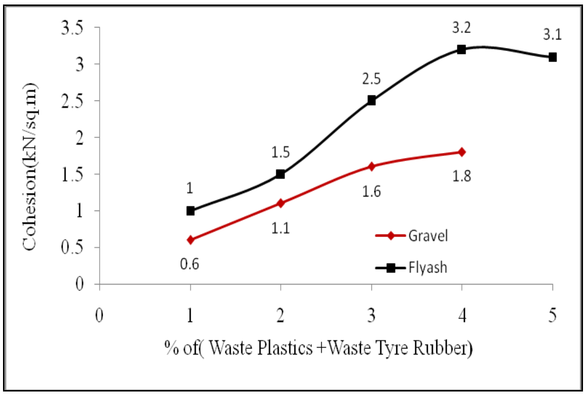

Fig: 10 Variation of Cohesion values for Gravel/Flyash Material Reinforced with Different Percentages of (WP+WTR)

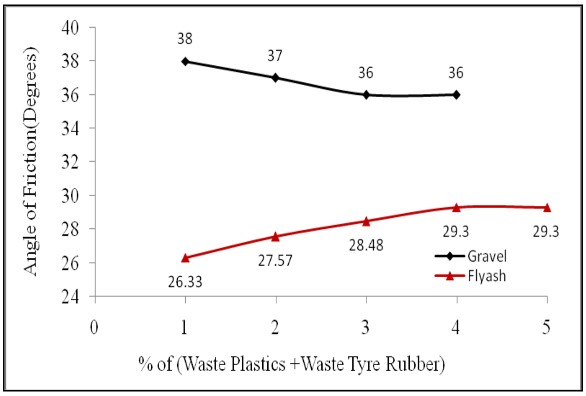

Fig: 11 Variation of Angle of Internal Friction values for Gravel/Flyash Reinforced with Different Percentages of (WP+WTR)

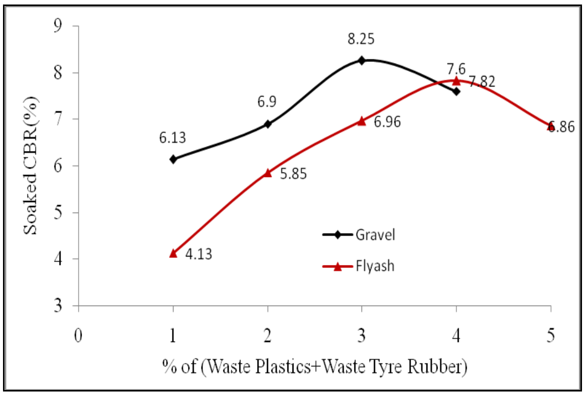

Fig: 12 Variation of Soaked CBR values for Gravel/Flyash Reinforced with Different Percentages of (WP+WTR)

Based on the above results, it is observed that, for gravel reinforced with waste plastic strips and waste tyre rubber chips, the angle of internal friction values are decreased from 38^0 to 36^0 and cohesion values are increased from 0.6 to 1.6 kN/m^2 with (0.2% WP + 2.0% WTR). Similarly for flyash materials cohesion values are increased from 1 to 3.2 kN/m^2 and angle of internal friction value increases from 26.33^0 to 29.3^0 with (0.3% WP + 3.0% WTR) respectively and further addition of waste plastics strips and waste tyre rubber does not effect the angle of internal friction and cohesion, as shown in figs. 10 and 11.It is observed from the results, that for gravel reinforced with (waste plastics strips + waste tyre rubber chips), soaked CBR values are increased from 6.13 to 8.25 with (0.2% WP + 2.0% WTR).For flyash material soaked CBR values are increased from 4.13 to 7.82 for (0.3% WP + 3.0% WTR) and further addition of (WP+WTR) does not affect the CBR value. From the laboratory test results of compaction, direct shear and California Bearing Ratio tests, the optimum percentage for gravel material is (0.2% WP + 2.0% WTR), for flyash is (0.3% WP + 3.0% WTR) respectively as shown in the fig. 12.

V. LOAD TEST RESULTS

The pressure - deformation curves for different model flexible pavements constructed on gravel/flyash subbase laid on expansive soil subgrade, shown in figs.13 & 14 respectively. At all the deformation levels, waste plastics + waste tyre rubber chips reinforced gravel/flyash subbases stretch shows better performance as compared to unreinforced gravel/flyash subbase stretch. At OMC state, the total and elastic deformations of unreinforced flyash a load of 500kPa are equal to 3.7mm, 2mm; for reinforced stretch at a load of 500 kpa are equal to 3.7 mm, 2.0 mm; similarly the total and elastic deformations of unreinforced gravel at a load of 600 kPa are equal to 4.15mm, 2.97mm; for reinforced stretch at a load of 500 kpa are equal to 2.85 mm, 1.275mm for waste plastics + waste tyre rubber reinforced stretch respectively, It can be observed that the load carrying capacity is increased and elastic deformation is increased for the (WP+WTR) reinforced flyash subbase stretch compared to reinforced gravel subbase stretch respectively.

Higher deformations are recorded at higher load intensities as expected. 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. At all the deformation levels, reinforced (WP+WTR) both gravel and flyash subbase stretch exhibits highest load carrying capacity compared to unreinforced gravel and flyash subbase stretches.

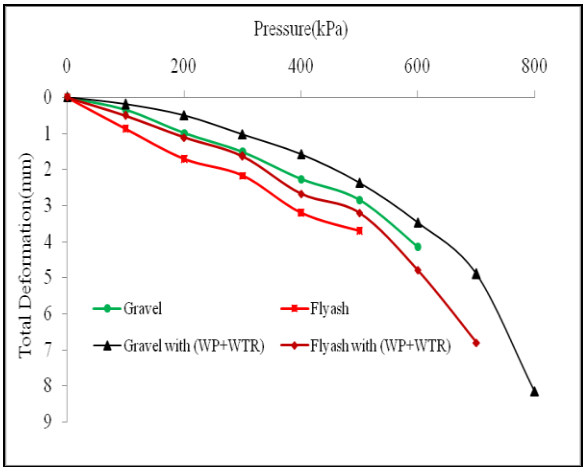

Fig: 13 Pressure-Total Deformation Curves for (WP+WTR) Reinforced Material in Gravel/Flyash Subbase of Laid on Expansive Soil Subgrade at OMC

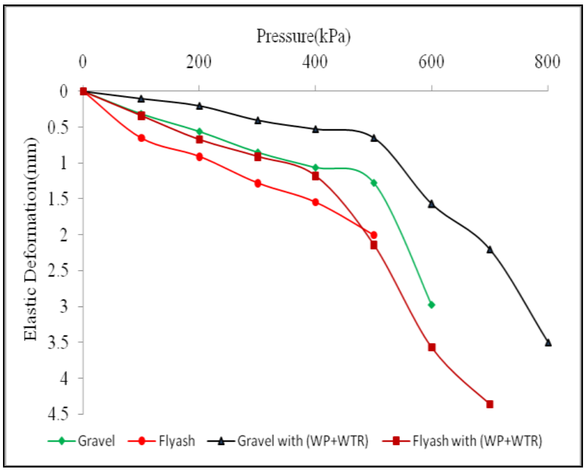

Fig: 14 Pressure-Elastic Deformation Curves for (WP+WTR) Reinforced Gravel/Flyash Subbase Laid on Expansive Soil Subgrade at OMC

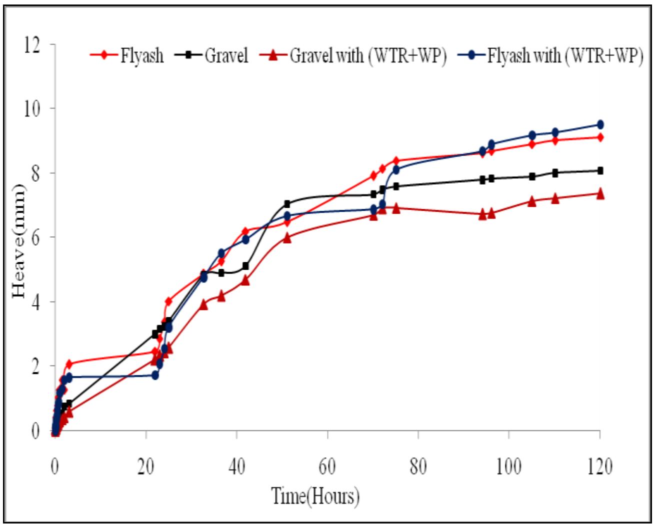

Fig: 15 Heave-Time Plot for (WP + WTR) Reinforced Model Flexible Pavements laid on Expansive Soil Subgrade on Gravel/Flyash Subbase

VI. HEAVE MEASUREMENTS

The heave measurements were taken for different time intervals for all the alternatives of model flexible pavements in the laboratory. The heave vs. time graphs for different reinforcing materials used in subbases of model flexible pavement system are presented in the fig. 15. The observed maximum values of heave for model pavement stretches laid on expansive soil subgrade for gravel,flyash,gravel with (WP+WTR) and flyash with (WP+WTR) subbases are equal to 8.10 mm; 9.13 mm; 7.38 mm and 9.54 mm respectively. There is no significant control of heave for reinforced and unreinforced subbases. This behavior is evident from the fact that there is no heave control mechanism with the reinforcement in pavement system. In fact, it is intended to incorporate reinforcement material in the flexible pavement system to strengthen it with little emphasis on heave control.

Performance of reinforcement materials on gravel/flyash subbases laid on expansive soil subgrade

The Pressure-Deformation curves for different laboratory model flexible pavements reinforced with gravel/flyash subbase laid on expansive soil subgrade are presented in figs. 13&14. The load carrying capacity of the model flexible pavement system has increased by introducing reinforcement material in gravel/flyash subbases on expansive soil subgrade.

No significant control of heave is observed when reinforcement is placed in flexible pavement subbase laid on expansive soil subgrade. In fact, it is intended to incorporate reinforcement material in the flexible pavement to strengthen it with little emphasis on heave control. Further it can be seen that heaving of the expansive soil considerably decreases the load carrying capacity of the pavement system.

The reinforcement attributes transmission of load to the subgrade over a wider area and hence will not contribute significantly towards settlement of the pavement. 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 transferred to subgrade, thus leading to lesser subgrade distress.

Waste plastics and waste tyre rubber are more elastic which can lead to higher deflections used as reinforced material tried in this experimental investigation. However the load carrying capacity has increased for gravel/flyash reinforced subbase when compared to gravel/flyash unreinforced subbase laid on expansive soil subgrades at OMC.

VII. CONCLUSIONS

CBR and direct shear tests were carried out for finding the optimum percentages of waste plastics and waste tyre rubber in gravel subbase material. Based on these results, laboratory model pavement studies were conducted with optimum percentage of waste plastics and waste tyre rubber in gravel subbase, laid on expansive soil subgrade in the flexible pavement system. Based on the laboratory studies carried out in this work, the conclusions that can be drawn here.

1. Addition of (waste plastics + waste tyre rubber) inclusions in gravel and flyash results in an appreciable increase in the shear characteristics and CBR value.
2. From the result of direct shear and CBR tests, gravel and flyash reinforced with different percentage of (waste plastics + waste tyre rubber), for gravel the optimum percentage of waste plastic strips and waste tyre rubber is equal to (0.2+2.0) % of dry unit weight of soil, Similarly for flyash it is equal to (0.3+3.0) % of dry unit weight of soil. The addition of (waste plastics + waste tyre rubber), beyond (0.2+2.0) % does not improve the strength characteristic values for gravel and similarly for flyash beyond (0.3+3.0) % does not improve the strength characteristic values appreciably.
3. No significant control of heave is observed when reinforcement is placed in flexible pavement subbase laid on expansive soil subgrade.
4. The total and elastic deformation values of flyash the flexible pavement system are increased is when compared to gravel by the provision of the (waste plastics + waste tyre rubber), reinforcement laid on expansive soil subgrade, in comparison with the conventional flexible pavement system.
5. The load carrying capacity of the laboratory model flexible pavement system is significantly increased by introducing (waste plastics + waste tyre rubber) reinforcement material in gravel and flyash subbases laid on expansive soil subgrade.
6. The maximum load carrying capacity followed by less value of rebound deflection is obtained for waste plastic strips and waste tyre rubber reinforced stretch laid on the flexible pavement system.

Based on the findings, waste plastic and waste tyre rubber to be used as alternative reinforcement materials in place of conventionally used reinforcing materials. Further research is recommended to extend the study to field and the cost economics of the use of waste materials in rural roads.

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