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Influence of Waste Tyre Rubber Chips on Strength and Settlements of Soils

A.Venkata Ratnam
PG Student, Dept. of Civil Engineering, BVC Engineering College, Odalarevu, AP, India
venky286121@gmail.com

Dr. D S V Prasad
Professor & Principal, Dept. of Civil Engineering, BVC Engineering College, Odalarevu, AP, India
drdsvp9@gmail.com

Dr. G V R Prasada Raju
Professor & Principal, Department of Civil Engineering, JNTU College of Engineering, Kakinada, AP, India
gvrp_raju@yahoo.com

P. Sowmya Ratna
Assistant Professor, Dept. of Civil Engineering, BVC Engineering College, Odalarevu, AP, India
sowmyaratnapitchika@gmail.com

***Abstract* – Flyash is a waste produced from thermal power stations, which contributes to environmental pollution. It is a waste material that can be utilized in construction of roads and embankments. One of the most promising approaches in this area is use of flyash as a replacement to the conventional weak earth material and waste tyre rubber as reinforcement will solve two problems with one effort i.e. elimination of solid waste problem on one hand and provision of a needed construction material on other. Disposal of a variety of wastes in an eco friendly way is the thrust area of today's research. This paper investigates to determine the optimum percentage of waste tyre rubber with flyash material by conducting direct shear and CBR tests. It was observed that from the laboratory test results, the optimum percentage of waste tyre rubber with flyash material is 6% and from the load tests flyash with waste tyre rubber shows better performance as compared to un reinforced flyash pavement.**

***Keywords* – Flyash, Waste Tyre Rubber, Shear, CBR and Load Tests.**

I. INTRODUCTION

Reinforcement is an effective and reliable technique for increasing strength and stability of soils. In general soil reinforcements can be classified into two major categories one by ideally inextensible and other by ideally extensible inclusions. The former includes high modulus metal strips and bars, while the latter includes relatively low modulus natural and synthetic fibers, plant roots and polymer fabric and shredded tyre chips. A lot of research work is going on worldwide to cope up with this problem. Waste tyres have characteristics that make them not easy to dispose, and potentially combustible. Reinforced earth technique has been gaining popularity in the field of geotechnical engineering due to its highly versatile and flexible nature. The application of waste tyres in various forms has been recently developed in reinforcing soil for a variety of geotechnical applications ranging from retaining structures and earth embankments, asphalt pavement and paving system, foundation beds and other applications. Umar Jan et al., (2015), has conducted experiments on pavement subgrade soil stabilized with varied proportions of 4%, 6%, 8% and 10% shredded rubber tyre and found that the 8% (25 mm×50 mm) of tyre content is the specific value where the CBR has got the improvement of 66.28% than in comparison of the plain soil. The optimum moisture content as well as maximum dry density is found to decrease with the increase of the percentage of rubber tyre content. This might be due to light weight nature of tyre waste. Shredded rubber tyre mixed with soil showed enhancement in CBR value with adding up to 8 % and there beyond decreased with additional increment in tyre content in unsoaked condition. Swarna Surya Teja and Paleru Siddhartha (2015), has investigated the effective use of waste tyres to stabilize the subgrade of highway pavement, showing improvement in CBR value with its addition up to 5% and there onwards decreased increase in tyre content in both soaked and unsoaked conditions and aggregates when partially replaced by waste tyre pieces showed considerable decrease in abrasion value, crushing value and impact value which proves them to be better composite material in the subbase layer of the pavement system. Ghatge Sandeep Hambirao, and Dr.P.G.Rakaraddi (2014) has been chosen shredded rubber from waste 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. Prasad et al.,(2013), 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. Purushotham G. Sarvade and Prashant R Shet (2012) had done experiments on geotechnical properties of clay Stabilized with Crumb Rubber Powder to investigate optimum CRP for stabilization of the clay from geotechnical properties like particle size, specific gravity, compaction characteristics, and unconfined compression strength of both problem clay and stabilized clay and also the effect of cement and lime on CRP stabilized clay and results that CRP altered the engineering properties of problem clay and 5% CRP and unconfined compressive strength was increased when the optimum mix (problem clay+5% of CRP) was blended with cement and lime. Ayothiraman and Ablish Kumar Meena (2011) conducted experiments on soil and soil+tyre mixtures, Dry density reduces with increase of % tyre waste, however, there is no significant change in OMC. This could be due to light weight nature of tyre waste. Tyre waste material mixed with soil showed improvement in CBR value with its addition up to 2% and there onwards decreased with further increase in tyre content in unsoaked/soaked condition. Hence the optimum value of waste tyre content is 2% in unsoaked and soaked conditions. Max. CBR values are 13.21 % and 12.31 % for unsoaked and soaked condition. As per AASHTO standards the CBR values for sub grade soils lies in the range of 10% to 25 %. The percentage improvement in CBR value of stabilized soil is 21% in unsoaked condition and 22% in soaked condition. An increase in CBR value can significantly reduce the total thickness of the pavement and hence the total cost involved in the project. Baleshwar Singh and Valliapan Vinot (2011) concluded the benefits of reusing chips of scrap tires to reinforce a cohesive soil and cohesion less soil. From the test results, tire chips mixed in a compacted fine-grained soil can result in greater strength and improved ductility. On the other hand, the addition of tire chips to sand increases the shear resistance at higher displacement although the magnitude and nature of this increase are affected by normal stress, chips content and aspect ratio, which are statistically significant at 95% confidence level. On the whole, the results reveal that the addition of 13% and 30% chips content can be considered as optimum to reinforce the cohesive soil and the cohesion less soil, respectively. D. S. V. Prasad and G. V. R. Prasada Raju (2009), observed that from the laboratory test results of direct shear and CBR, the gravel subbase shows better performance as compared to flyash subbase with different percentages of waste tyre rubber as reinforcing material, from the result of direct shear tests and CBR tests for gravel and flyash materials reinforced with different percentage of waste tyre rubber, the optimum % of waste tyre rubber are equal to 5% and 6% of dry unit weight of soil, respectively. No significant control of heave is observed for the laboratory model flexible pavements for both the gravel and flyash reinforced with waste tyre rubber tried in this investigation, laid on expansive soil subgrade. At all the deformation levels, gravel reinforced with waste tyre rubber in model flexible pavement has shown better performance, compared to flyash subbase reinforced with waste tyre rubber. Mousa F. Attom (2006) conducted laboratory study on the effect of shredded tires on the physical properties of three different types of sands with varying gradations. Each type of sand was mixed with four different percentages of shredded tires: 10, 20, 30 and 40% by dry weight. Direct shear tests were conducted to study the effect of the shredded tires on the shear strength properties of sands, such as angle of internal friction and shear strength. The addition of shredded waste tires increased both the angle of internal friction and the shear strength of the sands. Additionally, a prediction model was developed to calculate the shear strength of sand due to increasing shredded tire content. The shredded tires improved some engineering properties of sand. It is evident that not much work has been reported on the flyash subbases reinforced with waste tyre rubber for its application to flexible pavements on expansive soil subgrades. This paper investigates the performance of waste tyre rubber by mixing with different percentages in flyash materials to find the optimum percentage by conducting direct shear and CBR tests in the laboratory which followed by load tests .

II. Material Properties

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

Expansive Soil: The soil used as a subgrade in this study is a typical black cotton soil collected from Razole, East Godavari Dt., Andhra Pradesh. This soil is classified according to I.S classification as inorganic clay of high compressibility (CH) as shown in Fig.1 and table.1. The properties of the expansive soil assessed based on relevant I.S.Code provisions.

Fig. 1 Black Cotton Soil

Table 1 Properties of Expansive Soil and Flyash

Property	Expansive soil	Flyash
Specific Gravity	2.67	1.95
Grain Size Distribution		
Sand (%)	9	27
Silt (%)	34	66
Clay (%)	57	07
Compaction Properties		
Maximum Dry Density(kN/m^3)	15.45	13.37
O.M.C. (%)	25	24
Atterberg Limits		
Liquid Limit (%)	74	--
Plastic Limit (%)	33	--
Plasticity Index (%)	41	--
Shrinkage Limit (%)	15	--
IS Classification	CH	--
Differential Free Swell (%)	132	--
Soaked CBR (%)	2	4

Flyash: Flyash was collected from Vijayawada Thermal Power Station, Vijayawada. The properties of flyash are furnished in Tables 1&2.

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

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 the Fig. 2.

Table 2. Chemical Composition of Flyash (Courtesy: VTPS, Vijayawada)

Name of the 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
Sodium Oxide	Na_2O	0.26 to 0.48
Loss on ignition		0.20 to 0.85

Fig. 2. Waste Tyre Rubber Chips

III. Laboratory Tests

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 tyre rubber chips were mixed with flyash material for finding optimum percentage of waste tyre rubber and the details of these tests are given in the following sections.

Compaction Properties: Optimum moisture content and maximum dry density of flyash 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 Fig. 3. The required percentage of waste tyre rubber by dry unit weight of soil was mixed uniformly with the soil and the details are shown in table.3. The water content corresponding to OMC of was added to the soil in small increments and mixed by hand until uniform mixing of the chips was ensured. The soil was compacted to maximum dry density (MDD).The specimens were tested in a 6 cm × 6 cm square box at normal stresses of 3, 5, 7, 9 N/mm^2 for each percentage of waste tyre rubber with flyash and sheared at a rate of 1.25 mm/min. The graph was plotted between normal stress and shear stress at failure for each percentage of waste tyre rubber for obtaining the shear strength parameters.

California Bearing Ratio (CBR) Tests: Different samples were prepared in the similar lines for CBR test using flyash materials reinforced with waste tyre rubber the details of which are given in table 3. 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

Table 3. Different Percentages of Reinforcing Materials

Subbase Material	Reinforcing Material	% of Reinforcing Material
Flyash	Waste Tyre Rubber Chips	0, 1,2,3,4,.5,6,7,8

Preparation of Model Flexible Pavement

The expansive soil used as a subgrade which is collected at a depth of 0.3m below the ground level from Razole, Andhra Pradesh. The each layer is compacted to 2.0 cm thickness in 10 layers to a total thickness of 20 cm to its optimum moisture content and maximum dry density in the mild steel test tank. On the prepared expansive soil

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subgrade, flyash subbase material mixed with optimum percentage of waste tyre rubber (obtained from laboratory shear and CBR test results) with water at OMC is laid in two layers each of 2.5 cm compacted to a total thickness of 5.0 cm. These layers are also compacted to OMC and MDD and laid on the prepared subgrade. On the prepared subbase, two layers of WBM-III each of 2.5 cm compacted thickness, was laid to a total thickness of 5.0 cm as shown in the Fig.5.

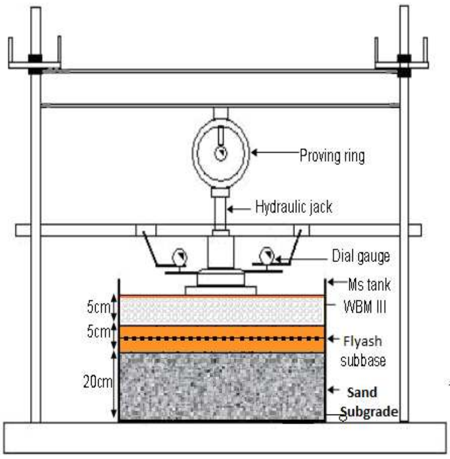

Fig. 5. Laboratory Experimental Set- Up for Conducting Cyclic Load Test

Cyclic Load Testing

Cyclic Plate load tests were carried out on flexible pavement system in a circular steel tank of diameter 600 mm as shown in Fig. 6. The loading is done through a circular metal plate of 100 mm diameter was placed on the center of model flexible pavement system. The steel tank is placed on the pedestal of the compression testing machine. A five ton capacity proving ring is connected to the loading frame and the extension rod welded to the circular plate is brought in contact with proving ring, two dial gauges of least count 0.01 mm are placed on the metal flats welded to the vertical rod to measure the vertical displacements of the loading plate. The load is applied in increments corresponding to tyre pressures of 500, 560,630, 700 and 1000 kPa and each pressure increment is applied cyclically until there is insignificant increase in the settlement of the plate between successive cycles. The testing is further continued till the occurrences of failure to record the ultimate loads. These tests are carried-out at complete saturation state.

IV. Results and Discussions

Direct shear and CBR tests were conducted as per IS: 2720 (part XIII, 1986); IS: 2720 (Part-16)-1979) respectively in the laboratory for flyash materials mixed with and without reinforcement material of waste tyre rubber chips with a view to find the optimum percentage which followed by load tests at complete saturation and the results are furnished below.

Direct Shear Test : Based on the results, shown in the Fig. 7, it is observed that, for flyash reinforced with waste tyre rubber chips , the angle of internal friction values are increased from 29^0 to 37^0 with 6 % of waste tyre rubber chips and thereafter decreased with further additions. The cohesion values are increased from 6.85 to 16.64 kN/m^2 with 6 % of waste tyre rubber chips and thereafter decreased.

Fig. 6. Laboratory Cyclic Load Test Apparatus

California Bearing Ratio (CBR) Test: CBR tests were conducted for flyash materials reinforced with different percentages of waste tyre rubber chips and the results were presented in the Fig.8. It is observed from that for flyash reinforced with waste tyre rubber chips, the soaked CBR values are increased from 4.0 to 7.23 for 6% of waste tyre rubber chips and there after decreased.

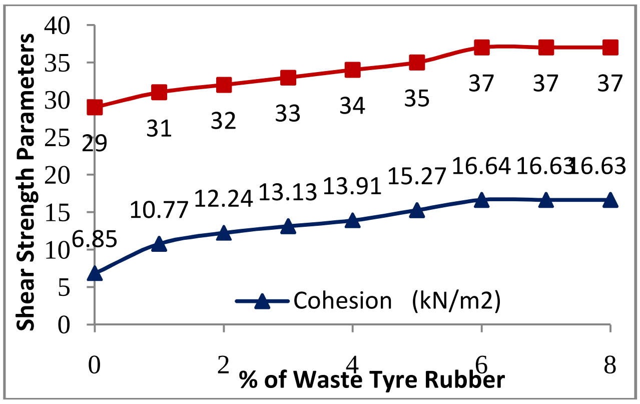

Fig. 7. Variation of Shear Strength Parameters for Flyash Reinforced with Different % of Waste Tyre Rubber

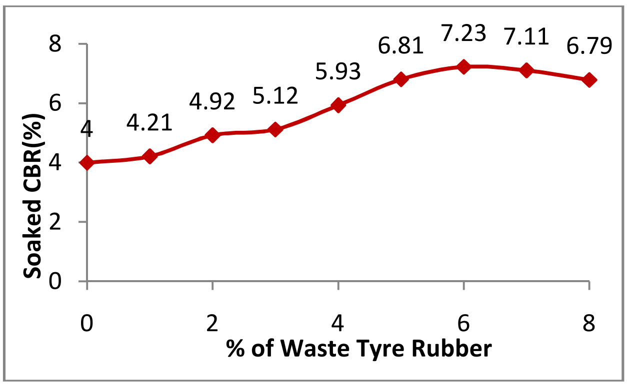

Fig. 8. Variation of Soaked CBR for Flyash Reinforced with Different % of Waste Tyre Rubber

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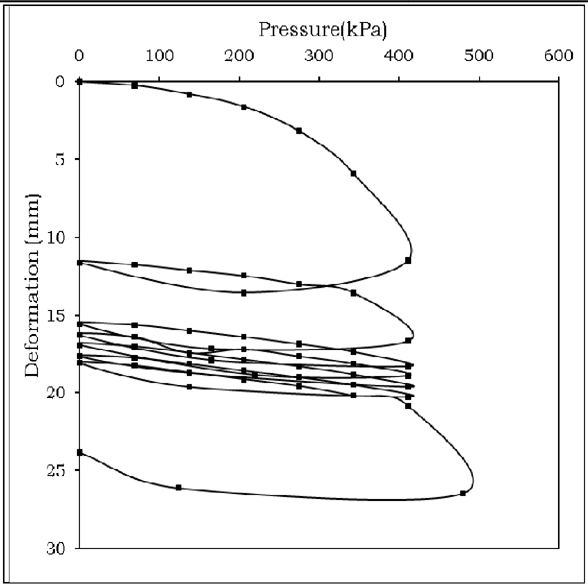

Fig. 9. Pressure Vs Deformation values for Flyash Subbase on Model Flexible pavement system laid on Expansive Soil subgrade

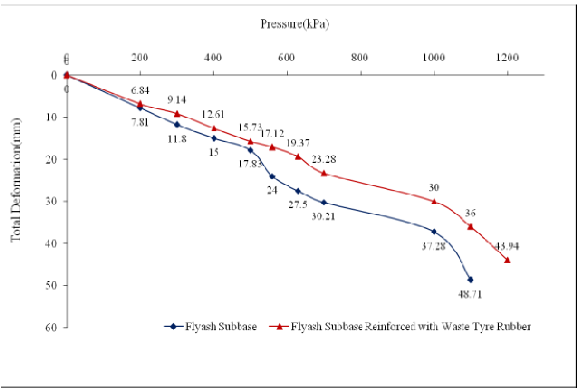

Fig. 10. Pressure-Total Deformation for Reinforced and Unreinforced Flyash Subbase of Flexible Pavement laid on Expansive Soil Subgrade at Saturation

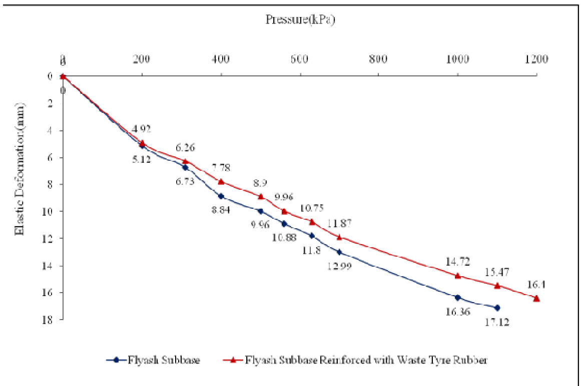

Fig. 11. Pressure-Elastic Deformation for Reinforced and Unreinforced Flyash Subbase of Flexible Pavement laid on Expansive Soil Subgrade at Saturation

Cyclic Load Test Results

Cyclic load tests were carried out at complete saturated states of the expansive soil bed at different pressure increments. The cyclic pressure-deformation curves for waste tyre rubber chips reinforced in flyash subbase laid on expansive soil subgrade pavement system tested at saturation are plotted and presented in fig. 9. It can be seen from this figure that the deformations 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. Similar pressure-deformation patterns are observed for other conditions of testing also except the variations in the magnitudes of deformations. The maximum and elastic deformation values obtained for different tests are deduced from the cyclic pressure-deformation curves discussed in the following sections.

The pressure - deformation curves for different model flexible pavements constructed on flyash subbase laid on expansive soil subgrade, shown in figs.10 & 11. At all the deformation levels, waste tyre rubber chips reinforced flyash subbase stretch shows better performance as compared to unreinforced flyash subbase stretch.

The total and elastic deformations at a load of 1000 kPa are equal to 37.28 mm, 16.36 mm; for untreated stretch; 26.36mm, 14.72 mm; for waste tyre rubber chips reinforced stretch respectively. The total and elastic deformation are decreased by 31%, 19% waste tyre rubber chips reinforced stretch as compared to unreinforced stretch respectively. However by providing reinforcement in the flyash subbase course, the load carrying capacity of the system has increased by 12% percentages for waste tyre rubber chips reinforced stretch saturated state of the expansive soil subgrade. It can be observed that the load carrying capacity is significantly increased and elastic deformation is decreased for the waste tyre rubber chips reinforced flyash subbase stretch compared to unreinforced subbase stretch respectively. 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. It is observed from the pressure - deformation curves for different reinforcement materials in flyash subbase laid on expansive soil subgrade. At all the deformation levels, reinforced waste tyre rubber chips flyash subbase stretch exhibits highest load carrying capacity compared to unreinforced flyash subbase stretches.

V. Conclusions

The optimum percentage of waste tyre rubber from direct shear and CBR test results is 6%.

The load carrying capacity of the model flexible pavement system is increased by introducing reinforcement in flyash subbases laid on expansive soil subgrade.

The total and elastic deformation are decreased by 31%, 19% waste tyre rubber chips reinforced stretch as compared to unreinforced stretch.

The maximum load carrying capacity followed by less value of rebound deflection is obtained for waste tyre rubber reinforces pavement as compared to unreinforced flexible pavement system.

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AUTHORS' PROFILES

A.Venkata Ratnam A completed B.Tech(civil) in Sathyabama University, Chennai and presently perusing M.Tech in Soil Mechanics and Foundation Engineering.

Dr. D. S. V. Prasad working as Principal BVC Engineering College, Odalarevu, AP, has more than 20 years of experience in teaching. Published more than 80 technical papers in National & International Journals & Conferences in the research area of soil mechanics and foundation engineering. He got a prestigious Crop's of Engineers Award constituted by IEI Journal.

Dr. G V R. Prasada Raju working as Registrar, JNT University, Kakinada has more than 24 years of experience in teaching and research, has more than 150 technical papers in National & International Journals & Conferences, Crop's of Engineers Award received by IEI Journal.

P. Sowmya Ratna working as Assistant Professor, Department of Civil Engineering, BVC Engineering College, Odalarevu, Andhra Pradesh has 2 years of experience in teaching.