Study on Effect of Waste Tyres in Flexible Pavement System

R. M. Subramanian[1] and S. P. Jeyapriya[2]

ABSTRACT: Today most tyres, especially those fitted to motor vehicles, are manufactured from synthetic rubber. As the number of vehicles is increasing so are the heaps of discarded rubber tyres. One of the main issues associated with the management of scrap tyres has been their proper disposal. In this project work, an effort has been made to make use of these waste tyres in subgrade and subbase layers of the flexible pavement. Soil and aggregates used in the study were collected from nearby locations. Tyre pieces of approximately square and rectangular shapes cut from tractor tyres passing IS 25mm sieve and retained in IS 20mm sieve and crumb tyres scrapped from light motor vehicle tyres passing IS 2.36mm sieve are used in the study. Crumb tyre was mixed with soil in various proportions and tested for compressive strength and California bearing ratio showed marginal improvement in its value. Tyre pieces mixed with soil and aggregates separately in various proportions and tested for California bearing ratio vto determine its optimum content. Aggregate crushing value, impact value and abrasion value decreased with increase in waste tyre content in the aggregates. Finally a pavement model study was performed in a tank of size 30 x 30 x 30 cm with and without optimum percentage of waste tyre pieces in subbase layer and pressure versus deflection curves were plotted and compared.

KEYWORDS: Waste tyres, subbase, Flexible pavement, CBR

Introduction

In civil engineering applications, usually tyres are used in a shred form referred to as “tyre chips”. These chips are between 12 and 50 mm in size and with steel belting removed in processing. Approximately 12 million scrap tyres in 1995 and 15 million in 1996 have been used for civil engineering applications including leachate collection systems, landfill cover, artificial reefs, clean fill for road embankment, road bed support and similar projects (Liu et al., 2000). Using tyre shreds for civil engineering application has several advantages due to their unique characteristics. One of most important properties is that tyre shreds are a lightweight material. It is relatively inexpensive compared to other light fill materials. Tyre shreds induce low horizontal stresses since they are lightweight and have relatively high shear strength. However tyre shreds have not been tried extensively for using it in subgrade and subbase layers of the pavement. In this project an attempt has been made to discover its possible use in these layers.

Literature Review

Tatlisoz, Benson, Edil, (1997) decrypted soil-tyre chip mixtures are unique fill materials with high compressibility and ductility. Soil-tyre chip mixtures also have unique mechanical properties that are primarily governed by the tyre chip content, not by soil type. **Zornberg, Costa, Vollenweider, (2000)** conducted a field investigation to assess the mechanical behavior of an experimental embankment fill built with tyre shreds and cohesive soil. Immediately after construction, the embankment was submitted to heavy truck traffic and settlements were monitored for over two years. The results indicate that the embankment sections built with tyre shreds and cohesive soil showed satisfactory long-term performances during traffic exposure. **Tatlisoz, Edil, Benson, (2001)** assessed the shear strength and geosynthetic interaction of tyre chip and soil-tyre chip backfills that may be used for geosynthetic reinforced walls and embankments and concluded that Soil-tyre chip mixtures have significantly higher shear strength than the soil used in the mixture. **Hassona, Hassan, Marei, Hashem, (2005)** based on their tests involving triaxial test and CBR test on shred tyre reinforced soil, concluded that The presence of shredded waste tyres in sand improves the stress-strain properties for all different sizes and contents of shreds waste tyre over that pure sand. The maximum deviator stress of randomly reinforced sand occurs at a higher axial strain compared to sand alone. CBR values increases with the increase of shreds tyre content up to 3 % content. After this content the increasing of CBR value decreases with the increase of shreds tyre content in both soaked and unsoaked specimens. **Prasad, Prasada Raju, Ramana Murthy, (2008)** carried out CBR and direct shear tests 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. The load carrying capacity of the model flexible pavement system significantly increased when the gravel subbase was reinforced with waste plastics as well as waste tyre rubber when compared to unreinforced subbase.

Materials

Soil used in the test was collected from a pit near the soil mechanics laboratory of Government College of Technology – Coimbatore. Soil was found to be inorganic clay of medium plasticity. Aggregates used in the tests were bought from a nearby shop. Aggregates size varied between 10mm to 40mm. Crumb tyre are small pieces of waste tyre scrapped from light motor vehicles. In this study the scrapped tyre pieces passing IS 2.36mm sieve

[1] M.E Student, Department of Civil Engineering, Government College of Technology, Coimbatore, subbu_geotechengg@yahoo.co.in

[2] Lecturer, Department of Civil Engineering, Government College of Technology, Coimbatore

were considered as crumb tyre rubber. Waste tyre pieces are small pieces of waste tyres of tractors that are approximately cut into square and rectangular shapes passing IS 25mm sieve and retained on IS 20mm sieve.

Laboratory Investigation

Laboratory tests were divided into four phases with the inclusion of waste tyre. In order the four phases include tests on soil-crumb tyre mix, tests on soil reinforced with waste tyre pieces, tests on aggregates reinforced with waste tyre pieces and test on model pavement. First the initial tests were performed on soil and aggregates to ascertain their engineering properties.

In the first phase of the test on soil, crumb tyre was considered as a additive material that can be added to the soil like lime and flyash. The composite material can be called as crumb tyre replaced soil or soil-crumb tyre mix. Crumb tyre was added to the soil in proportions of 2.5, 5, 7.5 and 10 in terms of percentage by weight of the soil and compaction tests tests were carried out to determine their optimum moisture contents at the respective tyre contents. Unconfined compressive strength tests were performed on soil-crumb tyre mix at the water contents corresponding to the tyre contents to obtain the optimum percentage of crumb tyre that can be included in the soil-crumb tyre mix based on unconfined compressive strength. CBR tests were also performed on soil-crumb tyre mix with given percentages of crumb tyre in soaked and unsoaked condition. Standard proctor compaction was adopted in the preparation of specimens for CBR tests.

In the second phase of the test on soil, waste tyre pieces were considered as a reinforcing material like geosynthetics. CBR tests were performed on the sample which contained partially replaced waste tyre pieces in proportions of 2.5, 5, 7.5, 10 and 12.5 by weight of the soil to determine the optimum waste tyre content in soaked and unsoaked condition. Since the tyre was considered as a reinforcing material, all the samples were compacted at optimum moisture content of the soil. Waste tyre pieces were randomly placed during compaction. Standard proctor compaction was adopted in the preparation of specimens for CBR tests.

In the third phase of the test on aggregates, CBR tests were performed on the sample which contained partially replaced waste tyre pieces in proportions of 2.5, 5, 7.5, 10 and 12.5 by weight of the aggregates to determine the optimum waste tyre content in unsoaked condition. Modified proctor compaction was adopted in the preparation of sample for CBR test. For the same percentages of waste tyre pieces, aggregate crushing value test, abrasion test and impact test were also performed.

In the final phase, based on the laboratory test results on soil and aggregates a model pavement study was performed. A model tank made of mild steel of dimension 30x30x30 cm with thickness 20mm was used in the study. Load tests were performed in the tank with and without the addition of optimum waste tyre pieces in the subbase layer alone. A sand bed of 3 cm was provided at the bottom of the tank to ensure the flexibility in the pavement system as in the case of natural pavement and also to have a change of soil strata. The soil used in the various laboratory experiments was used as a subgrade material. It was allowed to dry and then pulverized and sieved through IS 4.75 mm sieve. The subgrade thickness was calculated to be 15 cm and the volume of the soil required was 13500 g/cc. Soil mixed at optimum water content was laid in the tank in three layers and was compacted to its maximum dry density with each layer given 338 blows with 2.6kg rammer. The aggregates used in the various laboratory experiments were used as a subbase material. The subbase thickness was calculated to be 5 cm and the volume of the aggregate-tyre mix required was 4500 g/cc including 7.5% waste tyre pieces. Aggregate was mixed with fines having a liquid limit value of 20% and plasticity index value of 4.

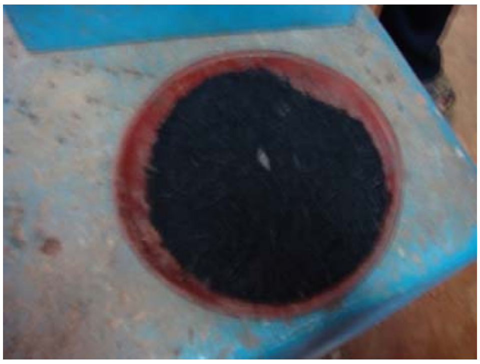

Fig. 1 Crumb Tyre

Fig. 2 Waste Tyre Pieces

In the first test, on the prepared subgrade, crushed stone subbase was laid in two layers and compacted to a total thickness of 5 cm. In the second test, on the prepared subgrade, crushed stone subbase mixed with optimum percentage of waste tyre pieces (obtained from laboratory CBR test) was laid in two layers and compacted to a total thickness of 5 cm. 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 a least count of 0.01mm was mounted on the tank as shown in Figure 3. Loading machine with 5 t capacity was used in the test. 1 division of the dial gauge of the proving ring used was found to be 34.44N. Deflection of the plate was recorded at pressures of 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, and 550 kN/m^2.

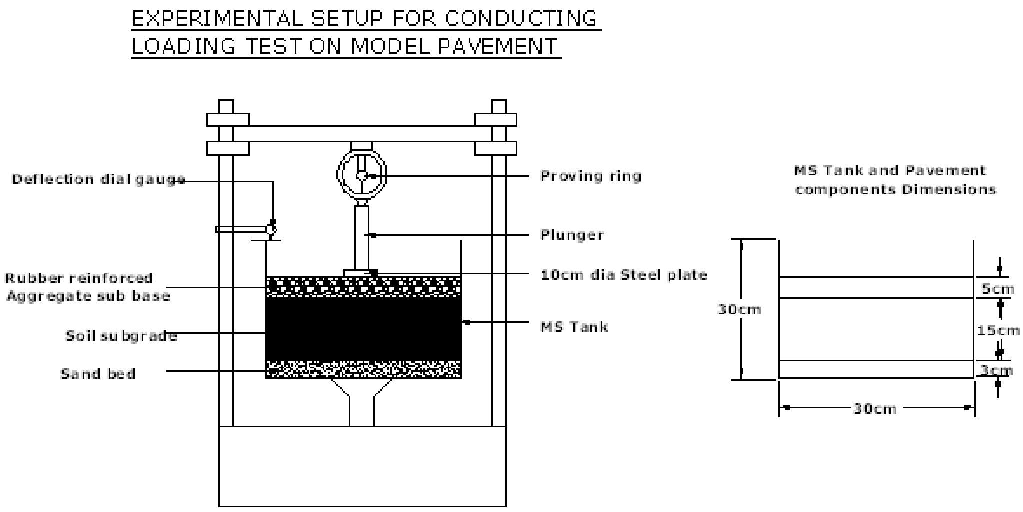

Fig. 3 Sketch Diagram of Model Pavement

Results and Discussions

As the tests were performed in four phases separate results are given for each phase and are discussed. Test results on soil and aggregates are summarized first,

Table 1 Summary of Test Results - Soil

Specific gravity	2.6
Percentage of sand	40.14
Percentage of clay	53.08
Percentage of silt	6.78
Liquid limit	43.5%
Plastic limit	26.78%
Plasticity index	16.72
Activity	0.315
Indian soil classification	Inorganic clay
Symbol	CI
Optimum water content	21.6%
Maximum dry density	15.83 kN/m^3
Unconfined Compressive Strength	117 kN/m^2
Cohesion	16.38 kN/m^2
Angle of internal friction	7º7'30''
California bearing ratio (Unsoaked)	4.29
California bearing ratio (Soaked)	3.27

Table 2 Summary of Test Results - Aggregates

Specific Gravity	2.5
Water Absorption	0.5%
Aggregate Crushing value	23.94%
Aggregate Impact test value	20.95%
Deval Abrasion test value	25%
CBR	20.5%

Tests on Soil-Crumb Tyre Mix

specific gravity of crumb rubber = 0.88

Compaction Test Results at Various Crumb Tyre Percent

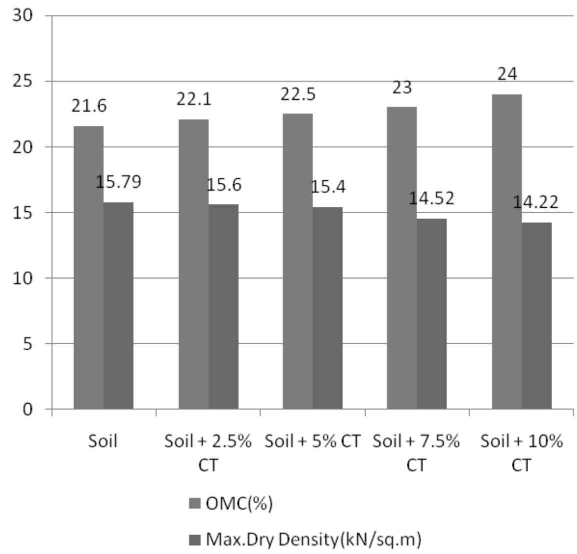

Fig. 4 Comparison of Optimum Moisture Content and Maximum Dry Density with varying percentage of CrumbTyre (CT

Determination of Optimum Crumb Tyre Content from Unconfined Compressive Strength Test

CBR Values at Various Crumb Tyre Contents

Discussions

- From figure 4 it is found that optimum moisture content increases and maximum dry density decreases with increase in percentage of crumb tyre.
- Optimum value of crumb tyre that can be replaced

to the soil as obtained from figure 5 shows only marginal improvement in the compressive strength value of the soil-tyre mix.

- From figure 6 it can be observed that there is a gradual decrease in CBR value of the soil-crumb tyre mix with increase in percentage of crumb tyre.
- In these tests on soil-crumb tyre mix in which the soil is classified as CI did not show positive results, it will not be wise to conclude the results without testing the effect of crumb tyre on wide range of soils.
- However, the obtained results can be concluded for this particular type of soil.

Tests on Soil Reinforced with Waste Tyre Pieces

Specific gravity of waste tyre pieces = 1.11

Determination of Optimum Waste Tyre Content from CBR Tests

Discussions

- Optimum value of waste tyre content was found to be 7.5% from CBR tests in Unsoaked condition and no improvement in CBR value was observed tests in soaked condition.
- From figure 7 it can be observed that there is a 2% improvement in the CBR value with the addition of 7.5% waste tyre pieces.
- Tests in soaked condition was stopped at 7.5% replacement of waste tyre pieces as the prior successive percentage replacement waste tyre pieces showed decrement in the CBR value.
- Again in these tests involving waste tyre pieces, final conclusion can made after testing in different types of soil.
- However, the obtained results can be concluded for this particular type of soil.

Tests on Aggregates Reinforced with Waste Tyre Pieces

Determination of Optimum Waste Tyre Content from CBR Tests

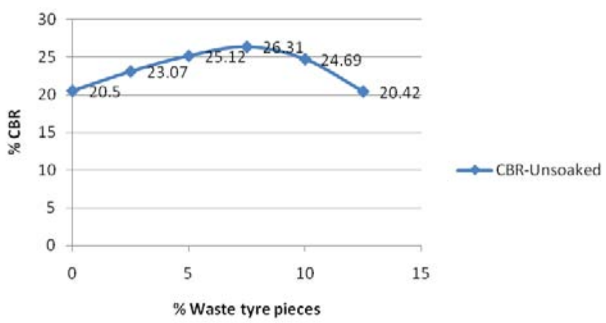

Fig. 8 CBR Vs % Waste Tyre Pieces Curve

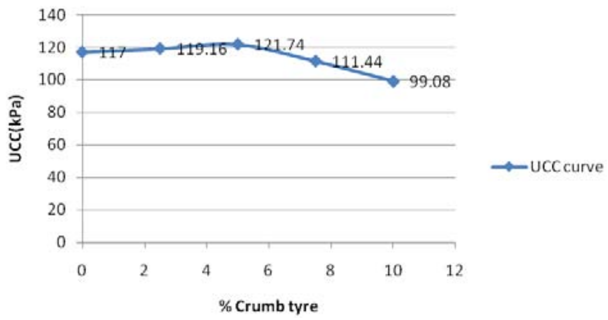

Fig. 5 UCC Vs % Crumb Tyre Curve

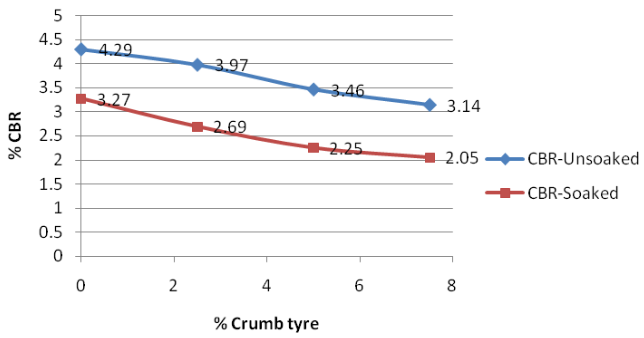

Fig. 6 CBR Vs % Crumb Tyre Curve

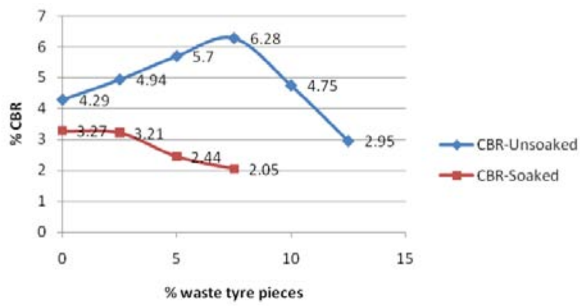

Fig. 7 CBR Vs % Waste Tyre Pieces Curve

Comparison of Results of Abrasion, Crushing and Impact Values

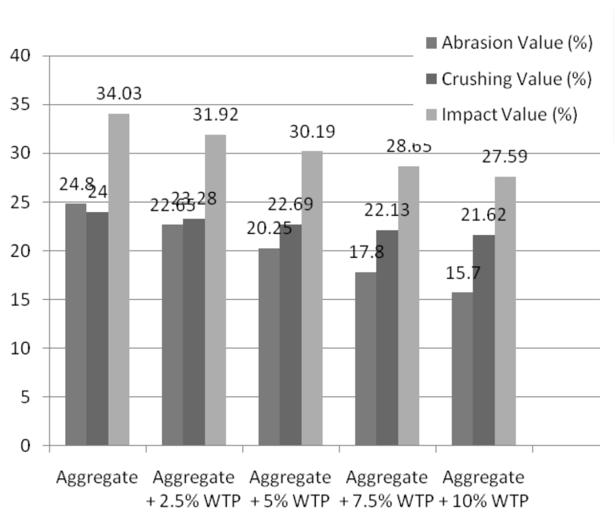

Fig. 9 Comparison of Abrasion Value, Crushing Value, Impact Value with Various Percentages of Waste Tyre Pieces

where

WTP = Waste tyre pieces

Discussions

- Optimum value of waste tyre content was found to be 7.5% from CBR tests in Unsoaked condition.
- Since there is no much difference in CBR value with 5% and 7.5%, the actual optimum content may lie between these two values for this particular type of aggregates.
- From figure 8, it can be observed that there is approximately 6% improvement in the CBR value with the addition of 7.5% waste tyre pieces.
- From figure 9, it can be seen that there is a decrease in abrasion value, crushing value, impact value with increasing percentage of waste tyre pieces.
- At optimum waste tyre content there is a considerable decrease in abrasion value, crushing value, impact value which proves them to be a better composite material to be used in subbase layer than aggregate alone.

Test on Model Pavement

Discussions

- Waste tyre was reinforced in subbase layer alone to determine its effect on the entyre pavement system.
- From figure 10 it can be observed, that with increase in pressure there is an increasing gap in deflection between the aggregate subbase model and waste tyre reinforced subbase model for the same pressure.
- These results can be considered for further study on the field.

Conclusions

Based on the experimental investigations and the results obtained the following conclusions are made

- Crumb tyre mixed with soil does showed marginal improvement in UCC value and gradual decrement in CBR value. Giving importance to the CBR value in design of the pavement the mixing of crumb tyre in the soil is found to be ineffective.
- Waste tyre pieces reinforced with soil showed improvement in CBR vaule with its addition upto 7.5% and there onwards decreased with further increase in tyre content in unsoaked condition.
- However, waste tyre pieces reinforced with soil does not show any improvement in the CBR value in soaked condition.
- Its failure in soaked condition may be attributed to the loose of grip of rubber surface with the soil in submerged condition and due to the properties of the soil (CI).
- But the waste tyre pieces in this particular soil can be effectively used in subgrade to improve its CBR value in areas where the rainfall is less and the ground water table is at a great depth below.
- An increase in CBR value of 2% can significantly reduce the total thickness of the pavement and hence the total cost involved in the project.
- Aggregates in subbase layer when partially replaced by waste tyre pieces showed considerable increase in CBR value with increase in tyre content upto 7.5% and there onwards decreased with further increase in tyre content.
- 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.
- With the help of model study it is understood that total deflections in a particular point of the pavement are reduced with reinforcing the waste tyre pieces in subbase layer alone.

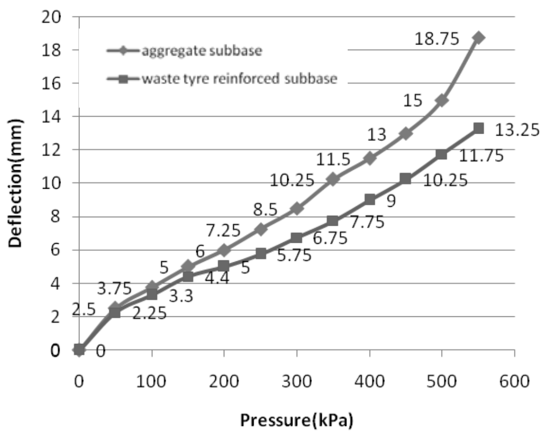

Fig. 8 Pressure Vs Deflection Curve

- This model study can be considered in doing field study on the pavement with waste tyre as reinforcing material in subbase or base layer
- End of use tyres are waste materials that can be cost effective when used in pavement.

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