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Rigid Pavement using Crumb Rubber and Synthetic Fibre

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Abstract: In many countries around the world, the adverse environmental impacts of stockpiling waste tyres have led to investigate alternative options for disposal of waste tyres. The disposal of waste tyres has been found to be an environmental concern due to waste tyres resisting degradation.

Waste tyres occupy large landfill spaces that contain nesting insects and rats. Stockpiles of tyres destined for landfill are also known to be flammable. One option to reduce this environmental concern is for the construction industry to consume a high amount of recycled tyres accumulated in stockpiles.

Day by day the production of tyre increases because of rapid growth of automobile industry. Increase in stockyard of tyre produces environmental-effects. Use of waste tyre rubber as aggregate in concrete reduces the harmful effect on surrounding environment and also solves the problem of disposal.

This paper presents the results of fatigue bending tests on prismatic samples of recycled tyre rubber-filled concrete (RRFC) with different volumetric fractions (VF) of rubber (0%, 3.5% and 5%) after a long term exposition to natural weathering in Madrid (Spain) (one year ageing). From these experimental results, an analytical model based on classical Westergaard's well known equations has been developed to calculate the minimum thickness of RRFC for rigid pavements subjected to high density tra□c, in order to obtain a durability of these rigid pavements of 106 cycles of 13 tons (127 kN) axle load. In this investigation any value of the modulus of sub-grade reaction for rigid pavement design have been considered.

I. RIGID PAVEMENT

A. Introduction

In many countries around the world, the adverse environmental impacts of stockpiling waste tyres have led to investigate alternative options for disposal of waste tyres. The disposal of waste tyres has been found to be an environmental concern due to waste tyres resisting degradation. Waste tyres occupy large landfill spaces that contain nesting insects and rats. Stockpiles of tyres destined for landfill are also known to be flammable. One option to reduce this environmental concern is for the construction industry to consume a high amount of recycled tyres accumulated in stockpiles. In the pavement industry, trialling the use of crumb rubber has been initiated with asphalt mixes. However, some difficulties, such as the high viscosity of the rubberised bitumen and the requirement of higher temperature for production of rubberised asphalt have been found to be barriers which limit its application. Consequently, the introduction of rubber to concrete pavements was the basis of this investigation. It is a well-established fact that introduction of rubber to concrete can cause a decline in concrete strength, however rubberised concrete has been found to be suitable for rigid pavement applications, where a lower range of strength are design.

A variety of rubber treatment methods have been applied to counteract the negative impact of rubber on concrete strength. This methods is recently introduced to enhance the mechanical properties of crumb rubber.

B. Experimental Study

1) *Rubber Aggregate:* Waste tyre crumb rubber collected from local tyre remoulding plant, from which steel wire and fabric have been removed has granular texture and the sizes are passing through 4.75 mm IS sieve and retaining on 2.36 mm IS sieve, passing through 2.36 mm IS sieve and retaining on 1.18 mm IS sieve, passing through 1.18 mm IS sieve and retaining on 600 µ IS sieve. The specific gravity of crumb rubber was 1.14
2) *Synthetic Fibre:* The synthetic fibre is added to increase the flexural strength of the pavement. These are prepared by extruding fibre-forming materials through spinnerets into air and water, forming a thread.
3) *Concrete Mix Design*

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Material Required

a) *Cement:* In this study PPC grade 53 was used for preparing concrete. The specific gravity was 2.88.
b) *Fine Aggregate:* Naturally occurring river sand passing through 4.75 mm IS sieve was used for concrete categorized under zone II.
c) *Water:* Clean portable water free from chemical, suspended particle and biological element etc. was used for concreting.
d) *Coarse Aggregate:* Crushed stone aggregates were used for concreting. Waste tyre crumb rubber collected from local tyre remoulding plant, from which steel wire and fabric have been removed has granular texture and the sizes are passing through 4.75 mm IS sieve and retaining on 2.36 mm IS sieve, passing through 2.36 mm IS sieve and retaining on 1.18 mm IS sieve, passing through 1.18 mm IS sieve and retaining on 600 µ IS sieve. The specific gravity of crumb rubber was 1.14
e) *Synthetic Fibre:* The synthetic fibre is added to increase the flexural strength of the pavement. These are prepared by extruding fibre-forming materials through spinnerets into air and water, forming a thread.
f) *Concrete mix Design:* Design for M30 grade of concrete with target strength after 28 days of curing was 31.6 MPa used for the study.

Fig(a): Impact Test Apparatus

C. *Test Specimen*

To study the impact strength of concrete circular disc specimen of size150 mm diameter and 50mm depth were cast and test was conducted after 28 days of curing by using drop weight impact test equipment. Circular disc specimen mould of 150mmø with a depth 50mm was made from PVC pipes. The moulds were placed over hard platform and concrete mix was filled in the mould with proper compaction. After 24 hours specimens were demoulded and kept in curing tank for 7 days and 28 days.

Fig (b): No. of blows at the age of 7 days

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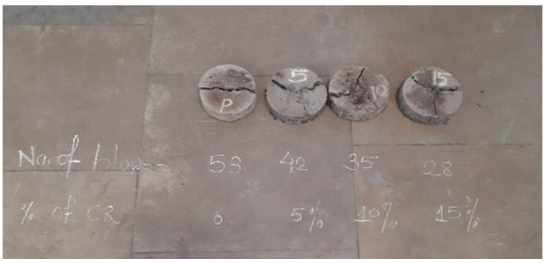

Fig (c): No. of blows at the age of 28 days

Three circular disc specimen were cast with normal concrete are referred as control specimen. The other three groups were made of concrete with partial replacement of crumb rubber particles to the fine aggregate in concrete at varying percentages from 5% to 15%. In each group for every percentage replacement of crumb rubber 3-disc specimen were cast. Hallow tubular of concrete were cast with different groups and with varying percentages of waste tyre crumb rubber particles from 5% to 15% and the sizes of crumb rubber particles.

1) *Impact Strength Test*

a) *Test Setup:* Equipment was fabricated as per standard recommendations which consist hammer of weight 3.5kg, diameter 6.4cm, length 30.5cm with height of fall 61.5cm and steel ball of weight 0.8kg, diameter 6.25cm. The specimen was placed on the base plate centered exactly below the vertical pipe of diameter 6.5cm, length 92cm and the hardened steel ball was placed on the top of specimen. The hammer was dropped repeatedly and the number of blows required for first visible crack was recorded.

2) *Compressive Strength Test:* Concrete cubes of size 150mm*150mm*150mm size were cast with varying percentages of crumb rubber and constant water– cement ratios. The specimens were de-moulded after 24 hours and tested for the compressive strength at the age of 7 days and 28 days of curing as per IS 456:2000.

With the constant water-cement ratio, the compressive strength showed a decreasing trend when percentage of crumb rubber increased. This loss in strength is mainly due to lack of adhesion between rubber particals and cement paste.

Fig(d): Casting of cubes for compressive strength test at the age of 7 days

Fig(e): Casting of cubes for compressive strength test at the age of 28 days.

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II. METHODOLOGY

It is an effective treatment method for making a homogenous mixture, that rubber particles are evenly distribute. Also, this method results in the formation of better bond between rubber and cement paste in concrete. The major problem associated with the direct addition of rubber into the concrete mixture is the tendency of rubber particles to trap air bubbles, which are clinging to them. During the period of 24 h of water-soaking the trapped air bubbles, which are attached to rubber particles can get enough time to release gradually and the observed rubber hydrophobic behaviour can significantly be resolved. It was observed that just after addition of rubber to the container of water most of the particles (roughly over 50% of rubber particles) were floating on water, but gradually after 24 hrs. most of them were sunk to the bottom of the container. The mixture of rubber and water is full of air bubbles; however, after 24 h most of the entrapped air bubbles were released from the mixture. . In addition, stirring the mixture of rubber and water facilitated releasing of the entrapped air bubbles to be detached and release from the mixture.

Fig(f): Addition of treated Crumb Rubber and Synthetic Fibre in concrete.

Fig.(g): Mixing of materials

Fig.(h): Casting and Compaction of cubes

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III. RESULTS AND DISCUSSION

Table No. 1: Compressive strength at the age of 28 days

% C.R	Avg. P (KN)	б = P/A (GPa)
0	31.6	1404.4
5	38.55	1713.3
10	37.77	1678.6
15	36.86	1639.1

Table No. 2: Impact Strength at the age of 28 days

% of C.R	Avg. P(KN)	б =P/A GPa
0	1819	104
5	1442	82
10	1202	68.2
15	9614	54.6

A. From the results of the compressive strength test, for water–cement ratios of 0.43, the compressive strength showed a decreasing trend when the percentage of crumb rubber is increased. For cubes, at the age of 28 days, For 5% addition of crumb rubber, the compressive strength was 81.92GPa, for 10% addition of crumb rubber, it was 68.26GPa and for 15% addition of crumb rubber, it was 54.61GPa. For The compressive strength showed decrease when the percentage of crumb rubber reached 20% of fine aggregate for the constant water-cement ratio.

B. The density of the concrete decreased with the increasing percentages of crumb rubber in concrete. The reason for this decrease is due to the low specific gravity of crumb rubber when compared with the natural sand.

IV. CONCLUSION

The following conclusion may be drawn from this study:

1) It was observed that crumb rubber may be utilized for the partial replacement for natural fine aggregates up to 10%, without enough reduction in its desired strength

2) The rubberized concrete may be recommended for the construction of pavements, structural works (up to 10% substitution) and non-structural works

3) The performance of different pre-treatment methods of crumb rubber were examined and evaluated. The “water-soaking method” was selected as the best treating method because of its advantages revealed according to the achieved results in this study. The benefits of this method can be listed as (i) It is an inexpensive and practical procedure; (ii) It can make homogenous and evenly distributed rubber particles in the concrete mix with a lower entrapped air.

4) This study clearly highlighted that the mix design should be based on aggregates volume if any replacement of aggregates with rubber The high concentrations of rubber particles, such as mixes prepared with 50% to 70% rubber were investigated. It was revealed that the high rubber concentration resulted in a non-homogenous mix, and formation of the weak rubber to rubber connections in the mix, leading to accelerate crack propagation and early failure of the mix.

5) Rubber substitution considering weight of aggregates may end up with an incorrect mix proportion, which is not adjusted for one cubic meter of concrete.

6) According to the results, the applied WC for rubberised concrete can be between 0.4 and 0.45. The Water-cement ratio that we have adopted was 0.43.

7) The test results of rubberised concrete contained water-soaked rubber were compared to the test results of a rubberised concrete type with untreated rubber. Using the water-soaking treatment method, the prepared rubberised concrete had a relatively less strength reduction. It was observed that the improvement was more significant for compressive strength rather than flexural strength. Samples prepared by water-soaking treatment rubber had 22% and 8% higher compressive and flexural strengths, respectively, compared to untreatedrubber.

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8) Modification of concrete with crumb rubber had a positive effect on fatigue behavior of concrete pavement. Although, introducing rubber at a low content had a negative effect on fatigue, introducing 20% or more rubber enhanced the resistance of samples against the fatigue resulted from the cyclic loads.

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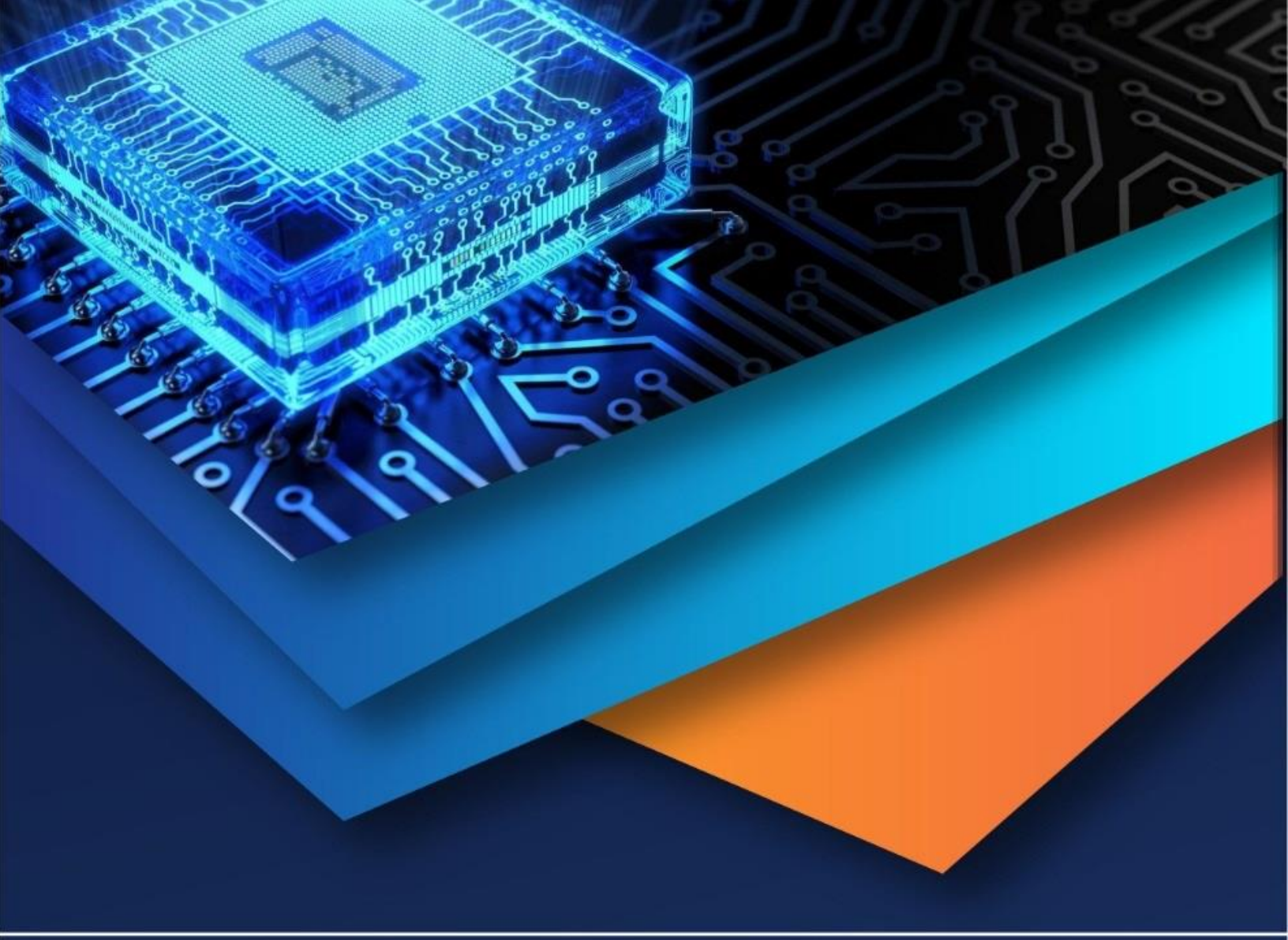

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