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Performance Evaluation of Rubberized Concrete with Micro-reinforcements

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Abstract

Concerted efforts are being made to use appropriate materials as replacement for binder and filler. Waste rubber remains a prospective material for use in normal strength concrete, high strength concrete and self-compacting concrete as replacement for aggregates towards enhancing their performance characteristics. Hence an attempt has been made through this study to replace coarse aggregates with rubber shreds obtained from conveyor belt and examine their impact on the mechanical characteristics of normal strength concrete. Aggregate replacement levels of 2.5%, 5.0% and 7.5% with rubber shreds have been tried. Steel fibres in dosages of 0.5% and 1.0% were also added to the rubberized concrete. The laboratory test results showed appreciable improvement in the performance of normal strength concrete with rubber shreds and micro-reinforcements.

Keywords: compressive strength, elasticity modulus, flexural strength, micro-reinforcement, normal strength concrete, rubber shreds.

1.0 INTRODUCTION

In the present days, disposal of waste rubber tyres has become a global problem. In several countries, burying the waste rubber tyres has become a common method of disposal. But this practice poses a very serious threat to ecology. Hence recycling and reuse of waste rubber is a sine qua non. Some efforts have been made to use waste rubber tyres for paving purposes, for artificial reef formation, for use as fuel in cement kilns and for producing carbon black [1,2]. Simultaneously researchers have attempted to use waste rubber in concrete as replacement for aggregates with a view to enhance its performance. Replacing mineral aggregates with crumb rubber particles can possibly reduce the mechanical properties of rubberized concrete [3,4,5,6,7,8]. This reduction may be due to weak bonding between the rubber particles and the cement matrix [9]. Several attempts have been made to strengthen the interfacial transition zone by alkali etching [10,11], particle surface coatings [12], using NaOH aqueous solution [13,14], using coupling agents [11], using thin layer of cement paste, using SBR latex and organic sulphur coating [15].Some methods significantly improved the mechanical properties of rubberized concrete [16].

Incorporation of steel fibres in concrete enhances its post crack resistance, ductility, toughness and resistance to fatigue and impact [17,18]. Addition of steel fibres imparts ductility to brittle concrete which is highly demanding for structures located in seismic prone regions.

An attempt has hence been made to assess the impact of micro-reinforcement on the performance of rubberized concrete.

1.1 Research Significance

Many research efforts are being undertaken to utilize rubber aggregates with micro-reinforcement in SCC, NSC and HSC. Several researchers have emphasized the need for pretreating the rubber aggregates for use in concrete with a view to improve the bond between the cement matrix and rubber aggregates. Some pretreatments such as acid etching, plasma, use of coupling agents, use of SBR latex, use of cement paste and use of NaOH saturated solution have been attempted. Inspite of the pretreatments, the bond characteristics could not be improved much. Keeping this in mind, an attempt has been made to pretreat the aggregates with sand coating. The effect of such pretreated rubber aggregates on various mechanical properties of NSC with micro-reinforcements has been investigated. Suitable conclusions have been drawn based on the results of the investigation carried out.

2.0 EXPERIMENTAL PROGRAMME

2.1 Test Materials

Portland Cement with a specific gravity of 3.15 was used in this study. Natural river sand with a specific gravity of 2.60 and confirming to grading zone-III was used as fine aggregate (IS 383 :1970)**.** Crushed granite with the maximum particle size of 20 mm was used as coarse aggregate (IS 2386:1963). Potable

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water was used for preparing concrete and curing the specimens. The rubber shreds having a size of maximum 20 mm with a specific gravity of 1.24 were prepared from conveyer belt. The concrete specimens were made with different replacement levels of CA (2.5%, 5.0%, 7.5%) with pretreated rubber shreds and different volume fractions (0.5%, 1.0%) of steel fibres. The rubber shreds were sand coated to improve their bonding with cement paste. The process involved in sand coating of rubber shreads is shown through Figs.1 - 5. The steel fibres used are shown in Fig.6. The properties of steel fibres are presented in Table 1. A cement content of 380 kg/m^3, fine aggregate of 715 kg/m^3, coarse aggregate of 1130 kg/m^3 and water of 186 litres was used in this study (IS 10262 : 2009).

Fig.1 Rubber Shreds

Fig.2 Resin Mix

Fig.3 Mixing of Rubber Shreds with Resin

Fig.4 Combining Sand and Rubber Shreds (with resin)

Fig.5 Sand Coated Rubber Shreds

Fig.6 Steel Fibres

Table 1: Properties of Steel Fibres

Sl.No	Fibre properties	Fibre Details
		Steel
1.	Length (mm)	60
2.	Size/Diameter(mm)	0.75mm
3.	Aspect Ratio	80
4.	Density (kg/ m^3)	7850
6.	Youngs Modulus(GPa)	210
7.	Tensile strength(MPa)	1225
8.	Shape	Hooked at ends

2.2 Test Specimens

The laboratory tests included compressive strength test (IS 516 : 1959), flexural strength test (IS 516 : 1959) and elasticity modulus test (IS 516 : 1959). The details of specimens are presented in **Table 2**. The nomenclature of all the test specimens is presented in **Table 3**.

Table 2: Experimental Plan

Sl.No	Experiment	Specimen	Size (mm)
1.	Compressive Strength Test (IS 516-1959)	Cube	150 X 150
2.	Flexural Strength Test (IS 516-1959)	Prism	100 X 100 X 500
3.	Elasticity Modulus Test (IS 516-1959)	Cylinder	150 X 300

Table 3: Nomenclature of Test Specimens

Test specimen	Description
CC	Control Specimen
RC1	Specimen with 2.5 % Rubber Shreds (as coarse aggregate)
RC2	Specimen with 5.0 % Rubber Shreds (as coarse aggregate)
RC3	Specimen with 7.5 % Rubber Shreds (as coarse aggregate)
SRC11	Specimen with 2.5 % Rubber Shreds (as coarse aggregate) and 0.5% Steel Fibres.
SRC12	Specimen with 2.5 % Rubber Shreds (as coarse aggregate) and 1% Steel Fibres.
SRC21	Specimen with 5 % Rubber Shreds (as coarse aggregate) and 0.5% Steel Fibres.
SRC22	Specimen with 5 % Rubber Shreds (as coarse aggregate) and 1% Steel Fibres.
SRC31	Specimen with 7.5 % Rubber Shreds (as coarse aggregate) and 0.5% Steel Fibres.
SRC32	Specimen with 7.5 % Rubber Shreds (as coarse aggregate) and 1% Steel Fibres.

3.0 RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength of rubberized concrete and steel fibre reinforced rubberized concrete specimens are presented in Fig.7. An increase in compressive strength was observed in rubberized concrete with and without steel fibres in comparison with the control specimens. The specimens with 5% pre-treated rubber shreds as coarse aggregate exhibit an increase of 12.6% in compressive strength over the baseline specimens. The specimens with 5% pre-treated rubber shreds as coarse aggregate and 1% steel fibres exhibit an increase of 46.9% in compressive strength over the control specimens and 30.5%

increase in compressive strength over the specimens with 5% pre-treated rubber shreds as coarse aggregate. The increase in compressive strength may be attributed to the strengthening of the interfacial transition zone by the presence of steel fibres and the pre-treatment (sand coating) given to the rubber shreds. Several authors have reported that the concrete specimens with rubber shreds as replacement for coarse aggregates show reduction in mechanical properties such as compressive strength, flexural strength and elasticity modulus [6,7]. The major reason cited for this issue was the poor bond between the cement matrix and rubber aggregates [3,6]. Hence pre-treatment of rubber aggregates is a sine qua non to improve the interfacial bond between the rubber particles and cement paste. Several techniques such as cement coating, use NaOH solution and use of SBR latex have been tried earlier by many researchers (11,13,14,15). But an appreciable increase in compressive strength could not be achieved through these techniques. Hence the rubber shreds have been pre-treated using sand coating technique in this research study. A 5% dosage of pre-treated (sand coated) rubber shreds with 1% volume fraction of steel fibres was found to be acceptable from the strength point of view.

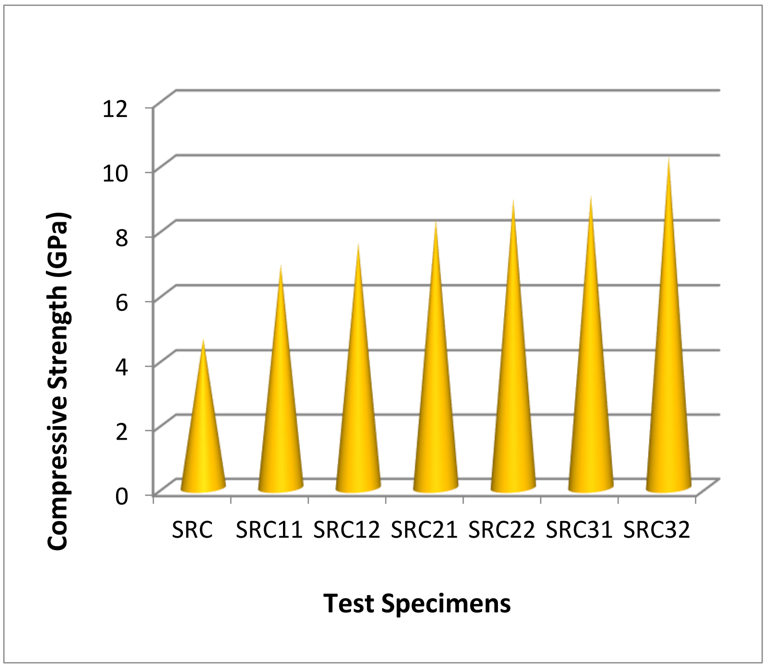

Fig. 7 Compressive Strength of Test Specimens

3.2 Modulus of Rupture

The flexural strength of rubberized concrete and steel fibre reinforced rubberized concrete specimens are presented in Fig.8. An increase in flexural strength was observed in rubberized concrete with and without steel fibres in comparison with the control specimens. The specimens with 7.5% pre-treated rubber shreds as coarse aggregate exhibit an increase of 84.1% in flexural strength over the baseline specimens. The specimens with 7.5% pre-treated rubber shreds as coarse aggregate and 1% steel fibres exhibit an increase of 120.9% in flexural strength over the control specimens and 20.0% increase in flexural strength over the specimens with 7.5% pre-treated rubber shreds as coarse aggregate. The flexural strength was found to increase with increasing fibre content and dosage of pre-treated rubber shreds. The increase in flexural strength may be attributed to the improvement of fibre - matrix interfacial bond.

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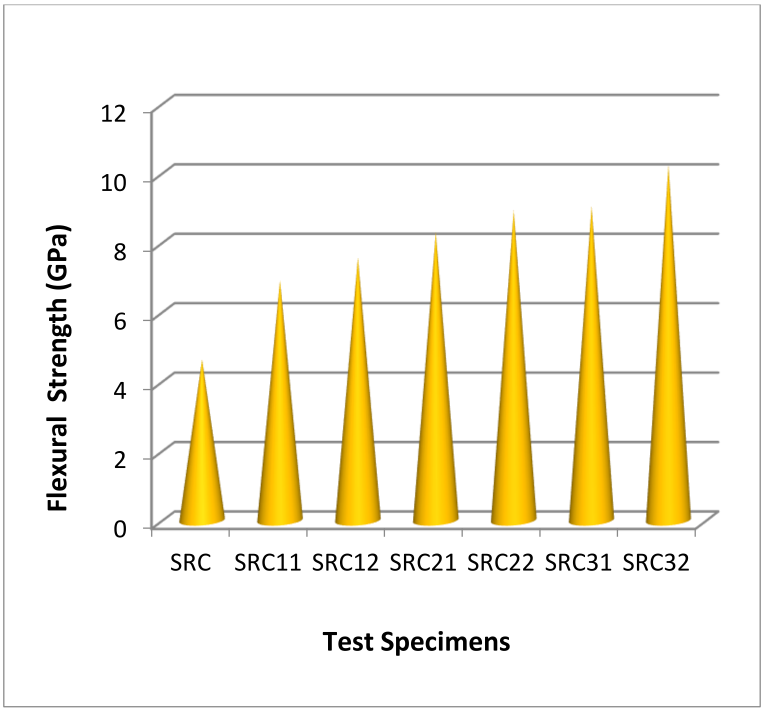

Fig. 8 Flexural Strength of Test Specimens

3.2.1 Failure Modes

The prism specimens were tested in a loading frame under four-point bending as shown in Fig.9. In all the specimens, a major crack initiated at the bottom fibre of the mid-span section. With increasing loads, it propagated vertically upward. It has been observed that the crack size decreased with increasing rubber and fibre contents. The incorporation of steel fibres produced a bridging effect along with rubber shreds. The micro-reinforcement restrained cracking through internal confinement effect.

Fig.9 Test Set-up for Prism Specimen

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3.3 Modulus of Elasticity

The modulus of elasticity for all the test specimens was obtained from the stress-strain curve. The stress-strain behaviour of test specimens containing rubber shreds and micro-reinforcements is similar to that of the conventional concrete specimens. The modulus of elasticity for rubberized concrete and steel fibre reinforced rubberized concrete specimens is presented in Fig.10. An increase in modulus of elasticity was observed in rubberized concrete with and without steel fibres in comparison with the control specimens. The specimens with 7.5% pre-treated rubber shreds as coarse aggregate exhibit an increase of 26.1% in modulus of elasticity over the baseline specimens. The specimens with 7.5% pre-treated rubber shreds as coarse aggregate and 1% steel fibres exhibit an increase of 56.5% in modulus of elasticity over the control specimens and 24.1% increase in modulus of elasticity over the specimens with 7.5% pre-treated rubber shreds as coarse aggregate. The modulus of elasticity was found to increase with increasing fibre content and dosage of pre-treated rubber shreds. The increase in modulus of elasticity may be attributed to the higher modulus of elasticity of steel fibres. The bridging action of steel fibres controls the micro-cracking of concrete and enhances its ultimate strain capacity. Further, the addition of rubber shreds enhances the ductility of concrete resulting in higher modulus of elasticity [19].

3.3.1 Failure Modes

The cylinder specimens were tested in a compression testing machine and subjected to axial loading as shown in Fig.11. A macro-crack was observed over the height of the concrete cylinders made without rubber shreds. Multiple micro-cracks were observed over the height of the concrete cylinders made with rubber shreds. This may be attributed to the low modulus of elasticity of rubber shreds which enhance the capacity to deform before cracking and resist the propagation of micro-cracks by decreasing the stress concentration [20].

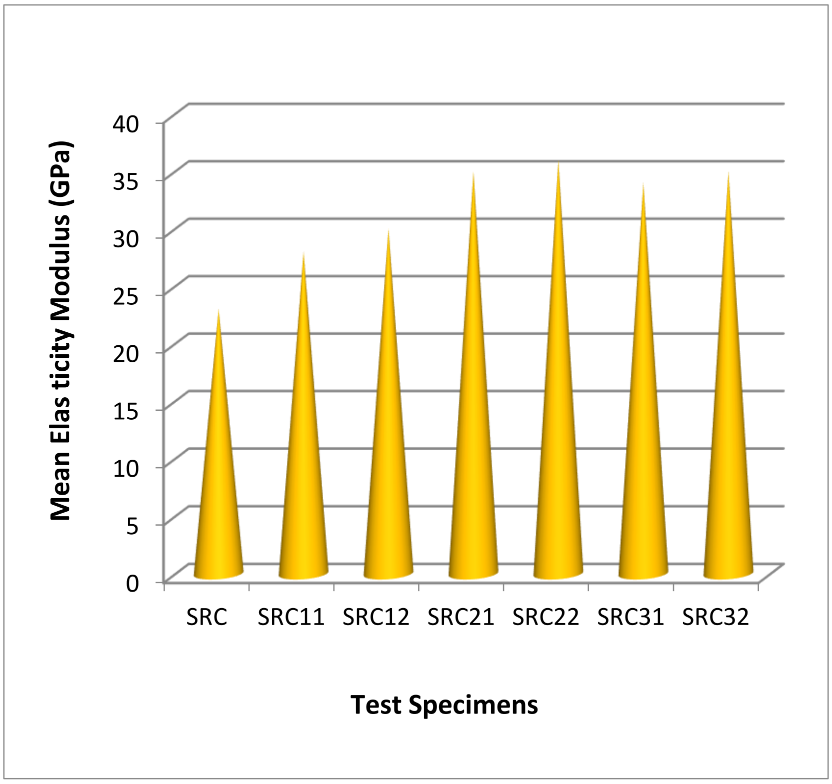

Fig. 10 Modulus of Elasticity of Test Specimens

Fig.11 Test Set-up for Cylinder Specimen

4.0 CONCLUSIONS

The focus of this study is on the influence of sand coated rubber shreds and micro-reinforcement on mechanical properties of rubberized concrete. Based on the experimental results, the following conclusions are drawn.

1. The compressive strength of rubberized concrete increased by about 46.9% at 5% dosage level of sand coated rubber shreds with 1% volume fraction of steel fibres. This increase may be attributed to the strengthening of the interfacial transition zone by the presence of steel fibres and the pre-treatment (sand coating) given to the rubber shreds

2. The flexural strength of rubberized concrete (with sand coated rubber shreds and 1% volume fraction of steel fibres) increased by about 120.9%. This increase may be attributed to the improvement of fibre - matrix interfacial bond.

3. The modulus of elasticity of rubberized concrete (with sand coated rubber shreds and 1% volume fraction of steel fibres) increased by about 56.5%. This increase may be attributed to the higher modulus of elasticity of steel fibres.

4. The resin based sand coating of rubber shreds adopted in this study proves to be effective in improving the bond between the cement matrix and the rubber aggregates.

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