# MATERIAL PERFORMANCE EVALUATION OF RUBBERIZED CONCRETE

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**Abstract.**
Disposal of non-biodegradable waste materials remain one of the most crucial environmental issues all over the world. In recent years, concerted efforts are being made to recycle and reuse polymeric waste materials. Several research efforts are underway to employ polymeric waste materials in concrete and in other Civil Engineering applications. Waste rubber stands out as a promising material for use in normal strength concrete, high strength concrete and self-compacting concrete for improving their performance characteristics appreciably. 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. The laboratory test results showed appreciable improvement in the performance of normal strength concrete with rubber shreds.

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

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## 1.0 Introduction

The onset of energy crisis and environmental consciousness has led to a rapid growth in the construction sector. Further, the world wide depletion of natural resources and the simultaneous accumulation of generated waste materials are increasing at an alarming rate (Torgal*et al*. 2012). Large quantities of waste materials cannot be eliminated (Oikonomou and Mavridou 2009). However, the environmental impact can be reduced by making more sustainable use of these waste materials (Day *et al.* 1993). Concerted efforts are being made to attempt innovative uses of waste materials. The direction of research efforts is to match the demand for a safe and economic disposal of waste materials. This situation calls for an upholding of sustainable development in the construction sector with major emphasis on the utilization of potential waste materials for use in mortar and concrete (Cairns *et al.*2004, Guneyisi*et al*,.2004, Aiello and Leuzzi 2010, Ganjian*et al.* 2009, Zheng*et al.* 2008, Topcu and Bilir 2009).

Utilization of rubber wastes in the construction sector is gaining momentum these days. Different kinds of rubber wastes are being employed as a substitute material in concrete and mortar (Son *et al.* 2011, Segre *et al.* 2006, Ling *et al.* 2010, Sukontasukkul 2009). Concrete has undergone several changes in its formulation and technology to become stronger and durable. Shredded or chipped rubber has been attempted as a replacement material for coarse aggregates (Ganjian*et al.* 2009, Zheng*et al.* 2008, Topcu and Bilir 2009). Crumb rubber has been tried as a replacement material for sand (Ling *et al.* 2010, Balaha*et al.*2007, Fioriti*et al.*2007).

A series of experiments were conducted to investigate the performance of rubberized concrete.

### *1.1 Research Significance*

Many research efforts are being undertaken to utilize rubber aggregates 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 paste 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. In spite 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 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 (IS 455:1989). 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 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. The rubber shreds were sand coated to improve their bonding with cement paste. The process involved in sand coating of rubber shreds is shown through Figs.1 - 5. 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 Shreds (with resin)

**Fig.4** Combining Sand and Rubber

**Fig.5** Sand Coated Rubber Shreds

**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 **Table3**.

**Table2** 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) |

**3.0 Results and Discussion**

**3.1Compressive Strength**

The compressive strength of rubberized concrete and steel fibre reinforced rubberized concrete specimens is presented in Fig.7. An increase in compressive strength was observed in rubberized concrete 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 increase in compressive strength may be attributed to the strengthening of the interfacial transition zone by the presence of 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 (Ghaly and Cahill 2005, Valadares 2009, Freitas*et al*. 2009). The major reason cited for this issue was the poor bond between the cement matrix and rubber aggregates (Ganjian*et al*. 2009, Ghaly and Cahill 2005). 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 (Oikonomou and Mavridou 2009, Cairns *et al*. 2004, Albano *et al*. 2005). 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 was found to be acceptable from the strength point of view.

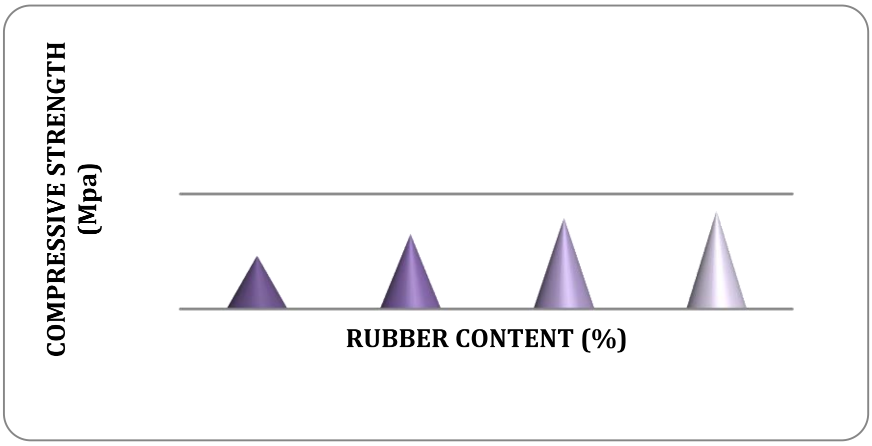


**Fig. 7** Compressive Strength of Test Specimens

### 3.2 Modulus of Rupture

The flexural strength of rubberized concrete specimens is presented in Fig.8. An increase in flexural strength was observed in rubberized concrete 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 flexural strength was found to increase with increasing dosage of pre-treated rubber shreds.

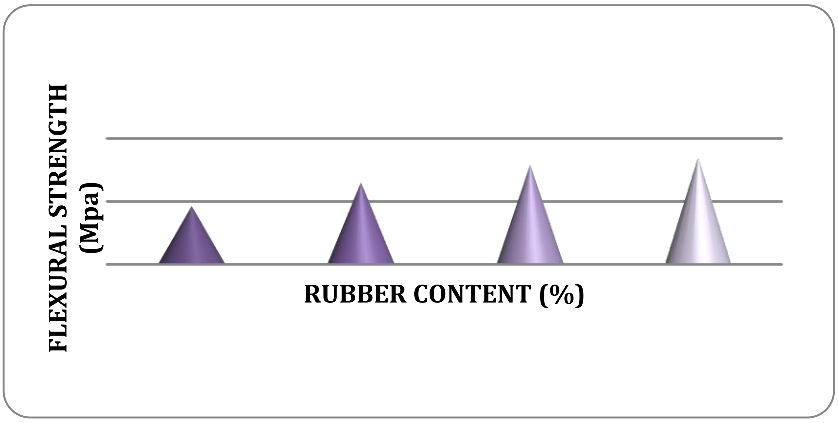


**Fig. 8** Flexural Strength of Test Specimens

#### 3.2.1 Failure Modes

The prism specimens were subjected to 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 propagated vertically upward with increasing loads. It has been observed that the crack size decreased with increasing rubber contents.

**Fig.9** Test Set-up for Prism Specimen

**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 is similar to that of the conventional concrete specimens. The modulus of elasticity for rubberized concrete specimens is presented in Fig.10. An increase in modulus of elasticity was observed in rubberized concrete 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 modulus of elasticity was found to increase with increasing dosage of pre-treated rubber shreds. Further, the addition of rubber shreds enhances the ductility of concrete resulting in higher modulus of elasticity (Khaloo*et al.* 2008).

**3.3.1 Failure Modes**

The cylinder specimens were subjected to axial compression as shown in Fig.11. A major 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 enhances the capacity to deform before cracking and resists the propagation of micro-cracks by decreasing the stress concentration (Turatsinze et al 12006).

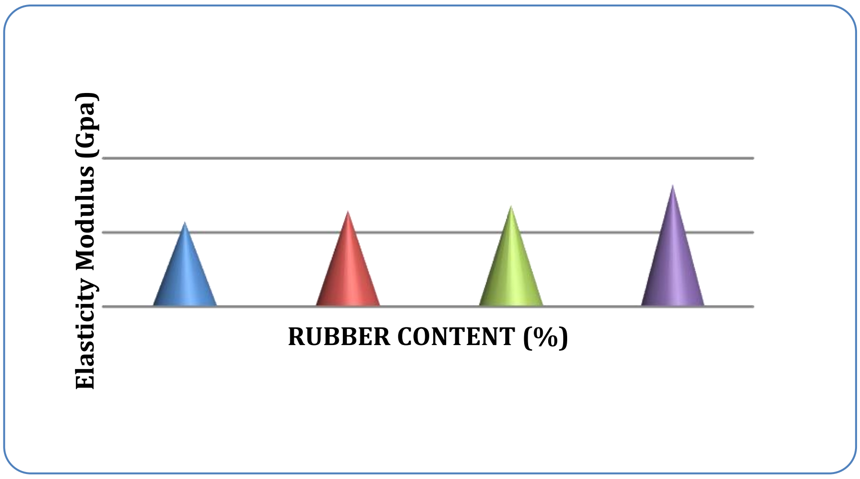


**Fig. 10**Modulus of Elasticity of Test Specimens

**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 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 12.6 % at 5% dosage level of sand coated rubber shreds. This increase may be attributed to the strengthening of the interfacial transition zone by the presence of pre-treatment (sand coating) given to the rubber shreds
2. The flexural strength of rubberized concrete (with sand coated rubber shreds) increased by about 84.1%. This increase may be attributed to the improvement of sand coating of rubber shreds.
3. The modulus of elasticity of rubberized concrete (with sand coated rubber shreds) increased by about 26.1%. This increase may be attributed to the sand coating of rubber shreds.
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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