Experimental Study on the Mechanical behaviour of Crumb rubber in High Strength Concrete

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Abstract – *Disposal of waste scrap tire rubber has become a major environmental problem due to its non-biodegradable nature. Recycling of these waste materials can reduce the accumulation of scrap tire in landfills. A series of laboratory investigations were performed to evaluate the mechanical properties of high strength concrete incorporating discarded tire rubber as aggregate. In this study, scrap tire in the form of crumb rubber was partially replaced for fine aggregates in concrete from 0% to 25% in multiples of 5%. 15% Silica fume and 15% Metakaolin to the weight of total cementitious content were used as property enhancers in high strength concrete. The mechanical properties of high strength concrete like compressive strength, split tensile strength and flexural strength were evaluated. The effect of percentage variation of crumb rubber on compressive strength, split tensile strength and flexural strength were studied.*

Key Words: **crumb rubber, high strength concrete, compressive strength, split tensile strength, flexural strength, fine aggregate.**

1. INTRODUCTION

With the rapid development of transportation and industries, a great amount of scrap rubber is produced. Recycling of scrap tire is becoming more important with the global expanding of the environmental problem in order to reduce the accumulation of scrap tire in landfills. The valorization and the recycling of this waste could be a partial solution to pacify the negative environmental impact. Its incorporation into cement concrete is one way of recycling the material. Research shows that using tire rubber in concrete mixtures can inversely affect the compressive strength, flexural strength and workability but Concrete mixed with crumb rubber has better toughness and impact strength than ordinary concrete and also has better heat insulation and sound insulation properties. Also, it can enhance other properties such as crack propagation, energy absorption, ductility and durability. Silica fume, Fly ash and Metakaolin were usually used to enhance strength in rubberized concrete which exhibits favorable engineering properties, including: the filler effect, the acceleration of OPC hydration, and the pozzolanic reaction.

Trilok Gupta et al. utilized waste rubber tire as a partial replacement of fine aggregate in the form of rubber ash and rubber ash with rubber fibers with three water cement ratios. Workability, compressive strength, flexural strength, density and water absorption (10% rubber ash and varied percentage of rubber fibers) have been obtained. The results showed that compressive strength, flexural strength and density decreases with increase in rubber content. Water absorption of rubber ash concrete was increased with increase in rubber content [1]. Blessen Skariah Thomas et.al investigated an experimental research to analyse the suitability of scrap tire rubber as a partial substitute for natural fine aggregate in high strength cement concrete. Crumb rubber replaced natural fine aggregate from 0% to 20% in multiples of 2.5%. Tests were performed to determine the compressive strength, flexural tensile strength, pull-off strength and water absorption of the concrete samples. The results showed that the compressive strength and flexural tensile strength values were gradually decreasing with increase in the amount of crumb rubber in concrete [2]. Osama Youssf et.al studied the mechanical performance of crumb rubber concrete using silica fume additives. Workability, short term and long term compressive strength and flexural strength were measured. The results showed that slump value increases with increase in rubber content but the compressive and flexural strength were decreased [3].

In this study, Concrete was designed with water–cement ratio of 0.3. Crumb rubber was incorporated in high strength concrete as a partial replacement for fine aggregate from 0 to 25% in multiples of 5%. Incorporation of crumb rubber decreases the workability of concrete such that super plasticizer (2% to the total cementitious content) was used to enhance workability in concrete. 15% Silica fume and 15% Metakaolin were replaced with the total cementitious content to enhance the performance of rubberized concrete. The properties of High strength concrete was confirmed by slump cone test. Compressive strength test, split tensile strength test and flexural strength test were performed. The effect of percentage variation of crumb rubber on compressive strength, split tensile strength and flexural strength were studied.

2. EXPERIMENTAL PROGRAM

2.1 MATERIALS

Ordinary Portland cement of grade 53 conforming to IS 12269:2013 was used (Specific gravity 3.15, Initial setting time 30 minutes and Final setting time 453 minutes). River Sand conforming to zone II as per IS 383-1970 (Specific gravity 2.64, Bulk density 1415 kg/m^3) was used as fine aggregate. Coarse aggregate conforming to IS 383-1970 of size 20mm, specific gravity 2.66 and bulk density 1383 kg/m^3 was used. Crumb rubber of particle size ranging from 0.075mm to not more than 2.36mm was used as a replacement for fine aggregate. The specific gravity of crumb rubber is 1.08. A Sulphonated Naphthalene polymer based super plasticizer of specific gravity 1.24 was used to enhance the workability of rubberized concrete. Silica fume and Metakaolin of specific gravity 2.2 and 2.6 respectively were used as property enhancers in high strength concrete.

2.2 MIX PROPORTION

Concrete mix design was designed as per the guidelines in ACI method (ACI 211.1 -1991). Silica fume and Metakaolin were used as a replacement for cement. The dosage of super plasticizer in high strength concrete is 2% by the total weight of cementitious content. Table 1 shows the mix proportion of crumb rubber concrete.

Table -1: Mix Proportions

Cement (kg/m^3)	Silica Fume (kg/m^3)	Metakaolin (kg/m^3)	Water (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Admixture (kg/m^3)
385	70	70	145	590	1175	10

2.3 PREPARATION OF TEST SPECIMENS

Cubes of size 150mm x 150mm x150mm, Cylinders of diameter 150mm and height 300mm and Prisms of size 500mm x 100mm x 100mm were cast for compressive strength test at 7 and 28 days, split tensile strength test and flexural strength test respectively. Slump cone test for various proportions were done on fresh concrete to determine its workability. All the tests were done as per IS codes.

2.4 COMPRESSIVE STRENGTH TEST

Compressive strength test was performed according to IS 516-1959. The test specimens (Concrete Cubes) after 7 and 28 days of curing at room temperature were oven dried and then subjected to Compressive strength test.

2.5 SPLIT TENSILE STRENGTH TEST

Split Tensile strength test was performed according to IS 5816-1999. The test specimens (Concrete cylinders) after 28 days of curing at room temperature were subjected to split tensile strength test.

2.6 FLEXURAL STRENGTH TEST

Flexural strength of concrete or modulus of rupture of concrete prisms were determined under two point loading. The test was performed conforming to IS 516-1959. Prisms after 28 days of curing were dried and subjected to Flexure test.

3 RESULTS AND DISCUSSIONS

3.1 SLUMP TEST

Fig-1 shows the variation of slump at different percentages of crumb rubber in concrete.

It was observed that increase in rubber content increases the slump value of concrete. Workability in concrete was enhanced by the addition of super plasticizer. Fig-1 shows that increasing the rubber content up to 10% exhibited a linear relationship between slump value and the rubber content.

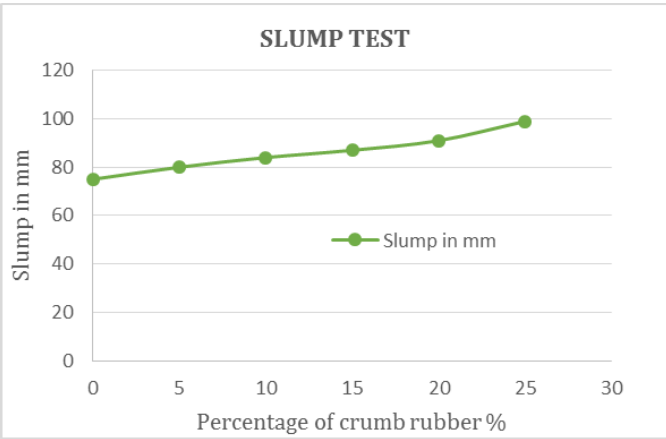

Fig -1: Variation in slump of rubber incorporated concrete specimens

3.2 COMPRESSIVE STRENGTH TEST

Fig-2 shows the compressive strength of concrete cubes at 7 and 28 days respectively.

It was observed that there was a gradual decrease in compressive strength of concrete when the percentage of rubber content increases. Higher the rubber content in concrete, higher the reduction in compressive strength of concrete. The loss of compressive strength of concrete at 28 days compared to the control mix was 6.5%, 21.5%, 44.4%, 53.4% and 68.3% at 5%, 10%, 15%, 20% and 25% respectively.

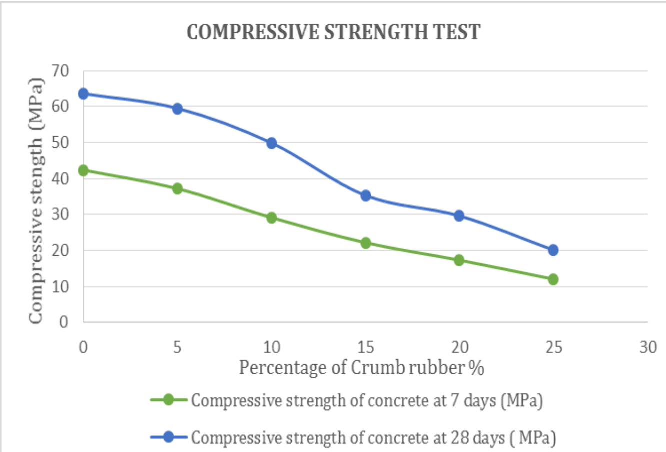

Fig -2: Variation in compressive strength of rubber incorporated concrete specimens

3.3 SPLIT TENSILE STRENGTH TEST

Fig-3 shows the effect of crumb rubber on the split tensile strength of concrete at 28 days.

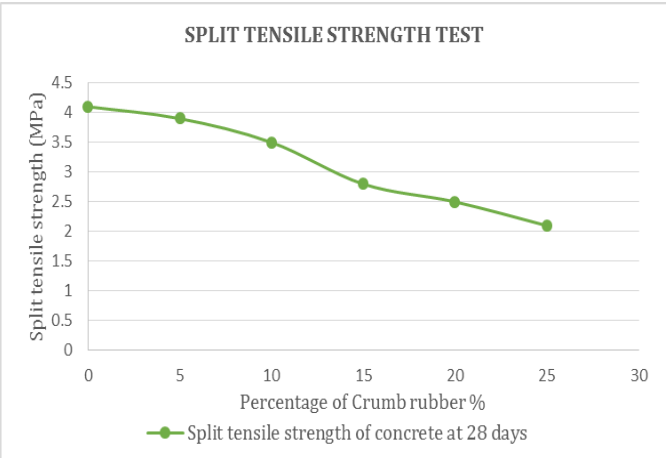

Fig -3: Variation in split tensile strength of rubber incorporated concrete specimens

It was noted that there was a decrease in tensile strength when the percentage of rubber content increased. The loss of tensile strength compared to control mix was 5%, 15%, 32%, 39% and 49% at 5%, 10%, 15%, 20% and 25% respectively. The decrease in tensile strength is due to the poor adhesion between rubber and cement particles.

3.4 FLEXURAL STRENGTH TEST

Fig-4 shows the effect of crumb rubber on the flexural strength of concrete at 28 days.

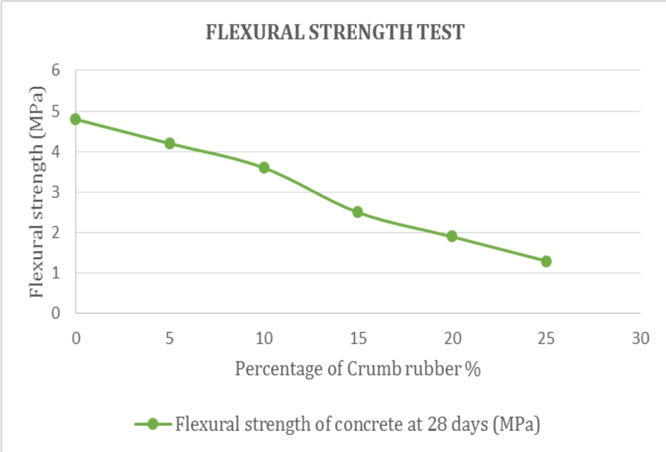

Fig -4: Variation in flexural strength of rubber incorporated concrete specimens

It was observed that there is a decrease in flexural strength of concrete when the percentage of rubber content increases. The control specimen sustained maximum load compared to rubberized concrete specimens. Decrease in flexural strength in concrete is due to decrease in density of concrete, weaker bonds and increase in voids.

4 CONCLUSIONS

Based on the test results, the following conclusions can be made:

1. Crumb rubber can be effectively used as a partial replacement for fine aggregate in concrete.
2. Increase in rubber content increase the slump value of concrete.
3. Concrete with higher percentage of crumb rubber has better toughness. The slump value increases from 7 to 32% with the increase in rubber content.
4. Higher the rubber content, higher the reduction in the strength of concrete. The loss of compressive strength varies from 6 to 68% due to the inclusion of rubber content.
5. The loss of split tensile strength varies from 5% to 49% with the increase in content of rubber.
6. The loss of flexural strength varies from 10 to 63% with the increase in rubber content.

7. Compressive strength, split tensile strength and flexural strength of concrete with 5% of crumb rubber content shows closer results compared to control mix.
8. The loss of compressive strength of concrete with 5% of crumb rubber content is 6%.
9. The loss of split tensile strength of concrete with 5% of crumb rubber is 5%.
10. The loss of flexural strength of concrete with 5% of crumb rubber content is 10%.
11. The loss of Compressive strength, Split tensile strength and flexural strength of concrete is due to the poor adhesion between rubber and cement particles.

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