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# Experimental Studies on Crumbed Rubber as Fine Aggregate in Structural Concrete

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## ABSTRACT

Crumbed rubber concrete (CRC) is a new material on the construction industry. It is developed by replacing sand with rubber particles when mixing concrete, the material provides and promises to significantly reduce certain environmental impacts. Sand is a vital component in giving concrete the necessary consistency and chemical properties, yet it is becoming increasingly depleted worldwide. As we continue to construct roads, buildings and industry at an accelerating rate, the demand for sand is forcing mining companies to cause damage to natural ecosystems, particularly in sandy habitats such as beaches and rivers. One potential solution to both of these issues could come in the form of crumbed rubber concrete (CRC). This material can be created by first grinding up end-of-life tyres into small particles with a similar consistency to sand. This 'crumbed' rubber can then replace a certain percentage of the sand used in the concrete mixing process – both giving the economic usefulness of tyre rubber a new lease of life while alleviating some of the demand for natural sand. In this research study, the use of crumb rubber to replace fine aggregates in concrete was studied. It is aimed that concrete acting as a binder mixed with crumb rubber can make concrete more flexible and thus, provide softness to the surface. The main objective of this paper is to investigate the mechanical properties of concrete when crumb rubber is used as partial replacement of fine aggregate in different percentage (5%, 10%, 15%, 20% and 25%) by volume. A comparison was also made between mixtures containing various percentages of crumb rubber to determine the optimum crumb rubber content and the test results also compared with conventional concrete (without crumb rubber).

**Keywords :** crumb rubber, fine aggregate, workability, compressive strength, tensile strength, flexural strength.

# I. INTRODUCTION

The use of rubber and plastic product is increasing every year in world. Waste tires are major environmental problem for metropolitan, corporation and Municipalities in the India. There are more than 1.2 billion scrap tires, approximately one tire per person, generated each year in the India. This creates a major environmental pollution problem for the earth and their livings. For this issue, the easiest and cheapest way of decomposing of the rubber is by burning it. This creates air and smoke pollution and other toxic emission and it create global warming. Currently 75-80% of scrap tyres are buried in landfills. Burying scrap tyres in landfills is not only wasteful, but also costly. From this one of the processes is to making the tyre rubber in to crumb and chipped rubber. The reuse of this material in concrete could have both environmental advantage and at the same time ensure economic viability with improvement the characteristic design properties of concrete mix. It is used in many construction works such as Road construction, light weight construction, flooring, Mold making etc. in the form of rubcrete concrete. The concrete mixed with waste rubber added in different volume proportions is called rubcrete concrete. Partially replacing the coarse or fine aggregate of concrete with some quantity of small waste tire in the the form of crumb and chipped can improve qualities such as low unit weight, high resistance to abrasion, absorbing the shocks and vibrations, high ductility and brittleness and so on to the concrete.

THE OBJECTIVE AND AIM OF THIS RESEARCH

1. Establish a standard concrete mix.
2. Replacement a fine and coarse aggregate of standard concrete mix with different weight ratios of scrap tires (both crumb and chipped rubber) as (0%, 10%, 15%, and 20%) respectively.
3. To find the physical, chemical, and mechanical properties for both standard and modification concrete mix.

# II. LITERATURE REVIEW

Bandyopadhyay et al(2008) in their suides tires are among the largest and most tricky sources of waste, due to the large amount produced, their durability,and the fact they contain a number of components that are ecologically problematic. It is estimated that 259 million tires are discarded annually. Eldin N N and Senouci A B in (1993), on rubberized concrete behaviour, using tyre chips and crumb rubber as aggregate substitute of sizes 38, 25 and 19mm exhibited reduction in compressive strength by (85%) and tensile splitting strength by (50%) but showed the ability to absorb a large amount of plastic energy under tensile and compressive loads. Erhan Guneyisi et al. presented the mechanical properties of rubberized concrete. The test results show that reduction in compressive strength and modulus of elasticity with the in-crease in rubber content 0% to 50%. Ganesan N(2013) et al. investigates the flexural fatigue behavior of SCRC with and without steel fibres. The addition of scrap rubber to SCC the flexural fatigue strength was increased around 15% and the addition of steel fibres in to SCRC the fatigue strength was increased 25-50%. GuoqiangLi et al .(2004), conducted investigation on chips and fibre's. The tyre surfaces are treated by saturated NaOH solution and physical anchorage by drilling hole at the centre of the chips were also investigated and they concluded that fibre's perform better than chips: NaOH surface treatment does not work for larger sized tire chips: using physical anchorage has some effect. Further efforts will be geared toward the enlarging he hole size and insuring that the hole be through the chip thickness entirely.Fibre length restricted to less than 50mm to avoid entangle: steel belt wires provide positive effect on increasing the strength of concrete. Khalid B. Najim and Mathew R. Hall(2012) found that the me-chanical and dynamic properties of self compacting rubber-ized concrete (SCRC). Incorporating rubber aggregates im-proved the strain capacity resulting in significant reduction in flexural crack mouth open displacement compared to the ref-erence mix. The dynamic modulus and ultrasonic pulse veloci-ty decreased as the proportion of rubber aggregate was in-creased. Ling T C (2010) et al. investigate the potential of using crumb rubber as substitute for coarse sand in the production of con-crete paving block. Crumb rubber was treated by using SBR latex. It was concluded that there is a systematic reduction in the density, compressive strength with the increasing in rubber content. Rana hasshim ghedan and dina mukheef hamza (2011)studied the compressive strength and thermal conductivity of rubber-ized concrete and compared with the traditional concrete. In this study rubber particles were treated by using SICAN of 0.1% of water as coupling agent. The test results show that the adding of rubber particles to the concrete obtains light weight and the compressive strength was reduced. G.Senthil Kumaran, et al(2011) proposed that, Recycling technology for concrete has significantly developed in the recent years, making the material sufficiently recyclable. It is evident that from the above discussion, the reduction of compressive and tensile strength can be increased by adding some super plasticizers and industrial wastes as partial replacement of cement will definitely increase the strength of waste tyre rubber modified concrete. Many studies reveal that there will be increase in strength enhancements as well as environmental advantages. The future NGC using waste tyre rubber could provide one of the environmental friendly and economically viable products. Though problems remain regarding the cost of production and awareness among the society the wastes can be converted into a valuable product. But further research is needed to increase performance against fire. decreased considerably with the increasing amount of rubber content. Zheng L, X. Sharon Huo and Y.Yuan in (2008), have done an experiment on concrete with untreated rubber chips of size 15mm to 40mm and ground rubber powder of 8mesh (less than 2.6mm size) by replacing the coarse aggregate and fine aggregate by 15%, 30% and 45% by the volume. It was observed that compressive strength, the static modulus of elasticity and the dynamic modulus of elasticity of the rubberized concrete.

## III. MATERIAL INVESTIGATION

### A. Ordinary Portland Cement (OPC)

Ordinary Portland cement is hydraulic cement. Locally available 53 grade of cement used for this research work and their physical properties are presented in Table 1.

Table 1: Properties of Cement

| S.No | Description | Values |
|---|---|---|
| 1 | Consistency | 32% |
| 2 | Initial setting time | 45 minutes |
| 3 | Final setting time | 190 minutes |
| 4 | Specific gravity | 3.2 |
| 5 | Fineness of Cement | 3% |

### B.Fine Aggregate(FA)

Locally available free of debris and nearly riverbed sand is used as fine aggregate.

The physical properties are tested in the laboratory and presented in Table 2.

Table 2: physical properties of sand

| S.No | Description | Values |
|---|---|---|
| 1 | Fineness modulus | 3.9 |
| 2 | Specific gravity | 2.60 |
| 3 | Bulk density | 1.43 |

C. Coarse Aggregate(CA)

Coarse aggregate were obtained in crushed form were of granite-type from the near by quarry mines. The natural coarse aggregate is of angular shaped crushed granite with maximum size of 20mm and its specific gravity is 2.77 respectively. The physical properties are presented in Table 3.

Table 3 : Physical properties of Coarse aggregate

| S.No | Description | Values |
|---|---|---|
| 1 | Fineness modulus | 3.9 |
| 2 | Specific gravity | 2.60 |
| 3 | Bulk density | 1.43 |

D. Crumb Rubber(CR)

The tire rubber used in the experiments was applied in the following two size grading and it was obtained from near by tyre companies, Chennai, Tamilnadu, India. Crumb rubber for the replacement of fine aggregate in concrete. The size of the crumb rubber used is 20 meshes and presented in Figure 1. The physical properties of crumb rubber in Table 4.

Table 4: physical properties of crumb rubber

| S.No | Description | Values |
|---|---|---|
| 1 | Unit weight (Kg/m³) | 1120 |
| 2 | Specific gravity | 1.20 |
| 3 | Tensile Strength | 2000 Kg/cm² |
| 4 | Water absorption | Very little |
| 5 | Elasticity | Depends on the tyre |
| 6 | Chemical resistance | Satified |

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| S.No | Description | Values |
|---|---|---|
| 1 | Fineness modulus | 3.3 |
| 2 | Specific gravity | 2.65 |
| 3 | Bulk density | 1.42 |

(a) Rubber aggregate

(b) Slump test

(c) Flexural strength test

Figure 1

## IV. EXPERIMENTAL INVESTIGATION

There were five type of mix considered of this research work . For one control mixture (without rubber) was caseted as per Indian Standard Specification IS: 10262-2009 (1:1.52:3.10 W/C ratio = 0.45) to achieve target mean strength 28.6 MPa.The other four concrete mixes were made by replacing the fine aggregates with 5%, 10%, 15%, 20% for M20 grade concrete. For testing the specimens were casted , sand used was cleaned from all inorganic impurities and passed through 2.36 mm sieve and retained on 150 micron. For each mix, cubes of 150 x 150 x 150 mm,cylinders of 150 mm diameter by 300 mm height, and small beams of 100 x 100 x 500 mm were prepared. All specimens were made-up and then cured in water for 7 and 28 days in accordance with Indian standard 10262. For each concrete mix, slump tests were executed. After 24 hours of casting of cubes, beams and cylinders were taken out from the mould and then immersed in water tank for curing purpose. Specimens were weighed before testing in the compression testing machine (CTM) of 2000 kN. The load was applied until failure and the crushing load.

TEST ON FRESH CONCRETE

*A. Workability –Slump Test*

To determine the workability of concrete mix the slump test conducted by as per IS 1199-1959. The internal surface of the mould thoroughly cleaned and freed from superfluous moisture than mould placed on a smooth, horizontal, rigid and non absorbent surface. The mould was filled in four layers, filled each approximately one-quarter of the height of the mould. Each layer was tamped with twenty-five strokes of the rounded end of the tamping rod. After the top layer has been rodded, the concrete was struck off level with a trowel or the tamping rod, so that the mould is exactly filled. The mould removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside and the slump shall be measured immediately by determining the difference between the height of the mould and that of the highest point of the specimen being tested. From the test result it has been identified that all the rubber replaced with fine aggregate might behaved very close to the flow of conventional concrete. Hence, it is preferred to make use of workability factor of 0.45 for M20 grade concrete. Test results of slump test given in Table 5.

| Sl.No | Specimen | Crumed Tyre Aggregate(%) | Slump (mm) |
|---|---|---|---|
| 1 | CRC0 | 0 | 52 |
| 2 | CRC05 | 5 | 55 |
| 3 | CRC10 | 10 | 50 |
| 4 | CRC15 | 15 | 48 |
| 5 | CRC20 | 20 | 35 |

Table 5 : Slump test

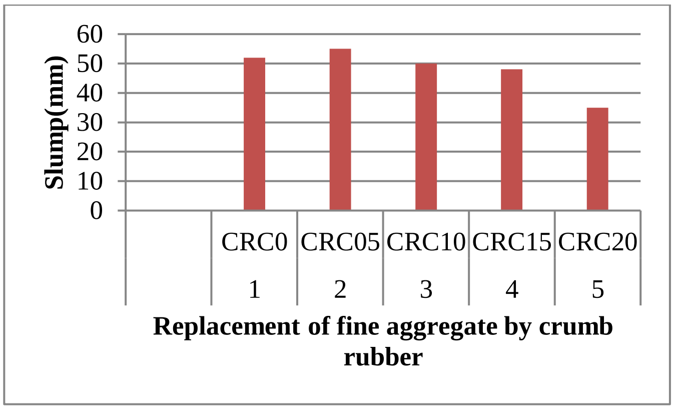


Figure. 2: Slump Test

Tests on Hardened Concrete

*B. Compressive Strength*

The test specimens of cube size 150 x 150 x 150 mm for the various mix proportion for 0%,5%, 10%,15% and 20% replacement of aggregate with rubber were prepared. The casted cubes are kept for curing for 7 days and 28 days. From the test it has observed that a gradual reduction of the compressive strength can be observed. This was caused by the increased porosity and lack of bonding between rubber particles and the cement paste. As cement paste surrounded rubber particles the aggregates is much softer than hardened cement paste without rubber, the cracks would rapidly develop around the rubber particles during loading and causing crack in the concrete. The cubes are tested in compression testing machine of capacity 200tonne for both 7 and 28 days and results are tabulated in Table 6.

Table 6 : Average Compressive Strength

| Sl.No | Specimen | Compressive Strength N/mm$^2$ | |
|---|---|---|---|
| | | 7 Days | 28 Days |
| 1 | CRC0 | 24.56 | 33.45 |
| 2 | CRC05 | 20.23 | 27.34 |
| 3 | CRC10 | 14.43 | 22.95 |
| 4 | CRC15 | 10.57 | 10.34 |
| 5 | CRC20 | 8.48 | 8.33 |

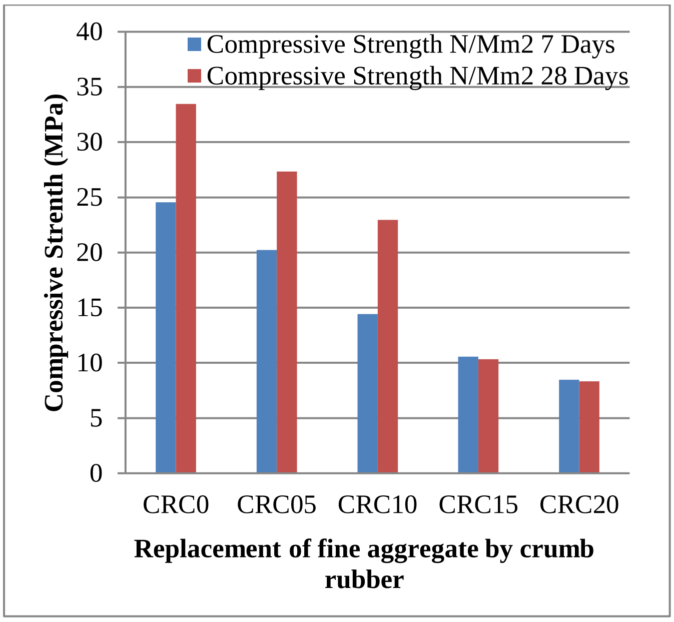


Figure 3 : Compressive strength of 7 days and 28 days

*C. Split tensile Strength*

The split tensile test is conducted with a cylinder of size 150 mm diameter and 300 mm length of specimens with 0%, 5%, 10%,15% and 20% replacement of fine aggregate with crumb rubber concrete mix. The casted cylinder specimen is kept under the curing period for 7 and 28 days. After curing the specimens are tested in compressive testing machine. Load is applied along the length and the load which the cylinder splits into two halves is observed. Tensile strength of concrete was reduced with increased percentage of rubber replacement in concrete. The important reason is lack of proper bonding between rubber and the cement paste. The split tensile stress is calculated using formula $2P/\pi DL$ where, P is load, L is the length of cylinder and D is diameter of cylinder and results are tabulated in Table 7.

Table 7 : Average Split Tensile Strength

| Sl.No | Specimen | Split Tensile Strength N/mm$^2$ | |
|---|---|---|---|
| | | 7 Days | 28 Days |
| 1 | CRC0 | 1.98 | 2.74 |
| 2 | CRC05 | 1.64 | 2.58 |
| 3 | CRC10 | 1.54 | 2.34 |
| 4 | CRC15 | 1.32 | 1.96 |
| 5 | CRC20 | 1.22 | 1.84 |

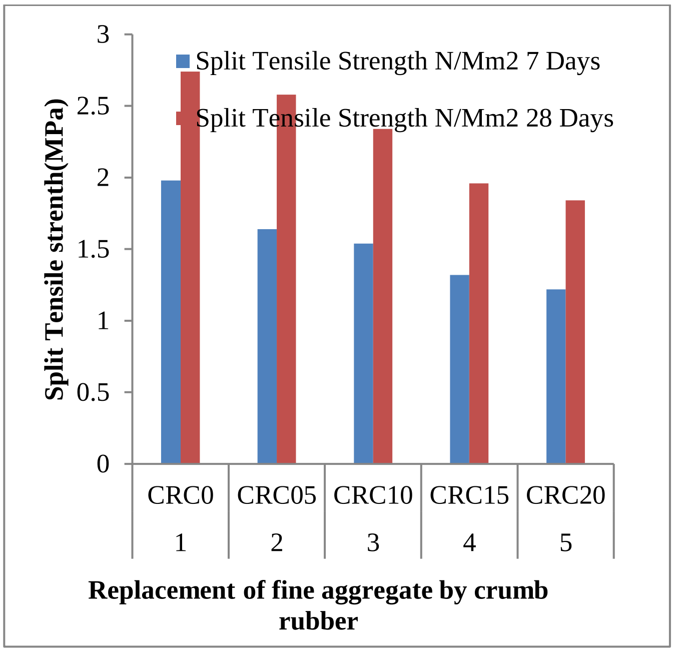


Figure 4 : Split Tensile strength of 7 days and 28 days

*D. Flexural Strength*

The flexural strength test was conducted to determine the modulus strength of concrete. The test was conducted on a beam of dimensions 100 x 100 x 900 mm. Concrete was casted and Cured for 7 and 28 days. The flexural strength of conventional and rubber replaced concrete was performed in flexural testing machine and the results are tabulated in Table 8.The flexural strength was determined by the two point loading method and the values were calculated by using the expression Fb = PL/bd2,

where
Fb is the flexural strength in MPa,
P is the maximum load applied in N,
L is the span length in m,
b is the width of specimen in mm, and
d is the depth of the specimen in mm.

Table 8: Average Flexural Strength

| Sl.No | Specimen | Split Tensile Strength N/Mm$^2$ | |
|---|---|---|---|
| | | 7 Days | 28 Days |
| 1 | CRC0 | 2.78 | 4.54 |
| 2 | CRC05 | 2.57 | 3.99 |
| 3 | CRC10 | 1.63 | 2.56 |
| 4 | CRC15 | 0.93 | 1.96 |
| 5 | CRC20 | 0.88 | 1.79 |

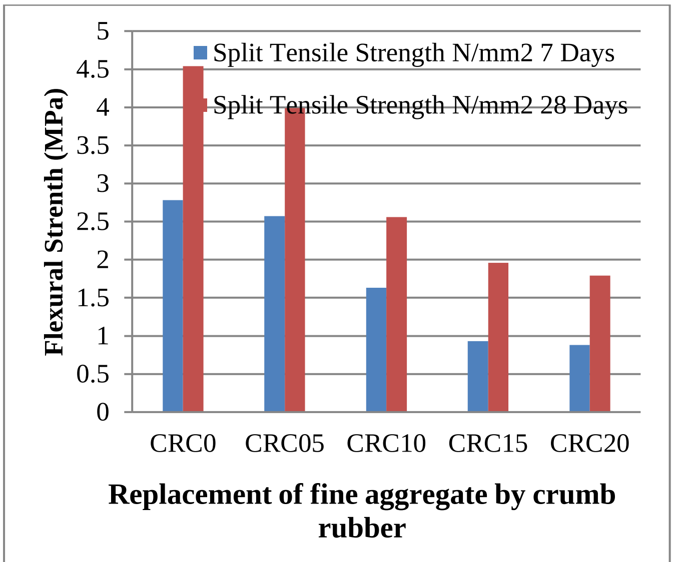


Figure 5 : Flexural strength of 7 days and 28 days

## V. CONCLUSION

Based on the above experimental result it has concluded that

1. Slump value decreases with the increase of the replacement level of the fine aggregates with the crumb rubber.
2. Compressive strength of the specimens were decreases when the percentage of replacement of crumb rubber increases.
3. Split tensile strength decreases at the maximum of 17% when crumb rubber replaces upto 10% in fine aggregate beyond the sudden decreases of strength.
4. Flexural strength of concrete is upto maximum of 5% of replaces of rubber crumbs.
5. It is identified that the grade of concrete plays the major role in the ductility performance of rubber replaced concrete.
6. Rubberized concrete showed good energy absorption and did not show brittle failure under compression or split tension loading.
7. 7.5% to 10% replacement of crumb rubber and its strength of compression, tensile and flexural is upto 20% strength limit of M20 grade of concrete. Hence 10% rubber content is to be considered as the optimum amount of replacement sand in concrete.
8. From the literature survey it were observed that Crumb rubber replacement in concrete gives better resistance to acid and Sulphate attack. These properties can be advantages of waste tire crumb rubber concrete in construction applications.
9. By replacing fine aggregate by crumb rubber protect the environment.

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