*Int. J. Struct. & Civil Engg. Res. 2015*

International Journal of Structural and Civil Engineering Research

*ISSN 2319 – 6009 www.ijscer.com*
*Vol. 4, No. 1, November 2015*


*Research Paper*

# STRENGTH APPRAISAL OF CONCRETE CONTAINING WASTE TYRE CRUMB RUBBER

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Waste-Tire rubber is one of the significant environmental problems worldwide because of increase in auto mobile production huge amounts of waste tire need to be dispose. Due to rapid depletion of available sites for waste disposal, many countries banned the disposal of waste tire rubber in landfills. Hence, efforts have been taken to identify the potential application of waste tyre crumb rubber in civil engineering projects. Crumb rubber is a waste material that is ideal for use in concrete applications. This has an additional advantage of saving in natural aggregates used in production of concrete which are becoming increasingly scarce. In this essence, our present study aims to study the use of waste tyre rubber as partial replacement of fine aggregate to produce rubberize concrete in M25 grade of mix. Different partial replacements of crumb rubber (0, 3, 6, 9 and 12%) by volume of fine aggregates are cast and tested for flexural strength and split tensile strength. The results show that there is a reduction in all type of strength for crumb rubber mixture, but crumb rubber content concrete becomes more lean due to increase in partial replacement of crumb rubber fine aggregates from 0% to 12% therefore such type of concrete of is useful in making light weight concrete. The experiments were carried out to determine flexural and split tensile strength of waste tyre crumb rubber concrete beams and cylinders on 7 and 28 days. The results of using waste tyre rubber aggregates in concrete as compared to normal concrete are analyzed. It is recommended to use the rubberized concrete for nonstructural applications.

***Keywords:*** Fine aggregates, Crumb rubber aggregates, Silica fume, Normal concrete, Rubberized concrete, Workability, Flexural strength, Split tensile strength

## INTRODUCTION

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This inevitably led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for utilization of natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that

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are either recycled or discarded as a waste. The discharge of waste tyres are expensive and continuously decreasing numbers of landfills generates significant pressure to the local authorities identifying the potential application for this waste products. One of the largest potential routes is in construction, but usage of waste tyres in civil engineering is currently very low. The sustainable management of the aforesaid waste tyre rubber is a huge task to the industries and public sectors because of the disposal of waste tyre to landfill is legally banned in all the countries due to the environmental impact. Several studies have been carried out to reuse scrap tyres in a variety of rubber products, incineration for production of electricity or as a fuel for cement kilns as well as in asphalt concrete (Mohammad Reza shorbi and Mohammad Karbalai, 2011). Investigations show that used tyres are composed of materials which do not decompose under environmental conditions and cause serious contaminations. Burning is a choice for their decomposition; however the gases exhausted from the tyre burning results in harmful pollutions. Based on examinations, another way is using the tyres in concrete. This results in the improvement of such mechanical and dynamical properties as energy adsorption, ductility, and resistance to cracking. However, this may cause a decrease in compressive strength of the concrete which will be compensated by adding Nano-silica to rubber containing concretes (Parveen, 2013). Partial replacement of rubber tyre aggregates in concrete has the additional advantage of saving in natural aggregates used in the production of concrete which are becoming increasingly scarce. This paper investigated a wide range of physical and mechanical properties of concrete containing recycled tyre aggregates, to assess its suitability as a construction material (Ameer, 2011). Crumb rubber mixture is more workable compare to normal concrete and also it is useful in making light weight concrete (El-Gammal, 2010). Using rubber waste in concrete, less concrete modulus of elasticity is obtained therefore modulus of elasticity is related to concrete compressive strength and the elastic properties of aggregates have substantial effect on the modulus of elasticity of concrete. The larger amount of rubber additives is added to concrete, the less modulus of elasticity is obtained. The objective of the work was to analyze the effect of fine composition of the elastic aggregate made from rubber waste on the elastic properties of concrete under the static and dynamic load (Kamil, 2005). It is recommended to use the rubberized concrete for nonstructural applications.

In this paper, general objectives of study is to evaluate the fresh and hardened properties of concrete produced by replacing part of natural fine aggregates with an aggregates produced from locally available recycled tyre rubber. The specific objectives of this study are (i) observation of some physical properties of concrete mix contained from waste tyre aggregates; (ii) flexural and split tensile strength of concrete mix using different percentage replacement; (iii) interpretation and discussion of test results obtained from various mixes in the laboratory; and (iv) comparing test results obtained from crumb rubber concrete with the normal concrete.

## CONCRETE INGREDIENTS AND PROPERTIES

For this experimental work material used to develop the concrete mixtures were cement, fine aggregate, coarse aggregate, water, and crumb tyre rubber. The cement used was Ordinary Portland Cement of 53 as per IS 12269: 1987. The fine and coarse aggregate samples for conducting the experiments are used from the store room of K K Wagh Institute of Engineering Education and Research Center, Nashik. Crumb rubber that replaces for sand as shown in Figure 1, is manufactured by special mills in which big rubbers change into smaller torn particles. To investigate its properties and suitability for the intended application, various tests are performed as (1) sieve analysis and fineness modulus; (2) specific gravity; (3) water absorption; (4) silt content. The test results obtained for fine aggregates are, fineness modulus = 2.31, specific gravity = 2.75, water absorption = 0.69% and silt content = 0.89% whereas for coarse aggregates, fineness modulus = 7.51, specific gravity = 2.8, water absorption = 0.39% and silt content = 0.25%.

The rubber aggregates used in the present investigation were made by mechanically cutting the tire in to the required sizes. It was very laborious, time consuming and was not easy to handle at the initial stages. However, all this complications can be easily sorted out if a large scale production is devised and proper cutting tools and machineries are made for this particular usage. Source of rubber aggregates is the discarded tyre that is, trucks tyre which is collected from the local market and rubber tyre fine aggregates are prepared from tyre remolding shop in Nashik as shown in Figure 1.

The rubber aggregates used in present study are prepared mechanically by cutting the tyres to maximum nominal size equal to 4.75 mm as shown in Figure 1 and kept for air drying after cleaning with potable water. The specific gravity is obtained from test equal to 1.10.

## EXPERIMENTAL SETUP

In this work various tests are performed by conducting the experiments in the material testing laboratory of K K Wagh Institute of Engineering Education and Research, Nashik.

**Figure 1: Waste Tyres and Crumb Rubber Aggregates Used in Concrete Mix**

In this study, four different concrete mixes of same concrete grade are prepared with constant 10% silica fume replaced to cement and by partial replacement of fine aggregates of 3, 6, 9 and 12% with rubber aggregates by an equal volume of rubber aggregates to form rubberized concrete. In addition, a normal concrete of same grade is also prepared with no replacement of fine aggregates and silica fume. Mixing was done in a small rotary drum mixer as shown in Figure 2. Coarse aggregate, sand, rubber aggregate, cement, and water were added to the mixer respectively. After the addition of each material, the mixer continues to mix until the mixture became homogenous. Oiled steel molds of beam dimensions 100 × 100 × 500 mm, and for cylindrical specimen having diameter 150 mm and length 300 mm shown in Figure 2, were filled in approximately three equal layers and compacted manually. After 24 h of casting, specimens were cured by soaking in to water until the age of testing. In experimental assessment, tests are performed are, compaction factor, and flexural strength and split tensile strength at $7^{th}$ and $28^{th}$ days for various concrete mixes.

## STEEL MOULDS FOR CONCRETE CASTING

### Test Results and Discussion

This section describes the results of tests carried out to investigate the various properties of rubberized concrete mixes prepared in contrast with the control mixes. In the succeeding parts, the results for workability, flexural strength, splitting tensile strength tests are presented. The concrete mix of $M_{25}$ with 0, 3, 6, 9 and 12% replacement of rubber aggregates to natural aggregates are designated as CR-0, CR-3, CR-6, CR-9 and CR-12, respectively for further discussion and interpretation.

### Compaction Factor Test

Ingredients of mixes are properly mixed so as to produce homogeneous and uniform fresh concrete in macro-scale in order to know its workability using compaction factor test as shown in Figure 3. The results of same test for the normal concrete and various rubberized concrete are shown in Table 1.

**Figure 2: Rotary Drum Concrete Pan Mixer and Steel Moulds for Concrete Casting**

**Figure 3: Compaction Factor Test for Workability of Concrete**

**Table 1: Test Results of Compaction Factor**

| Specimen | % Rubber Replacement | Compaction Factor |
|---|---|---|
| CR-0 | 0 | 0.92 |
| CR-3 | 3 | 0.86 |
| CR-6 | 6 | 0.84 |
| CR-9 | 9 | 0.76 |
| CR-12 | 12 | 0.72 |

It is noted that compaction factor has been decreased due to increase in percentage of rubber aggregates in all samples of concrete mix. In normal concrete mix, compaction factor is seen to 0.92 and when the fine aggregates are replaced with 12% tyre crumbs then the compaction factor is about 0.72 mm which becomes nearly low compaction factor value. Such mixtures had to be compacted using a mechanical vibrator. It was found that increasing the size or percentage of rubber aggregate decreased the workability of mix and subsequently caused a reduction in the compaction factor values obtained. From the same study, it was noted that the size of rubber aggregate and its shape (mechanical grinding produces long angular particles) affected the measured compaction factor.

## Flexural Strength

In order to assess the flexural strength of various concrete mixes, the specimens of various proposed mixes are casted along with pre-requisite operations and process are carried out are shown in Figure 4. The various concrete specimens are tested for flexural strength and the same results are reflected through Figure 5. Each value on bar chart is the average of at least three cube specimens. For determining strength of specimen of size 100 × 100 × 500 mm are supported symmetrically over a span of 400 mm and two point load was applied at the middle third of the span. All the beams were loaded up to failure. The rubber replaced by fine aggregates from 0% to 12% there was a reduction in flexural strength value but the observation shown that crumb rubber concrete remained an acceptable workability.

The flexural strength of specimen shall be expressed as the modulus of rupture $f_{cu}$, which, if '*a*' equals the distance between line of fracture and nearer support, measured on the center line of tensile side of specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows

$$f_{cu} = Pl/ bd^2$$

where,

b and d are the measured width and depth in cm respectively of the specimen at the point of failure

l be the length in cm of the span on which the specimen was supported,

P be the maximum load in kg applied to the specimen.

After air curing for 24 h, the same beam specimens are cured in water curing tank in laboratory at normal room temperature and are tested at 7th and 28th days with the help of flexural testing machine. The test results obtained for the flexural strength of various concrete mixes are tabulated in Table 2. After test results obtained, their comparative performance are shown in through Figure 6.

During test of flexural strength, it is observed that nature of crack formation in rubberized concrete different from normal concrete because bond strength between rubber aggregates and cement paste is poor than that

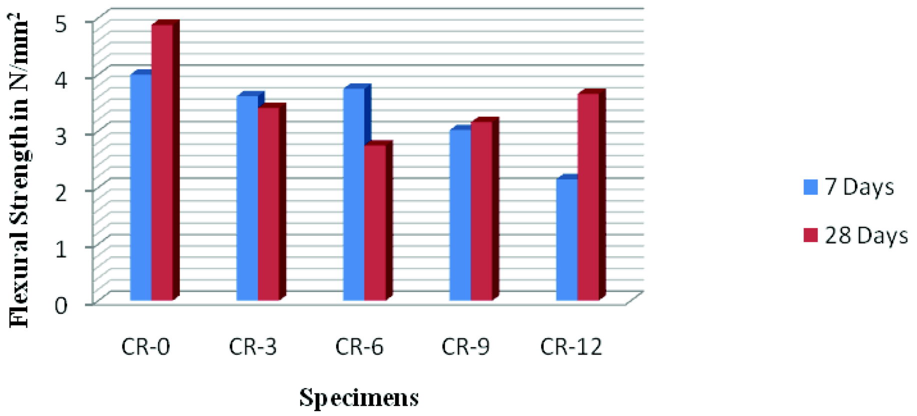
**Figure 4: Curing Process of Concrete Specimens and Its Testing**

**Figure 5: Testing of Cement Concrete Beams During and After Test**

**Table 2: Flexural Strength of Various Concrete Mixes**

| Specimen | % age Rubber Aggregates | Actual Comp. Strength (MPa) | | Av. Flexural Strength (MPa) | | % age Strength Loss | |
|---|---|---|---|---|---|---|---|
| | | 7 days | 28 days | 7 days | 28 days | 7 days | 28 days |
| CR-0 | 0 | 4 | 4.75 | 4.00 | 4.88 | 0.00 | 0.00 |
| | | 4.25 | 5.00 | | | | |
| | | 3.75 | 4.90 | | | | |
| CR-3 | 3 | 3.50 | 3.75 | 3.62 | 3.41 | 9.50 | 30.12 |
| | | 3.75 | 3.50 | | | | |
| | | 3.62 | 3.00 | | | | |
| CR-6 | 6 | 4.25 | 4.00 | 3.75 | 2.75 | 6.25 | 43.64 |
| | | 4.00 | 2.00 | | | | |
| | | 3.00 | 2.625 | | | | |
| CR-9 | 9 | 3.25 | 3.30 | 3.02 | 3.16 | 24.5 | 35.24 |
| | | 3.25 | 3.20 | | | | |
| | | 2.80 | 2.80 | | | | |
| CR-12 | 12 | 2.20 | 3.00 | 2.15 | 3.66 | 46.25 | 25.0 |
| | | 1.75 | 3.75 | | | | |
| | | 2.50 | 4.25 | | | | |

**Figure 6: Comparison of Flexural Strength of at 7 and 28 Days of Curing**




of between mineral aggregates and cement paste. Therefore, initial cracks were formed around rubber aggregates and cement paste. The test result shows that there is much significance change in flexural strength of crumb rubber concrete with increase in percentage of crumb rubber. Flexural strength of crumb rubber is less than that of normal concrete on an average of 27%. The behavior of crumb rubber concrete cannot remain same as for normal concrete up to the 9% of crumb rubber compared to 7 days flexural strength and 28 days strength is decreasing 24%. Flexural strength of concrete containing crumb rubber decreases with the comparison of normal concrete. Whereas Figure 7 shows the comparison of flexural strength of subsequent concrete mix at 7$^{th}$ and 28$^{th}$ days in comparison to normal concrete.

## Split Tensile Strength

In this test, compressive line loads are applied along a vertical symmetrical plane setting up tensile stresses normal to plane, which causes splitting of specimen. The formula derived using theory of elasticity has been used to calculate the split tensile strength which is well known as indirect test used to determine the tensile strength of concrete and calculated by using following formula.

$$f_t = 2P/\pi DL_c$$

where

$f_t$ be the tensile strength

P is the load at failure in N

D be the diameter of cylinder or side if cubes

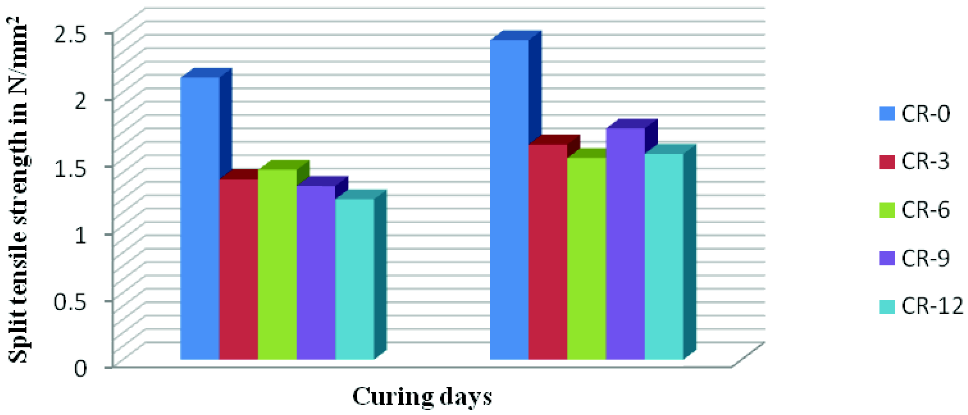
$L_c$ be the length of cylinder

The test is carried out on cylindrical specimens using a bearing strip of 3 mm plywood that is free of imperfections and is about 25 mm wide. The specimen is aligned in machine as shown in Figure 7. Figure 8 shows the comparative study and performance of proposed concrete mixes for the split tensile strength at 7 and 28 days whereas the same results also written in Table 3 for normal and concrete containing crumb are mentioned.

For rubberized concrete, results show that splitting tensile strength decreased with increasing rubber aggregate content in a

**Figure 7: Testing of Cylindrical Specimen During and After Test**

**Figure 8: Comparison of Split Tensile Strength at 7 and 28 Days of Curing**




similar manner to that observed in flexural strength test. However, there was a relatively smaller reduction in splitting tensile strength as compared to the reduction in flexural strength. It can be observed that rubberized concrete does not exhibit typical compression failure behavior. The control concrete shows a clean split of sample into two halves, whereas concrete with the rubber aggregate tends to produce a less well-defined failure.

The result from concrete containing crumb rubber show that upto 12% replacement of

**Table 3: Split Tensile Strength of Various Concrete Mixes**

| Specimen | % age Rubber Aggregates | Actual Comp. Strength (MPa) | | Av. Flexural Strength (MPa) | | % age Strength Loss | |
|---|---|---|---|---|---|---|---|
| | | 7 days | 28 days | 7 days | 28 days | 7 days | 28 days |
| CR-0 | 0 | 2.34 | 2.66 | 2.11 | 2.39 | 0 | 0 |
| | | 2.07 | 2.15 | | | | |
| | | 1.92 | 2.35 | | | | |
| CR-3 | 3 | 1.37 | 1.485 | 1.35 | 1.61 | 36.0 | 32.63 |
| | | 1.34 | 1.795 | | | | |
| | | 1.34 | 1.573 | | | | |
| CR-6 | 6 | 1.62 | 1.488 | 1.42 | 1.51 | 32.70 | 36.82 |
| | | 1.34 | 1.641 | | | | |
| | | 1.32 | 1.40 | | | | |
| CR-9 | 9 | 1.27 | 1.66 | 1.30 | 1.73 | 38.38 | 27.61 |
| | | 1.3 | 2.09 | | | | |
| | | 1.33 | 1.468 | | | | |
| CR-`12 | 12 | 1.20 | 1.431 | 1.2 | 1.54 | 43.12 | 35.56 |
| | | 1.204 | 1.55 | | | | |
| | | 1.19 | 1.66 | | | | |

crumb rubber into normal concrete, there is no significant change in split tensile strength. The decrease in split tensile strength is inversely proportional to percentage of crumb rubber. With reference to normal concrete there is no significance change in split strength of crumb rubber concrete further investigation is required for more than 12% of crumb rubber.

The split tensile strength is approximately decreases to average of 35% and its is same as normal concrete after 7 days and 28 days of curing which means there is much change in characteristics of concrete.

## CONCLUSION

From the test results of various mix samples, the following conclusions are drawn

1. Addition of recycled crumb rubber aggregates into normal concrete mix leads to decrease in workability for the various mix samples.
2. Flexural strength of concrete decreases about 40% when 3% sand is replaced by crumb rubber aggregates and further decrease in strength with increase of percentage of crumb rubber aggregates.

3. Split tensile strength of concrete decreases about 30% corresponding to 3% sand replaced by crumb rubber and further decreases the strength with increase in percentage of crumb rubber. One of the reasons that splitting tensile strength of rubberized concrete is lower than conventional concrete because of bond strength between cement paste and rubber tyre aggregates poor.

4. The rubberized concrete can be used in non-load bearing member's, i.e., lightweight concrete walls, other light architectural units, thus concrete containing fine rubber aggregates could give a viable alternative to where strength is not prime requirements.

5. Experimental results of study show that it is possible to use recycled rubber tyre in terms of aggregates in concrete construction as partial replacement to natural fine aggregates.

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