EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATE WITH CRUMB RUBBER

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ABSTRACT

Due to rapid growth in automobile industry and increase in the use of vehicles, the production of tyres is also increased which in turn generates waste /discarded/ scrap tyres. Most waste tyres are buried in the landfills and only fewer are used as fuel or as raw materials for the manufacture of rubber goods. Due to the health and environmental risks presented from waste tyres as well as the scarcity and cost of natural mineral aggregate, utilization of crumb rubber in concrete as a partial replacement of its mineral aggregates for the production of building material in construction industry would help to preserve the natural recourses and also maintain ecological balance. It is with this intension, an investigation is proposed to be conducted by using crumb rubber as replacement of fine aggregate (sand) in cement

In the present study crumb rubber of different sizes (Mesh 10, Mesh 20 and Mesh 30) is used as a replacement of fine aggregate by volume in proportion of 1:1:1 from 0% to 25% in multiple of 5% (CRC0, CRC5, CRC10, CRC15, CRC20 and CRC25). The fresh and mechanical properties of concrete with and without inclusion of crumb rubber were evaluated in terms of workability, dry density or unit weight, compressive strength, splitting tensile strength and flexural strength. Also fresh and mechanical properties of concrete with inclusion of crumb rubber was observed and compared with normal concrete of grade M20.

Keywords:- *Waste tyres, Mesh, Crumb Rubber, Crumb Rubber Concrete, Tyre Rubber Aggregate Concrete Mechanical properties etc.*

1. INTRODUCTION

India is a developing country where multipurpose development projects are proposed. All the construction schemes require best possible and efficient use of construction resources. Most of the constructions require huge quantity of cement concrete which leds to depletion of natural resources such as river sand and rock strata. Because of inadequate raw materials and rise of transport cost due to hike in fuel prices and other inputs cost of river sand and crushed rock particles is escalating rapidly. Severe environmental damages are caused by mining of river sand

since ground water table is lowered and also landslides and earthquakes are caused by the disintegration of rock strata. This emerging problem obliges modern material usage to balance the ecology. In this essence the plentiful availability of waste tyre rubber/crumb rubber can be utilized as an effective replacement for natural aggregate which will be beneficial for both circumstances.

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1.1 Crumb Rubber Concrete (CRC)

Crumb Rubber Concrete (CRC) is a concrete which is produced by replacing a volume percentage of traditional coarse and/or fine aggregate with crumb rubber particles. Crumb Rubber Concrete is also known as Rubberized Concrete (RC) or Tyre Rubber Aggregate Concrete (TRAC) or Rubber Modified Concrete (RMC). Crumb Rubber Concrete is affordable, cost effective and withstand for more pressure, impact and temperature when compared to the conventional concrete. It is observed that Crumb Rubber Concrete is very weak in compressive and tensile strength. But it has good water resistance with low absorption, improved acid resistance, low shrinkage, high impact resistance, and excellent sound and thermal insulation.

1.2 Crumb Rubber (CR)

Crumb rubber (CR) is recycled rubber produced from automotive and truck scrap tyres. Shredding waste tyres and removing steel debris found in steel-belted tyres generates crumb rubber. CR is fine rubber particles ranging in size from 0.075-mm to no more than 4.75-mm. In the concrete mix, CR constitutes a portion of the aggregate in the concrete mix.

Figure 1- Crumb Rubber

1.3 Objectives

- To find the alternative material to basic materials which are used in construction from past.
- To utilize the crumb rubber in concrete in order to minimize the global warming.
- To reduce unnecessary landfills.
- To study the effectiveness of crumb rubber as substitute for fine aggregate in concrete.
- To study the effects of crumb rubber on properties of fresh concrete like workability.
- To study the effects of crumb rubber on properties of hardened concrete like unit weight, compressive strength, split tensile strength and flexural strength.
- To provide the necessary information regarding the use of crumb rubber for concrete and to co-relate the past and existing studies about rubberized concrete.

1.4 Need for present research

The accumulation of used/waste tyres is an environmental threat. So there is an urgent need to identify alternative outlets for these tyres, with the emphasis on recycling the waste tyre. One such possible outlet is to produce crumb rubber for use in concrete as aggregate. Hence, the successful utilization of crumb rubber in concrete could provide one of the environmentally responsible and economically viable ways of converting the waste tyres into a valuable resource.

2. SUMMARY FROM LITERATURE SURVEY

On the basis of the published literature on crumb-rubber concrete (CRC) as a full or partial replacement for natural aggregates, it is apparent that unit weight, compression strength, splitting tensile strength and elastic modulus is reduced in CRC whereas ductility, energy absorption and impact resistance are enhanced which are the most important parameters in concrete structures resisting earthquakes. So, it can be concluded that there is a promising future for the recycling of discarded tyre rubber as a partial substitute for fine aggregates in concrete, which can result in huge environmental and sustainability benefits.

3. METHODOLOGY

3.1 Raw materials and variables

Cement:-

Ultratech Portland Pozzolana Cement confirming to IS 1489 was used in producing the concrete mixes. The specific gravity of the cement was 3.15.

Fine Aggregate

Natural river sand confirming to zone II as per IS 383-1970 was used as fine aggregate. The specific gravity and water absorption of fine aggregate were 2.65 and 1.02% respectively.

Course Aggregate

12 mm and 20 mm crushed stones were used as course aggregate. The specific gravity and water absorption were 2.55 and 1.08% respectively for 12 mm course aggregate and 2.92 and 0.84% respectively for 20 mm course aggregate. But average specific gravity and average water absorption of coarse aggregate used in the design were 2.74 and 0.96 % respectively.

Water

Fresh or Portable water was used to hydrate the cement in the mixtures.

Crumb Rubber (CR)

The shredding of waste tires produced crumb rubber particles that were used as a replacement of sand by volume. Three different sizes of rubber particles were used. Mesh 10 (25.4 mm), Mesh 20 (1.27 mm) and Mesh 30 (0.85 mm) rubber particles were used in the mixes in proportion 1:1:1. The crumb rubber was reported to have specific gravity of 0.85.

3.2. Concrete mix design

The concrete mixes were designed as per IS 10262-2009 and IS 456-2000. The mix design of the reference concrete (CR0) aimed to achieve a target mean strength of 26.6 MPa (often referred to grade M20) at 28 days with slump value of 75 mm. The crumb rubber of different sizes (Mesh 10, Mesh 20 and Mesh 30) was used as a replacement of fine aggregate by volume in proportion of 1:1:1 from 0% to 25% in multiple of 5%. The amount of water and cement were all held constant, to reduce the number of variables and maintain water-to-cement ratio of 0.55 for all the mixes.Six mix proportions were used for slump test, unit weight or dry density test, compressive strength test, splitting tensile strength test & flexural strength test. The mixture proportions are presented in **Table 1.**

Table 1- Mix proportions of concrete

Mixture ID	WC	Cement (kg/m^3)	Sand		Coarse Aggregate (kg/m^3)	Water (kg/m^3)	Crumb Rubber	
			Volume (%).	Weight (kg/m^3)			Volume (%)	Weight (kg/m^3)
PC	0.55	383	100	685	1157	210	0	0
CRC5	0.55	383	95	650	1157	210	5	11
CRC10	0.55	383	90	616	1157	210	10	22
CRC15	0.55	383	85	582	1157	210	15	33
CRC20	0.55	383	80	548	1157	210	20	44
CRC25	0.55	383	75	513	1157	210	25	55

Note- Crumb rubber content in (kg/m3) = volume of all in aggregate x proportion volume of fine aggregate x mass density of rubber x percentage volume of rubber. (Ex. 0.688 x 0.38 x 0.85 x 1000 x 5 % = 11.1 kg/m3)

4. LABORATORY TESTING PROGRAM

Six different tests were carried out at the Department of Civil Engineering, SSIERAS, Rahata and consisted of slump cone test on fresh concrete as well as unit weight test, compressive strength test, splitting tensile strength test and flexural strength or modulus of rupture test on hardened concrete which were conducted on the specimens after removing the specimens from curing tank after specified curing period.

5 RESULTS AND DISSCUSSIONS

5.1 Slump cone test

The slump cone test is used to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of work. The effect of crumb rubber on workability of concrete for various mixtures is demonstrated in Figure-2.

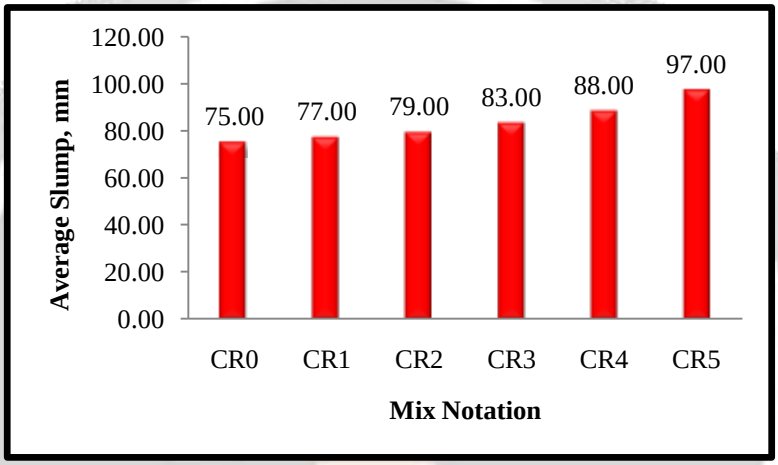

Figure 2-Average slump of all mixes

The results demonstrated that slump value (workability) of fresh concrete increased with increase in replacement of crumb rubber. As seen in Figure-12, the lowest slump value happened on the reference concrete with 100 % natural fine aggregate whereas the mixture incorporating 25% crumb rubber replacement reached the highest one. There is increase in slump value (workability) since the crumb rubber does not absorb the water as compared to fine aggregate.

5.2 Unit weight or Dry density test

The unit weight or dry density is the ratio of weight per unit volume of a material. The effect of crumb rubber on unit weight of concrete for various mixtures is demonstrated in Figure-3.

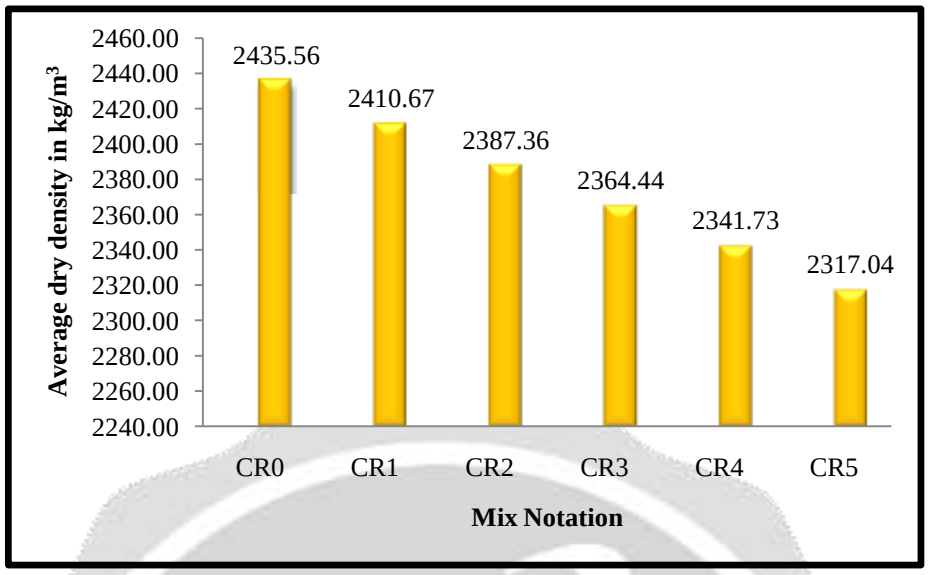

Figure 3-Unit weight or Dry density of all mixes

From the results it is noted that the unit weight or dry density decreases with increase in percentage of fine aggregate by crumb rubber. The reduction in unit weight is due to the fact that density of crumb rubber is much lower than other concrete constituents. The unit weight declined from 2435.56 kg/m^3 to 2317.04 kg/m^3 with increasing crumb rubber replacement rate from 0% to 25% at 28 days.

5.3 Compressive Strength Test

Especially for concrete compressive strength is an important parameter to determine the performance of material during service conditions. The effect of crumb rubber on compressive strength of concrete for various mixtures is demonstrated in Figure-4.

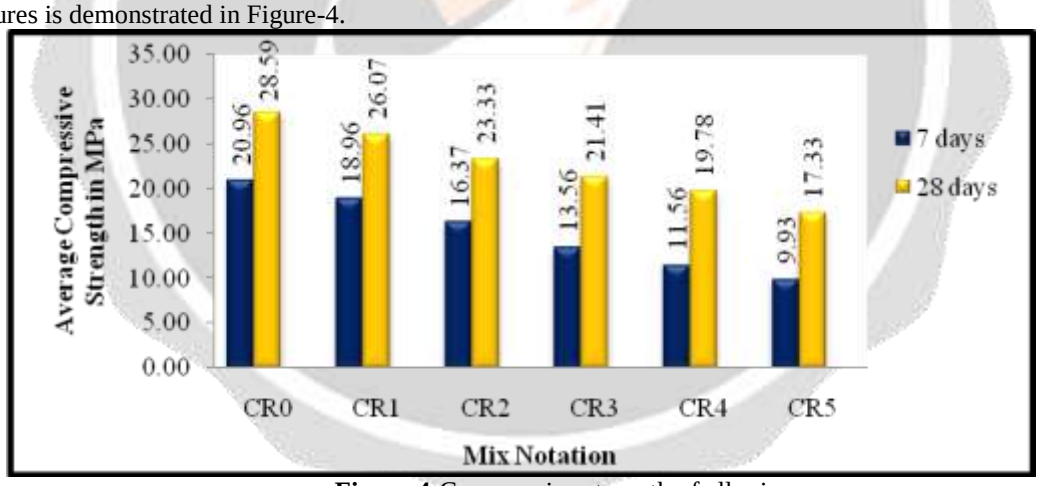

Figure 4-Compressive strength of all mixes

From the results it is observed that the compressive strength decreases with increase in percentage of fine aggregate by crumb rubber. The decrease in compressive strength may be due the lack of bonding between crumb rubber particles and surrounding cement paste and also due to the low stiffness and poor surface texture of crumb rubber particles. The increase in crumb rubber particle content from 0% to 25% resulted in decrease in compressive strength from 28.59 MPa to 17.33 MPa which is equivalent to about 40 % reduction of strength on day 28. However the mean characteristic compressive strength is achieve by the mixtures incorporating 0%, 5%, 10%, 15% and 20% (CR0, CR1, CR2, CR3 and CR4) crumb rubber in concrete on 28 day.

5.4 Splitting tensile strength

Splitting tensile strength is used to determine the tensile strength of concrete in an indirect way. The effect of crumb rubber on splitting tensile strength of concrete for various mixtures is demonstrated in Figure5.

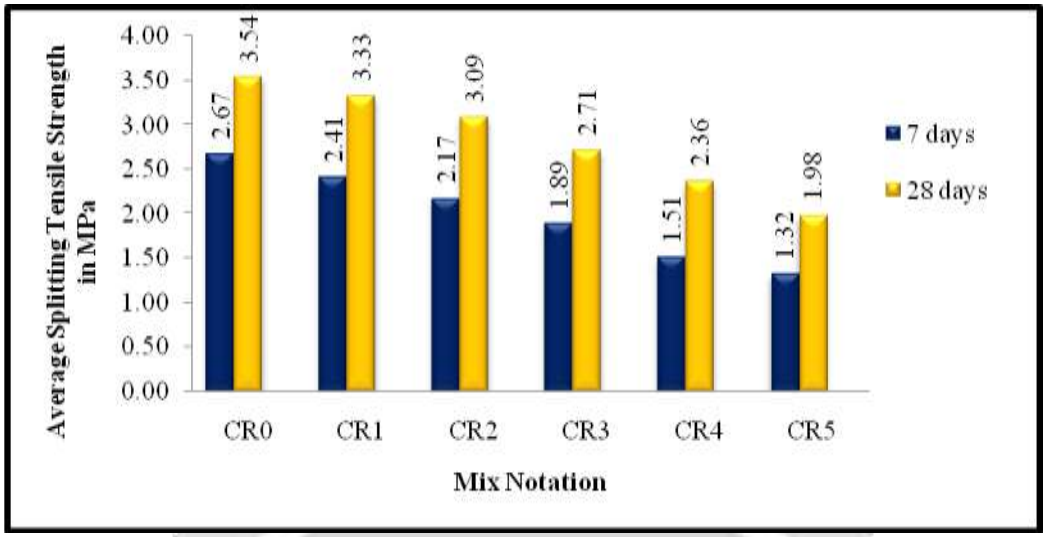

Figure 5-Splittling tensile strength of all mixes

From the results it is noted that the splitting tensile strength decreases with increase in percentage of fine aggregate by crumb rubber. The decrease in strength is due to non polar action of crumb rubber particles which attract air and repels water. The increase in crumb rubber particle content from 0% to 25% resulted in decrease in compressive strength from 3.54 MPa to 1.98 MPa which is equivalent to about 44 % reduction of strength on day 28.

5.5 Flexural Strength Test

Flexural strength test is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. The effect of crumb rubber on flexural strength of concrete for various mixtures is demonstrated in Figure-6.

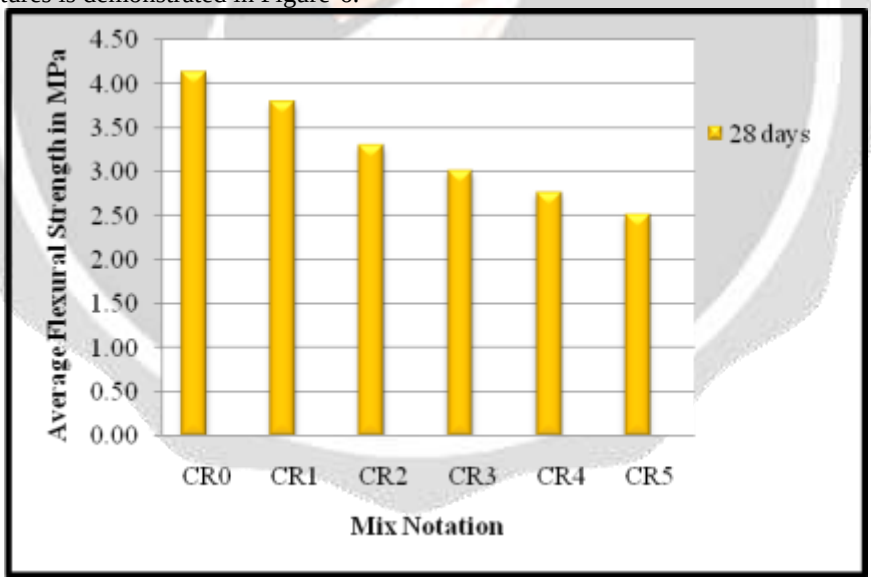

Figure 6-Flexural strength of all the mixes

From the results it is noted that the flexural strength decreases with increase in percentage of fine aggregate by crumb rubber. The decrease in strength is due to the increase in voids and weak bonding as crumb rubber content increases. The flexural strength values between 4.14 MPa and 2.51 MPa at 28 days in which the reference mix had highest strength value.

6. CONCLUSIONS

After studying the several test results of different specimens ranging in crumb rubber content from 0% to 25% in replacement of fine aggregate, the following conclusions are deduced:

1. The workability of concrete improves due to addition crumb rubber and is acceptable in terms of the ease in handling, the placing and finishing of wet concrete as compared to normal concrete.
2. The dry density and compressive strength of concrete reduces as the percentage of crumb rubber content increases.
3. Good compressive strength was recorded at crumb rubber contents lower than 25% in replacement of fine aggregate.
4. The splitting tensile strength and flexural strength of concrete decreases as the crumb rubber percentage increases.
5. The incorporation of crumb rubber to concrete changes the failure pattern from brittle mode to ductile mode.
6. Although the strength of concrete is reduced with increase in crumb rubber content, its lower unit weight meets the criteria of light weight concrete.
7. Although it is not recommended to use the concrete containing crumb rubber in structural elements where high strength is required, it can be used in many other construction elements like partition walls, road barriers, pavements, sidewalks etc which are in high demand in construction industry.

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