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MECHANICAL CHARACTERISTICS OF CRUMB RUBBER CONCRETE

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Abstract

Concrete is a composite material composed mainly of water, aggregate, and cement. Additives and reinforcements used to change and improve the physical properties of the material and including mixture. They form a fluid mass that is easily moulded into shape when these ingredients are mixed. With time, the cement binds with the rest of the ingredients into a durable stone-like material in many forms, thereby forming a hard matrix. Production of good quality concrete requires meticulous care exercised at every stage of the manufacture of concrete. The proposed study was intended to identify the mechanical properties of concrete, which replaced with crumb rubber as fine aggregate named Crumb Rubber Aggregate Concrete (CRAC). The Rubberized Concrete was prepared by adding the following materials, such as cement; fine aggregate, coarse aggregate, Crumb Rubber aggregate, and portable water. Present paper is also one among such intention to develop a supplementary use of natural aggregates with abundantly available rubber wastes.

Keywords : Concrete, mechanical, crumb, rubber, quality.

MECHANICAL PROPERTIES

Material investigation involves proper material selection, utilization, and effective management. The materials collected are investigated properly to get appropriate quality and desired results. All the investigations are done according to the standard procedures mentioned in IS codes. The mechanical properties of CRAC, several mixtures with varying weight of crumb rubber (CR) aggregates were prepared. The weight fraction of fine aggregate is ranged from 2% to 20%.

Materials

An elaborative material study was carried out and discussed below.

Cement:

In the present work, for casting, Ordinary Portland Cement of 53 grade is used. The cement"s physical properties are obtained by conducting the specified tests as per the IS standards, namely IS 12269:2013, IS 1727:1967, and IS 4031(Part – 5): 1988. Table 3.1 provides all the properties of cement.

Table 3.1 Physical properties of cement

S.No	Properties	Values
1	Specific gravity of cement	3.10
2	Fineness of cement	4%
3	Standard consistency of cement	30%
4	Initial setting time	35 min
5	Final setting time	512 min
6	Compressive strength of cement mortar in 28 days	53.80 MPa

Fine Aggregate:

According to the grading zone II, the locally available river sand is used for experimental works. The fine aggregate (FA) sieve analysis was carried out in the laboratory as per IS: 383-1970. The specified tests are achieved on fine aggregate as per IS: 2386 (Part3) - 1963 to find out its physical properties. Table 3.2 and Table 3.3 provide all the properties of sand. Figure 3.1 shows the fineness modulus of fine aggregate.

Table 3.2 Properties of sand

S.No	Properties	Values
1	Specific gravity of sand	2.62
2	Water absorption	2%

Table 3.3 Fineness modulus of fine aggregate

Sieve Size (mm)	Weight of Retained Sand (g)	% Weight Retained	Cumulative % of Weight Retained	Cumulative % Weight Passed
4.75mm	24	2.4	2.4	97.6
2.36mm	48	4.8	7.2	92.8
1.18mm	132	13.2	20.4	79.6
0.6 mm	208	20.8	41.2	58.8
0.3 mm	356	35.6	76.8	23.2
0.15 mm	196	19.6	96.4	3.6
Pan	36	3.6	100	0.0
Total Cumulative % of Weight Retained = 355.6				
Fineness Modulus of Fine Aggregate = 356/100 = 3.56				

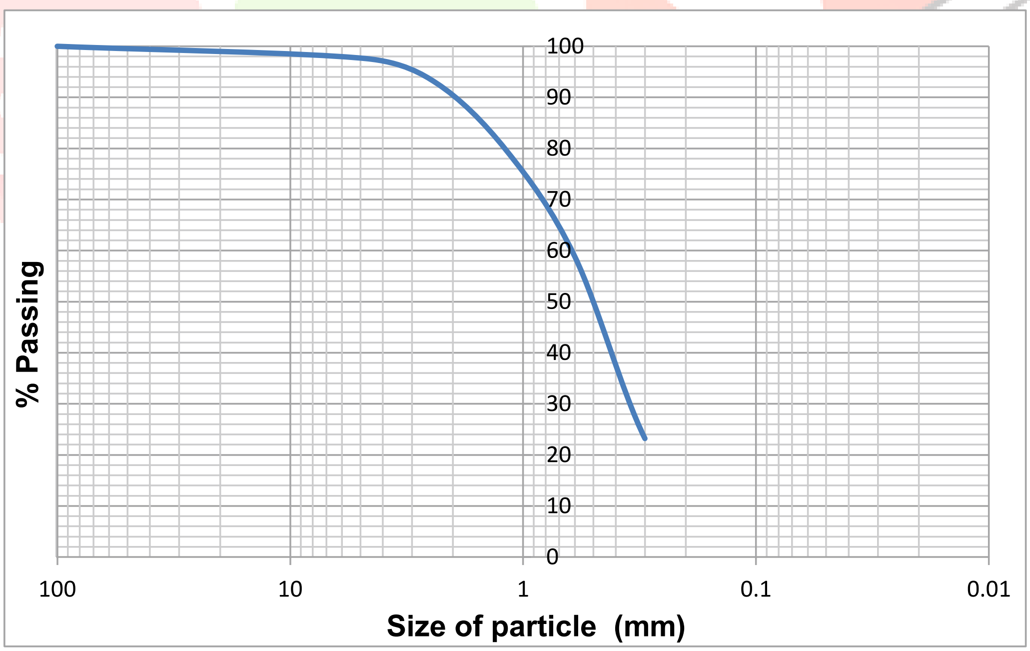

Figure 3.1 Particle size distributions for sand

Coarse Aggregate:

The coarse aggregates commonly used at work have a maximum size of 20 mm and are locally available. The following tests are carried out as per IS: 2386 (Part3) – 1963. Table 3.4 provides all the properties of coarse aggregate.

Table 3.4 Properties of coarse aggregate

S.No	Properties	Values
1	Specific gravity of coarse aggregate	2.72
2	Water absorption	1%
3	Fineness modulus	4.72
4	Aggregate Impact test value	13.58%
5	Aggregate Crushing value	18.24 %

Crumb Rubber Aggregate:

The crumb rubber (CR) is recycled rubber. In this project, these rubbers are passing through the sieve size of 2.36 mm (10 mesh), and it is used as the partial substitute for fine aggregate. The crumb rubber aggregates behaved very much close to the normal aggregates. The rubber fibers (RF) are used as additives in this project have an aspect ratio ranging from 25- 30. Table 3.5 provides all the properties of Rubber. The crumb rubber aggregates are shown in Figure 3.2.

Table 3.5 Properties of rubber

S.No	Properties	Values
1	Specific gravity of rubber	1.3
2	Water absorption	1.3%
3	Fineness modulus	4.15

Figure 3.2 Crumb rubber aggregates

Chemical Solution:

The various amounts of crumb rubber of tires treated with three different acidic solutions such as CH_3COOH (5%), H_2SO_4 (35%), and HCL (5%) used as partial replacement of sand in concrete. Before adding to the concrete, the rubber was immersed in acidic solutions and kept undisturbed for 24 hours. After 24 hours, it is taken out, rinsed with water, dried, and used in concrete manufacturing. Figure 3.3 shows the treatment of crumb rubber.

Figure 3.3 Treatment of crumb rubber

Water:

Clean portable water free from suspended particles, chemical substances and biological elements is used both for mixing concrete and curing.

Mix Design

Mix design is the process of selecting and determining the relative proportions of materials with the object of producing concrete of specific or absolute minimum strength and durability as economically as possible. The main objective is to stipulate the minimum strength and durability. Mix design is carried out as per the Indian Standard Code method (IS 10262 – 2009) for the test specimen. The mix proportions are made for the M25 and M30 grades of concrete. Table 3.6 shows the calculated mix proportions.

Table 3.6 Mix proportion for the concrete specimen

S. No.	Grade of Concrete	Mix Proportion (Cement: FA: CA)	Water Cement Ratio
1	M25	1:1.46:2.57	0.45
2	M30	1:1.15:2.12	0.38

Casting of Specimens

The ingredient of concrete are weighed and taken as per the mix proportions arrived from the mix design. Pretreatment has been done by soaking the recycled tire particles in an acidic solution for 24 hours, then washed with clean water and at room temperature, it is left to air-dry. In the hybrid layered (two - layers with rubber concrete on the top layer and at bottom layer plain concrete), specimens were prepared for compressive strength, splitting tensile strength, and flexural strength, respectively. The percentage of crumb rubber (CR) replacement ranged from 2 to 20% in the top rubber layer. Mixing is done by hand by using a trowel after arriving at the required materials. After the addition of each material, mixing has to be done until the mix becomes homogeneous. These materials are filled and compacted manually using a damping rod in the oiled steel mould. After 24 hours of casting, the specimen is removed from the mould and cured. The properties of rubberized concrete containing crumb rubber treated with the acidic solution are tested and compared with untreated rubberized and conventional concrete. From the tests conducted on specimens, it can be concluded that the fine aggregate replacement of the optimum percentage of rubber is justified and use three chemical solutions for the treatment of rubber. Table 3.7 and Table 3.8 shows the various percentages of replacement and the weight proportions of crumb rubber aggregate. The results show that the treatment of rubber by acetic acid solution significantly improves the properties of rubberized concrete when compared with untreated rubberized concrete. For the total weight of concrete 0.5%, 1%, 1.5% & 2% of rubber fibers (RF) were additionally added to the rubber layer.

Table 3.7 Specimen details

S. No	Series ID	Specimen ID	Grade of concrete	% of replacement as		No of Cubes	No of Cylinders	No of Prisms
				FA	RF			
1	UCR1	UCR01	M25	0	-	9	9	9
2		UCR11		2	-	9	9	9
3		UCR21		4	-	9	9	9
4		UCR31		6	-	9	9	9
5		UCR41		8	-	9	9	9
6		UCR51		10	-	9	9	9
7	TCR1	TCR01	M25	10	0	9	9	9
8		TCR11		10	0.5	9	9	9
9		TCR21		10	1	9	9	9
10		TCR31		10	1.5	9	9	9

11		TCR41		10	2.0	9	9	9
12	TCR2	TCR02	M25	10	0	9	9	9
13		TCR12		10	0.5	9	9	9
14		TCR22		10	1	9	9	9
15		TCR32		10	1.5	9	9	9
16		TCR42		10	2.0	9	9	9
17	TCR3	TCR03	M25	10	0	9	9	9
18		TCR13		10	0.5	9	9	9
19		TCR23		10	1	9	9	9
20		TCR33		10	1.5	9	9	9
21		TCR43		10	2.0	9	9	9
22	TCR4	TCR04	M25	15	0	9	9	9
23		TCR14		15	0.5	9	9	9
24		TCR24		15	1.0	9	9	9
25		TCR34		15	1.5	9	9	9
26		TCR44		15	2.0	9	9	9
27	TCR5	TCR05	M25	20	0	9	9	9
28		TCR15		20	0.5	9	9	9
29		TCR25		20	1.0	9	9	9
30		TCR35		20	1.5	9	9	9
31		TCR45		20	2.0	9	9	9
32	TCR6	TCR06	M30	0	-	9	9	9
33		TCR16		10	0	9	9	9

34		TCR26		10	0.5	9	9	9
35		TCR36		10	1	9	9	9
36		TCR46		10	1.5	9	9	9
37		TCR56		10	2.0	9	9	9
38	TCR7	TCR07	M30	15	0	9	9	9
39		TCR17		15	0.5	9	9	9
40		TCR27		15	1.0	9	9	9
41		TCR37		15	1.5	9	9	9
42		TCR47		15	2.0	9	9	9
43	TCR8	TCR08	M30	20	0	9	9	9
44		TCR18		20	0.5	9	9	9
45		TCR28		20	1.0	9	9	9
46		TCR38		20	1.5	9	9	9
47		TCR48		20	2.0	9	9	9
Total No. of Specimens						423	423	423

Table 3.8 Mix Proportion for CRAC per bag of cement by weight

Series ID	Specimen ID	Grade	Cement(kg/m^3)	Fine Aggregate (kg/m^3)				Coarse Aggregate(kg/m^3)	Rubber Fibers (kg/m^3)	W/C Ratio	Treating Type
				Sand		Crumb Rubber					
				Top Layer	Bottom Layer	Top Layer	Bottom Layer				
UCR1	UCR01	M25	50.00 73.00 73.00			0.00	-	128.50	-	0.45	Untreated
	UCR11		50.00 71.54 73.00			1.46	-	128.50	-	0.45	
	UCR21		50.00 70.08 73.00			2.92	-	128.50	-	0.45	
	UCR31		50.00 68.62 73.00			4.38	-	128.50	-	0.45	
	UCR41		50.00 67.16 73.00			5.84	-	128.50	-	0.45	
	UCR51		50.00 65.70 73.00			7.30	-	128.50	-	0.45	
TCR1	TCR01	M25	50.00 65.70 73.00			7.30	-	128.50	0.00	0.45	H_2SO_4 (35%)
	TCR11		50.00		65.70 73.00	7.30	-	128.50	1.26	0.45	
	TCR21		50.00		65.70 73.00	7.30	-	128.50	2.52	0.45	
	TCR31		50.00		65.70 73.00	7.30	-	128.50	3.77	0.45	
	TCR41		50.00		65.70 73.00	7.30	-	128.50	5.03	0.45	

TCR2	TCR02	M25	50.00 65.70 73.00			7.30	-	128.50	0.00	0.45	HCL (5%)
	TCR12		50.00 65.70 73.00			7.30	-	128.50	1.26	0.45	
	TCR22		50.00 65.70 73.00			7.30	-	128.50	2.52	0.45	
	TCR32		50.00 65.70 73.00			7.30	-	128.50	3.77	0.45	
	TCR42		50.00 65.70 73.00			7.30	-	128.50	5.03	0.45	
TCR3	TCR03	M25	50.00 65.70 73.00			7.30	-	128.50	0.00	0.45	CH_3COOH (5%)
	TCR13		50.00		65.70 73.00	7.30	-	128.50	1.26	0.45	
	TCR23		50.00		65.70 73.00	7.30	-	128.50	2.52	0.45	
	TCR33		50.00		65.70 73.00	7.30	-	128.50	3.77	0.45	
	TCR43		50.00		65.70 73.00	7.30	-	128.50	5.03	0.45	
TCR4	TCR04	M25			50.00 62.05 73.00 10.95		-	128.50	0.00	0.45	CH_3COOH (5%)
	TCR14		50.00		62.05 73.00	10.95	-	128.50	1.26	0.45	
	TCR24		50.00		62.05 73.00	10.95	-	128.50	2.52	0.45	
	TCR34		50.00		62.05 73.00	10.95	-	128.50	3.77	0.45	
	TCR44		50.00		62.05 73.00	10.95	-	128.50	5.03	0.45	
TCR5	TCR05	M25			50.00 58.40		-	128.50	0.00	0.45	CH_3COOH (5%)

					73.00 14.60						
	TCR15		50.00		58.40 73.00	14.60	-	128.50	1.26	0.45	
	TCR25		50.00		58.40 73.00	14.60	-	128.50	2.52	0.45	
	TCR35		50.00		58.40 73.00	14.60	-	128.50	3.77	0.45	
	TCR45		50.00		58.40 73.00	14.60	-	128.50	5.03	0.45	
TCR6	TCR06	M30	50.00 57.50 57.50			0.00	-	106.00	-	0.38	CH_3COOH (5%)
	TCR16		50.00		51.75 57.50	5.75	-	106.00	0.00	0.38	
	TCR26		50.00		51.75 57.50	5.75	-	106.00	1.07	0.38	
	TCR36		50.00		51.75 57.50	5.75	-	106.00	2.14	0.38	

Series ID	**Specimen ID**	**Grade**	**Cement(kg/m^3)**	**Fine Aggregate (kg/m^3)**				**Coarse Aggregate(kg/m^3)**	**Rubber Fibers (kg/m^3)**	**W/C Ratio**	**Treating Type**
				Sand		**Crumb Rubber**					
				Top Layer	**Bottom Layer**	**Top Layer**	**Bottom Layer**				
	TCR46		50.00	51.75	57.50	5.75	-	106.00	3.20	0.38	
	TCR56		50.00	51.75	57.50	5.75	-	106.00	4.27	0.38	
TCR7	TCR07	M30	50.00 48.88 57.50			8.62	-	106.00	0.00	0.38	CH_3COOH (5%)
	TCR17		50.00		48.88 57.50	8.62	-	106.00	1.07	0.38	

	TCR27		50.00		48.88 57.50	8.62	-	106.00	2.14	0.3 8	
	TCR37		50.00		48.88 57.50	8.62	-	106.00	3.20	0.3 8	
	TCR47		50.00		48.88 57.50	8.62	-	106.00	4.27	0.3 8	
TC R8	TCR08	M30			50.00 46.00 57.50 11.50		-	106.00	0.00	0.3 8	CH_3^{COOH} (5%)
	TCR18		50.00		46.00 57.50	11.50	-	106.00	1.07	0.3 8	
	TCR28		50.00		46.00 57.50	11.50	-	106.00	2.14	0.3 8	
	TCR38		50.00		46.00 57.50	11.50	-	106.00	3.20	0.3 8	
	TCR48		50.00		46.00 57.50	11.50	-	106.00	4.27	0.3 8	

PROPERTIES OF FRESH CONCRETE

The workability of concrete is very important in fresh concrete. Workability is defined as the ease with which sample given a set of materials can be mixed into concrete and subsequently handled, transported, placed and compacted with minimum loss of homogeneity. The fresh concrete properties of concrete are done by conducting a slump test for concrete as per IS 1199: 1959. The measurement of workability is done by slump test for all mixes. The slump test is the most commonly used method of measuring the workability of concrete. The apparatus for conduction the slump test consists of a 20 metallic mould in the form of a frustum of a cone having a200 mm bottom diameter, 100 mm top diameter, and 300 mm height. The mould is filled with concrete in three layers. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross-section. The mould is removed from the concrete by raising it slowly and carefully in a vertical direction. The difference level between the height of the mould and the height of subsided concrete is noted, and it is taken as slump value.

CRAC samples showed acceptable workability in terms of ease of handling, trowelling, placement, and finishing. CRAC samples can be finished to the same standard as the conventional concrete without any difficulties. However, mixes containing higher rubber aggregate content require more effort and work to smooth the finished surface because of the lower unit weight. Figure 3.4 shows the slump test conducted for CRAC. Figures from 3.5 and 3.6 show the slump value of CH_3COOH treated CRAC. The outcome of fresh concrete is increasing in workability while adding the rubber aggregate and rubber fibers to the concrete. The concrete might be due to the lower water penetration capacity of the crumb rubber.

The results indicated that there was an increase in slump value when treated crumb rubber content increased from 0% to 20%. It can be observed from this Figure that the incorporation of rubber into CRAC resulted in increases in the workability. It means for that ordinary concrete, the rubberized concrete‟s workability is acceptable in terms of placing, handling, and finishing.

Figure 3.4 Slump test of CRAC

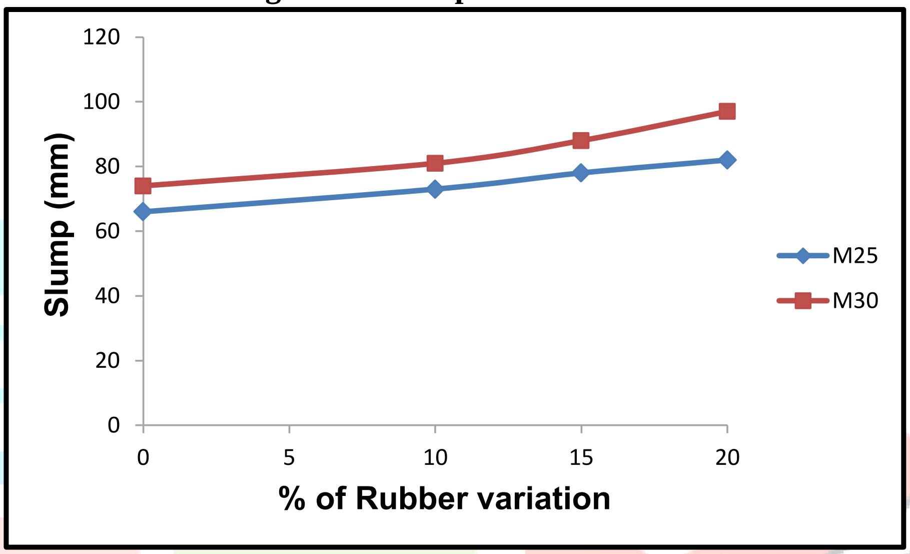

Figure 3.5 Slump values of conventional and rubberized concrete for M 25 and M 30 Grades

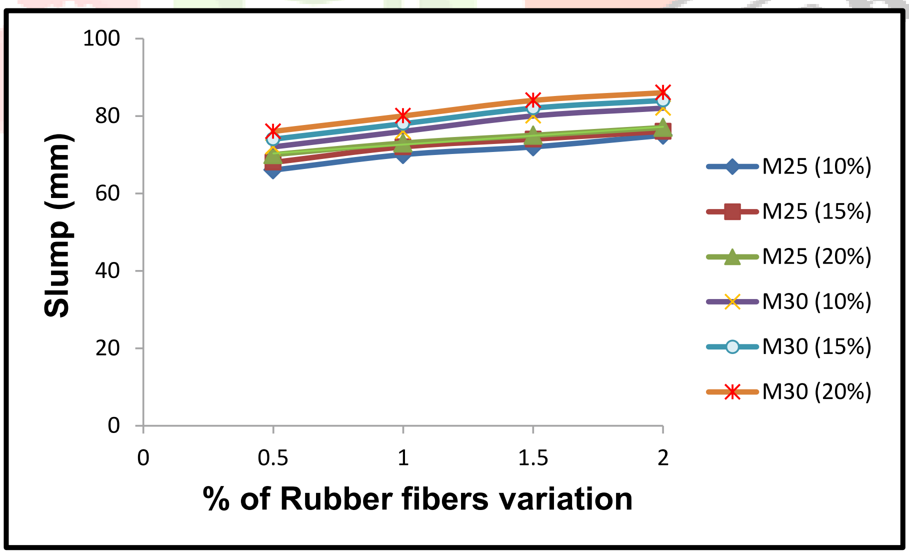

Figure 3.6 % of Rubber fibers variation Vs slump

FINDINGS

Were cast at 1269 specimens to test the mechanical properties of Crumb Rubber Aggregate Concrete. From the test, the following findings were observed.

i. The outcome of fresh concrete is increasing in workability while adding the rubber aggregate in the concrete. This concrete might be due to the lower water penetration capacity of the crumb rubber.

ii. Generally, compressive strength decreases when the percentage of replacement of rubber aggregate increases. But 10% CRAC treated with CH_3COOH (5%) up to 2.0% rubber fibers replacement shows an increase in strength compared to conventional and untreated rubberized concrete. Pre-treatment of rubber improves cement concrete properties when compared with untreated rubberized concrete.

iii. Split tensile strength of concrete increases when rubber fibers increase up to 2.0% of all 10% CRAC replacements in both grades. Increasing the percentage of rubber fibers from 0.5 to 2.0% lead to an increase in the tensile strength of rubberized concrete. 10% CRAC treated with CH_3COOH (5%) up to 2.0% rubber fibers replacement shows higher tensile strength than conventional and H_2SO_4 (35%), while HCL (5%) gives a small increase in strength.

iv. Flexural strength of concrete increases with an increasing percentage of crumb rubber up to 20% of all CRAC replacements. All other CRAC achieves more than 90% strength compared with the conventional specimen.

v. Replacement of crumb rubber by 10% with the addition of 2.0% rubber fibers proves exceptionally well in compression, tensile, and flexural strength and follows the curvature of conventional specimens all the tests in both the grades.

vi. The theoretical analysis has been formulated for predicting mechanical properties using the regression model and proposed new Equations to predict the split tensile and flexural strength of CRAC.

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