Crumb Rubber in Concrete: Static and Dynamic Evaluation

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Abstract **-** Concrete is most widely used building material in the world. Concrete consists of aggregates, cement and water. The major part of concrete besides the cement is the aggregate. Aggregate include sand and crushed stone / Gravel. About 3 corers tonnes of waste tyres are produced in India per year. Rubber materials are flexible, durable and elastic which are the properties required for manufacturing itself. But crumb rubber is found to possess properties that are required for replacement of fine aggregate in concrete. Hence this project aimed to study the effectiveness of rubber as substitute for fine aggregate and utilize the waste tyre crumb rubber in concrete, to minimize global warming. Concrete specimens casted and tested for concrete mix with various percentage of replacement (0.5 to 7%) and its effect for replacement are discussed in this project.

Keywords **-** Crumb rubber, Compressive strength, Waste Tyre Crumb Rubber Concrete, Drop weight test, Compressive strength, Ductility index.

I. INTRODUCTION

In recent years, waste handling and management is the primary issue faced by the countries all over the world. One of the critical wastes to be managed in today's scenario is 'waste tyre' because; modern development in transportation has produced large number of vehicles, which creates enormous amount of waste tyres. One of the largest potential recycling routes is in construction, but usage of waste tyres in civil engineering is currently very low. Currently, only 5% of scrap tyres are recycled in civil engineering applications. Hence this project aimed to study the effectiveness of rubber as substitute for fine aggregate and utilize the crumb rubber tyres in concrete, to minimize global warming. In the present investigation an attempt is made to find out energy absorption capacity of WTCRC under impact drop test and find out the respective reduction in compressive strength

II. OBJECTIVE OF INVESTIGATION

1. Use of waste tire crumb rubber particle (WTCRP) as a partial replacement to fine aggregate in concrete at varying percentages from 0.5% to 7% ,to check the energy absorption capacity of concrete.
2. To reduce the effect of waste tire rubber on surrounding environment
3. To check the workability of concrete for varying percentage of cement paste.
4. To determine the ductility index of crumb rubber concrete.

III. LITERATURE REVIEW

This part represents the a review of most literature to bring out the background of the study to be undertaken in the present work. The research contribution which have direct relevance and contributed greatly to understanding the behavior of rubber concrete. T.senthil Va Divel 1 et.al discussed the behavior of waste tyre rubber aggregate concrete under impact loading. In his paper attempt is made to cast and test the cylindrical specimen made of normal concrete(plain) and concrete with waste tyre crumb rubber as aggregate for impact loads with a steel ball drop weight the result shows that, WTRAC 6% replacement of both fine and coarse aggregate improves the energy absorption capacity and ductility characteristics. Tantala et.al2 in his study presented the toughness of normal concrete mixture and the concrete with WTRAC mixtures with 5%and 10% buff rubber replaced by volume of coarse aggregate the result shows that, toughness of both WTRAC mix was higher than normal concrete mixture however the toughness of WTRAC with 5% buff rubber was higher than 10% buff rubber (2to6mm) because for higher rubber content compressive strength decreases. M.R. Wakchaure et.al6 Reported that, use of waste tyre crumb rubber particle of size passing through 1.18 mm is sieve and retained on 600 micron sieve are used in concrete at varying percentages from 0.5% to 2% increases the workability of concrete.

IV. EXPERIMENTAL STUDIES

A. Materials used

a) Cement

For this research, locally available ordinary Portland cement (53 grade) of Specific gravity of cement 3.15 was used throughout the work.

b) Physical properties of fine aggregate

Locally available fine aggregate used was 4.75 mm size confirming to zone II with specific gravity 2.693. The testing of sand was conducted as per IS: 383-1970.

c) Physical properties of coarse aggregate

Crush stone aggregate of size 20 mm and 12.5 mm was used throughout the experimental work. Coarse aggregate used was 20mm with specific gravity 2.912 and coarse aggregate of 12.5 mm with specific gravity 2.82. Testing of coarse aggregate was conducted as per IS: 383-1970.

d) Water

The water used was potable, color less and odor less that is free from organic impurities of any type.

e) Rubber aggregate

Waste tyre crumb rubber collected from local tyre remolding plant, from which steel wire and fabric have been removed has granular texture and the sizes are passing through 4.75 mm IS sieve and retaining on 2.36 mm IS sieve (R1), passing through 2.36 mm IS sieve and retaining on 1.18 mm IS sieve (R2), passing through 1.18 mm IS sieve and retaining on 600 µ IS sieve (R3). Pictures of crumb rubber used in this study is shown in fig 1.The specific gravity of crumb rubber is 1.14

Fig.1(a) R1

Fig.1(a)R2

Fig.1(a)R3

Fig.1 Different sizes of crumb rubber particles

B. Mix Proportioning

Concrete mix design in this experiment was designed as per the guidelines in IS 10262-2009. All the samples were prepared using design mix. M20 grade of concrete was used for the present investigation. The table 1 shows mix proportion of concrete (Kg/m3)

Table 1: Mix proportioning

Water (kg/m3)	Cement (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)
209.87	383.16	685.75	1157.55
0.5	1	1.789	3.02

V. TESTING PROGRAM

In this study concrete cube and cylinders were cast of M20 grade concrete. For compression test total 45 standard size cubes were casted to estimate the decrease in compressive strength with increase in rubber content and for drop weight test 45 cylinders were casted to estimate energy absorption capacity of concrete under impact loading.

A. Compressive Strength

The cured cubes were tested to find the effects of the crumb rubber on the compressive strength of concrete were determined using static compressive tests. For each sample three representative samples were tested. These tests were performed at Amrutvahini College of engineering, testing of material laboratory, Sangamner on a compression testing machine. The loading rate was 3.4 KN/Sec. Fig. 2 shows the details of the compression test setup.

B. Impact resistance under drop weight test

Drop weight test was performed on cylindrical specimens (150 mm in diameter and 64 mm in height, three specimens for each mix) as per ACI Committee 544 to estimate the energy absorption capacity of concrete specimens. In this test, repeated loading was applied on the specimen from a height. The number of blows was obtained for the prescribed level of distress (occurrence of first crack and failure cracks). Specimens of 28 days age were tested by the drop weight impact testing machine fabricated in the laboratory as per guidelines of ACI committee 544. The machine consists of a 4.5 kg hammer dropping from 450 mm height on a hardened steel ball of 65 mm diameter. The steel ball was placed at the centre of specimen and this specimen was placed on the base plate within the positioning lugs as shown in fig 3. The hammer was dropped repeatedly and the number of blows (N1) required to cause the first visible crack on the top was recorded. Number of blows (N2) which caused opening of cracks in such a way that the concrete pieces started touching side lugs was also recorded. The values of N1 and N2 were designated as initial crack resistance factor and ultimate crack resistance factor respectively.

Fig 2 compression testing machine

Fig 3 Drop weight testing machine

The impact energy at initial crack, Ep,dwi (where first subscript p denotes the type of energy absorbed i.e. potential energy and second subscript dw denotes the type of test i.e. drop weight) was calculated by the equation given below:

$Ep_{dwi} = N1mgh$

Similarly, the impact energy at ultimate crack, Ep,dwu was

calculated by the equation given below:

$Ep_{dwu} = N2mgh$

where, N1 and N2 are the number of blows at initial and ultimate crack level, m is the mass of drop hammer (4.5 kg), g is acceleration due to gravity (9.81 m/s2) and h is the releasing height of drop hammer (450 mm).

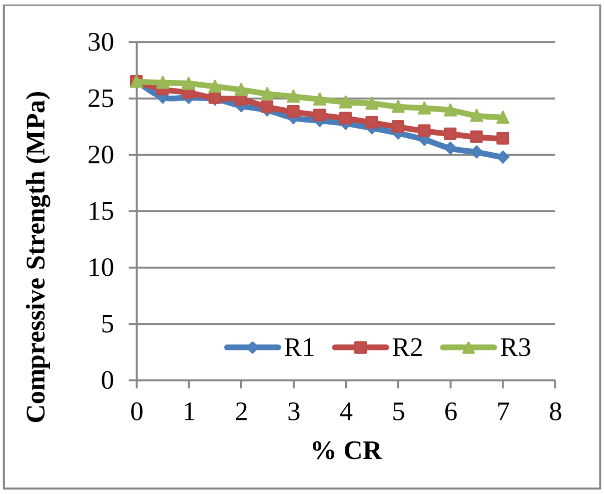
VI. RESULTS AND DISCUSSION

A. Compressive Strength Test

Test results for compressive strength at 28 day are as shown in Table 2 and demonstrated in Graph 1

Table 2: Test results for compressive strength at 28 days

Percentage of crmb rubber	Compressive Strength (MPa)		
	R1	R2	R3
0.0	26.5	26.5	26.5
0.5	25.12	25.82	26.41
1.0	25.08	25.52	26.33
1.5	24.95	25.04	26.07
2.0	24.35	24.92	25.78
2.5	23.96	24.26	25.42
3.0	23.28	23.82	25.18
3.5	23.04	23.52	24.93
4.0	22.78	23.24	24.68
4.5	22.38	22.86	24.56
5.0	21.92	22.48	24.28
5.5	21.36	22.12	24.15
6.0	20.58	21.85	23.96
6.5	20.24	21.58	23.48
7.0	19.78	21.44	23.33



Graph 1-Compressive strength of all mixes

B. Impact resistance under drop weight test

a) Energy consumed at initial crack
Test results for energy consumed at Initial crack are as shown in below table 3 and demonstrated in Graph 2.

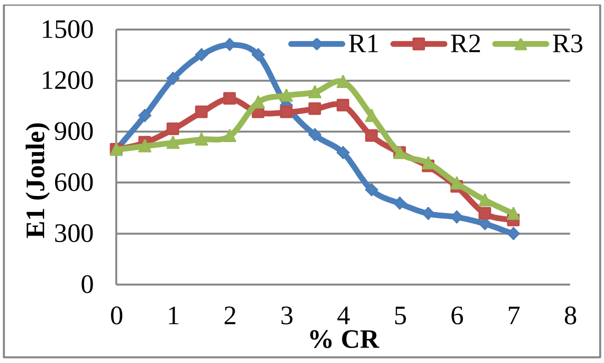
Table 3: Impact test results for energy consumed at initial crack (E1)

Percentage of crumb Rubber	E1 (Joule)		
	R1	R2	R3
0.0	794	794	794
0.5	993	834	814
1.0	1212	914	834
1.5	1351	1013	854
2.0	1410	1093	874
2.5	1351	1013	1073
3.0	1053	1013	1112
3.5	880	1033	1132
4.0	775	1053	1192
4.5	556	874	993
5.0	477	775	775
5.5	417	695	715
6.0	397	576	596
6.5	358	417	497
7.0	298	377	417

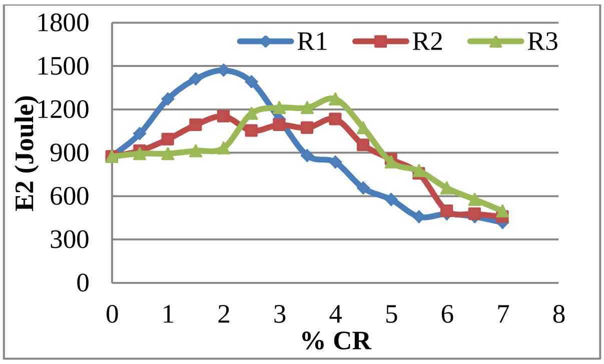
b) Energy consumed at final crack (Joule)
Test results for energy consumed at final crack are as shown in below table 4 and demonstrated in Graph 3.

Table 4 : Impact test results for average energy consumed at ultimate crack (E2)

Percentge of crmb rubber	E2 (Joule)		
	R1	R2	R3
0.0	874	874	874
0.5	1033	914	894
1.0	1271	993	894
1.5	1410	1093	914
2.0	1470	1152	934
2.5	1391	1053	1172
3.0	1132	1093	1212
3.5	880	1073	1212
4.0	834	1132	1271
4.5	656	954	1073
5.0	576	854	834
5.5	457	755	775
6.0	477	497	656
6.5	457	477	576
7.0	417	457	497



Graph 2- Energy consumed at initial crack (Joule)



Graph 3- Energy consumed at final crack (Joule)

Table 5: Energy consumed at ultimate crack to energy consumed at first crack

Percentge of crmb rubber	Ductility index (E2/E1)		
	R1	R2	R3
0.0	1.10	1.10	1.10
0.5	1.04	1.10	1.10
1.0	1.05	1.09	1.07
1.5	1.04	1.08	1.07
2.0	1.04	1.05	1.07
2.5	1.03	1.04	1.09

3.0	1.08	1.08	1.09
3.5	1.00	1.04	1.07
4.0	1.08	1.08	1.07
4.5	1.18	1.09	1.08
5.0	1.21	1.10	1.08
5.5	1.10	1.09	1.08
6.0	1.20	0.86	1.10
6.5	1.28	1.14	1.16
7.0	1.40	1.21	1.19

CONCLUSIONS

Based on experimental study on compressive strength, energy absorption capacity and by literature review following conclusion can be deducted:

1) Use of smaller size waste tire crumb rubber particles gives higher workability
2) The R1 type of crumb rubber concrete give higher value of energy absorption capacity up to 2% replacement of fine aggregate so that it can be used structure which subjected heavy shocks.
3) The R3 type of crumb rubber concrete give good resistant to impact upto 4% replacement of fine aggregate so that it can be useful in structural members and joints where more deflection occurs also in seismic resistant structures.
4) The difference between number of blows for ultimate failure and first crack increases significantly with the increase in replacement level of crumb rubber, which indicates the reduction in brittleness of concrete or increase in ductility of WTCRC.
5) Although the compressive strength of concrete is reduced with increase in crumb rubber content, but it can be overcome by increasing the grade of concrete.
6) The incorporation of crumb rubber to concrete changes the failure pattern from brittle mode to ductile mode.
7) Although the strength of concrete is reduced with increase in crumb rubber content, its lower unit weight meets the criteria of light weight concrete.
8) Crum rubber concrete 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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