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Behavior of "Waste Tyre Crumb Rubber Particle Partially Replaced to Fine Aggregate in Concrete" under impact loading

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Abstract— Day by day the production of tyre increases because of rapid growth of automobile industry. Increase in stockyard of tyre produces environmental mal-effects. Use of waste tyre rubber as aggregate in concrete reduces the harmful effect on surrounding environment and also solves the problem of disposal.

In this study, the waste tyre crumb rubber particle (WTCRP) with three different sizes(R1,R2,R3) are partially replaced to the fine aggregate in concrete with varying percentages from 0.5 % to 7% to check the energy absorption capacity of concrete. It is important in seismic design, shock absorbing structures and structural element where more deflection is occurs. An attempt is made in this paper to cast and test the cylindrical specimen of size 150 mm ø x 50 mm depth made with plane cement concrete and concrete with WTCRP of M_{25} grade. For impact loads with a steel ball drop weight the concrete with different sizes and varying percentages was used. The result shows that , In R1(WTCRP) specimen the energy absorption capacity increases upto 3% crumb rubber(CR) replacement, in R2 specimen it increases upto 4% CR replacement and in R3 specimen it increases upto 5% CR replacement. After these percentages for further increment in CR replacement upto 7% , the energy absorption capacity decreases. From literature review it is concluded that, with increase in rubber content compressive strength of concrete decreases.

.**Keywords**— Plane cement concrete, Waste tyre crumb rubber concrete, Waste tyre crumb rubber particle, Impact Test, Impact Test Apparatus, Energy absorption capacity, Ductility index.

I. INTRODUCTION

The basic material required in construction by using concrete are aggregate, cement and steel. Concrete is the most used material in construction. Dredging of river sand from the river bed causes severe environmental damage. The researchers suggested the use of waste tyre crumb rubber which is available in large amount as alternative to aggregate in concrete because of scarcity of the fine aggregate like natural sand .Many researchers replaced fine aggregate by waste tyre crumb rubber and coarse aggregate by waste tyre rubber chips and mechanical properties are discussed.

II. RESEARCH OBJECTIVES:

Use of waste tyre 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 and ductility index of concrete and to reduce the effect of waste tyre rubber on surrounding environment because it is non-degradable in nature.

III. LITERATURE SUREVEY :

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.al[2] 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.

Raghavan et.al[3] Presented that, mortor specimen's with rubber shreds were able to provide resistances to additional load after peak load. Because of briding of cracks by rubber shreds, the specimens were not break's into two pieces under the failure flexure load, but the specimen with granular rubber particle breaks into two pieces at failure load. It is concluded that post crack strength decreases when granular rubber particle are used and it is increases when rubber shreds are used.

Zhang et.al[4] Reported that, impact resistance and flexural toughness of steel fibre-reinforced lighe weight concrete, and the result shows that for good impact resistance of plain concrete. High density and compressive strength are desirable and also indicate that, use of steel fibers increased the impact resistance.

Gaulias and Ali[5] Found that the dynamic modules of elasticity and rigidity decreased with an increase in the rubber content indicating less stiff and less brittle material.

M.R. Wakchaure et.al[6] Reported that, use of waste tyre crumb rubber particle of size passing through 1.18mm is sieve and retained on 600. It is sieve used in concrete at varying percentages from 0.5% to 2% increases the workability of concrete and also indicated that, use of WTCRP in concrete when compared with similar normal concrete. (In the present investigation an attempt is made to find out energy absorption capacity of WTRAC concrete under impact drop test)

IV. EXPERIMENTAL STUDY:

a) Material:-

In this study opc grade 53 was used for preparing concrete. The specific gravity was 3.14.

b) Fine aggregate:

Naturally occurring river sand passing through 4.75 mm IS sieve was used for concrete categorized under zone II.

c) Coarse aggregate:

Crushed stone aggregates were used for concreting

d) Water:

Clean portable water free from chemical, suspended particle, and biological element etc. was used for concreting.

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). The specific gravity of crumb rubber was 1.14

Fig. 1(a) R_1

Fig. 1(b) R_2

Fig. 1(c) R_3

Fig.1 Different sizes of crumb rubber particle

f) NaoH Treatment:

To enhance the adhesion between waste tyre crumb rubber particle and cement paste rubber particles are immersed in NaOH aqueous solution for 20 minutes and then dried before using in the concrete mix.

g) Concrete mix Design:

Design for M20 grade of concrete with target strength after 28 days of curing was 31.6 Mpa was used for the study. The mix design proportion for 1 m3 concrete is given in the table below.

TABLE NO. 1 CONCRETE MIX PROPORTIONS

Ingredients of concrete	Weight (kg/m^3)	Specific gravity g/cc
Cement	384 Kg	3.15
Natural sand	742 Kg	2.69
Coarse Aggregate	1068 Kg	2.58
Water	192 Kg	1

Replacement of waste tyre crumb rubber particle to the fine aggregate (sand) in concrete was done by mass only.

TABLE NO. 2 CRUMB RUBBER REPLACED TO FINE AGGREGATE IN CONCRETE.

Concrete Batch	Percentage of WTCRP	Ingredients of concrete (kg/m3)				
		Cement	Fine Aggregate	Coarse Aggregate	Crumb Rubber	Water
Three Batches WTCRP of Size R1,R2, R3	0%	384	742.00	1068	0.00	192
	0.5	384	738.29	1068	3.71	192
	1.0	384	734.58	1068	7.42	192
	1.5	384	730.87	1068	11.13	192
	2.0	384	727.16	1068	14.84	192
	2.5	384	723.45	1068	18.55	192
	3.0	384	719.74	1068	22.26	192
	3.5	384	716.03	1068	25.97	192
	4.0	384	712.32	1068	29.68	192
	4.5	384	708.61	1068	33.39	192
	5.0	384	704.9	1068	37.1	192
	5.5	384	701.19	1068	40.81	192
	6.0	384	697.48	1068	44.52	192
	6.5	384	693.77	1068	48.23	192
	7.0	384	690.06	1068	51.94	192

V. TEST SPECIMEN:

To study the impact strength of concrete circular disc specimen of size150 mm diameter and 50mm depth were cast and test was conducted after 28 days of curing by using drop weight impact test equipment. Circular disc specimen of concrete were cast with different groups and with varying percentages of waste tyre crumb rubber particles from 0.5% to 7% and the sizes of crumb rubber particles are R1,R2,R3 .

Three circular disc specimen were cast with normal concrete are referred as control specimen. The other three groups were made of concrete with partial replacement of crumb rubber particles to the fine aggregate in concrete at varying percentages from 0.5% to 7%. In each group for every percentage replacement of crumb rubber 3- disc specimen were cast. For each group total 42 number of specimen were cast and for each mix slump of the concrete was measured. Hallow tubular mould of 150mmø with a depth 50mm was made from PVC pipes. The moulds were placed over hard platform and concrete mix was filled in the mould with proper compaction. After 24 hours specimens were demoulded and kept in curing tank for 28 days.

VI. TEST SETUP:

Equipment was fabricated as per standard recommendations which consist hammer of weight 3.5kg, diameter 6.4cm, length 30.5cm with height of fall 61.5cm and steel ball of weight 0.8kg, diameter 6.25cm.

Fig.2 Impact Test Apparatus

The specimen was placed on the base plate centered exactly below the vertical pipe of diameter 6.5cm, length 92cm and the hardened steel ball was placed on the top of specimen. The hammer was dropped repeatedly and the number of blows required for first visible crack and at ultimate failure was recorded to calculate energy absorption capacity.

The failure modes of specimen for each category of specimen are shown below.

Failure pattern for R1

Failure pattern for R2

Failure pattern for R3

Fig.3 The failure modes of specimens

VII. EXPERIMENTAL RESULTS AND DISCUSSION:

a) Workability:

In this study 0.5w/c ratio was used throughout. Three different batches of concrete were prepared with three different sizes of crumb rubber as R1, R2 and R3 with varying

percentages from 0.5% to 7%. In each batch of concrete slump values were recorded for varying percentages of crumb rubber by slump cone test.

Slump values are given below:

TABLE NO.3 SLUMP VALUES FOR DIFFERENT BATCHES WITH VARYING PERCENTAGES OF CRUMB RUBBER

%CR ⇩ / BATCH ⇨	Slump in mm		
	R_1	R_2	R_3
Normal	75	75	75
0.5%	76	76	76
1.0%	77	76	77
1.5%	78	76	77
2.0%	78	77	79
2.5%	79	77	81
3.0%	79	78	83
3.5%	80	79	84
4.0%	80	80	85
4.5%	80	82	87
5.0%	80	84	89
5.5%	80	86	92
6.0%	81	88	94
6.5%	82	90	96
7.0%	82	92	98

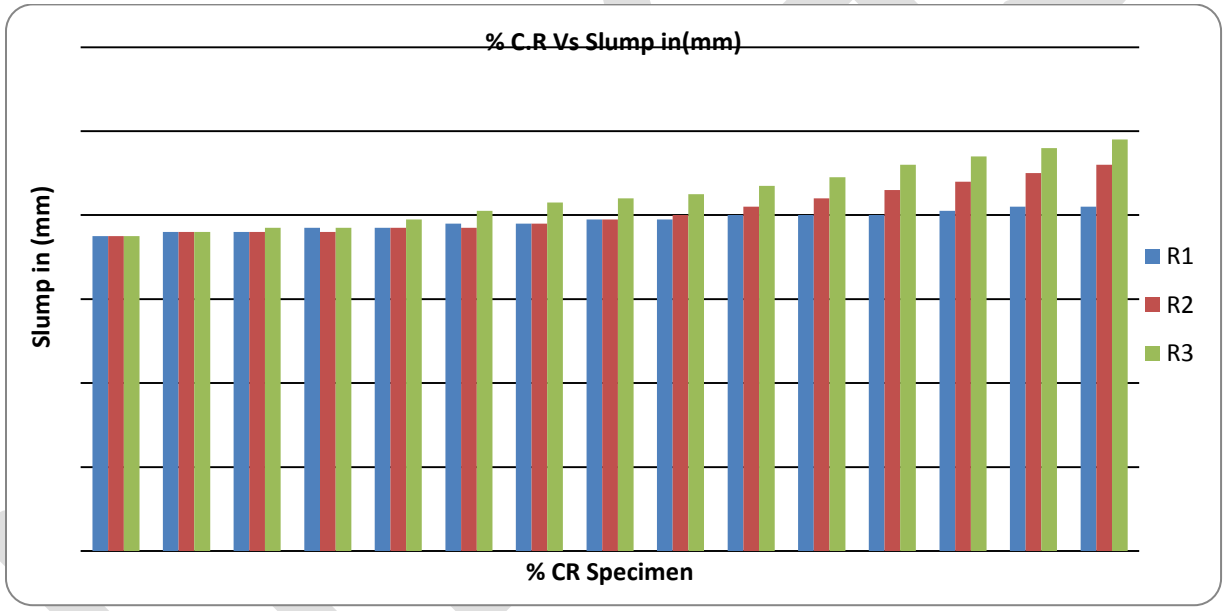

Fig.4 Percentage crumb rubber Vs Slump in mm

It was observed from above result, for higher content of crumb rubber workability of concrete increases and it was also observed that, slump values in R3 batch increased than R1 and R2 batch because of smaller size of crumb rubber particle.

b) Impact strength test:

After workability test by slump cone the impact strength test was carried out after 28 days of curing on cylindrical concrete specimen of dimension 150 mm ø and 50 mm depth by using drop weight impact test apparatus. In this 3.5 kg hammer fall down from height of 61.5 cm and number of blows for first crack and ultimate failure crack when full damage occur were recorded to calculate its energy absorption capacity. The energy absorption capacity was calculated from following equation,

Energy = Weight (N) X Height (m) X No. of Blows

Where,

H = Height of fall of hammer in meter

W= Weight in Newton = Mass (kg) X g (m/sec2)

g = Acceleration due to gravity

The result of impact test is tabulated in table no.4 in this table average of three specimen for each percentage replacement of CR were taken for number of blows and energy consumed.

TABLE NO. 4 IMPACT TEST RESULTS FOR M_{25} GRADE CONCRETE WITH WTCRP

% CR	Average No. of Blows						Average energy consumed (E_1)			Average energy consume (E_2)			Ductility E2/E1		
	Initial			Final			Initial			Final					
0%	35			39			733			817			1.11		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
0.5%	45	37	35	47	41	39	942	775	733	984	859	817	1.04	1.10	1.11
1.0%	56	41	37	59	45	40	1173	859	775	1235	942	838	1.05	1.09	1.08
1.5%	63	46	38	66	49	41	1319	963	796	1382	1026	859	1.04	1.06	1.07
2.0%	66	50	39	68	53	43	1382	1047	817	1424	1110	900	1.03	1.06	1.10
2.5%	66	46	49	69	50	54	1382	963	1026	1445	1047	1131	1.04	1.08	1.10
3.0%	48	47	51	52	49	55	1005	984	1068	1089	1026	1152	1.08	1.04	1.07
3.5%	28	48	52	31	52	56	586	1005	1089	650	1089	1173	1.10	1.07	1.07
4.0%	24	39	55	29	43	59	503	817	1152	607	900	1235	1.20	1.10	1.07
4.5%	23	35	45	28	39	48	482	733	942	586	817	1005	1.21	1.11	1.06
5.0%	18	30	34	20	33	37	377	628	712	419	691	775	1.11	1.10	1.08
5.5%	16	24	31	20	28	34	335	503	649	419	586	712	1.12	1.16	1.15
6.0%	16	20	25	21	24	29	335	419	524	440	503	607	1.31	1.20	1.15
6.5%	10	16	20	14	20	24	209	335	419	293	419	503	1.40	1.25	1.20
7.0%	9	11	14	15	15	18	188	230	293	314	314	377	1.67	1.28	1.20

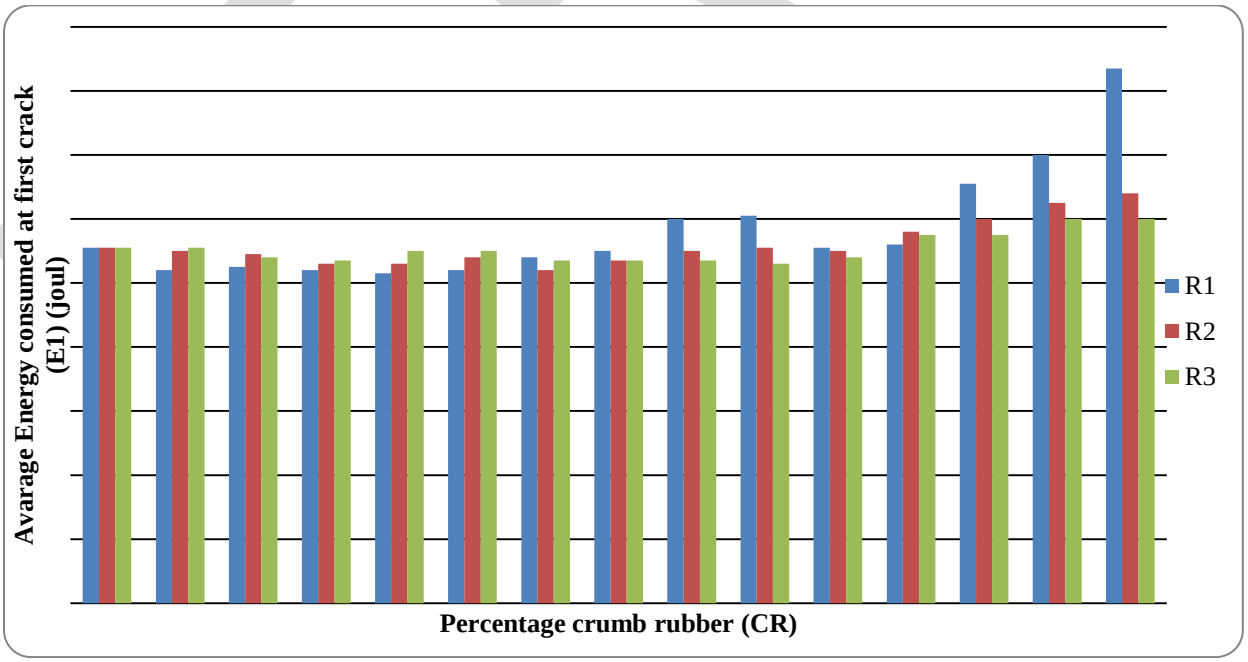

Fig.5 Percentage crumb rubber (CR) Vs Average Energy consumed at first crack (E1) in joul

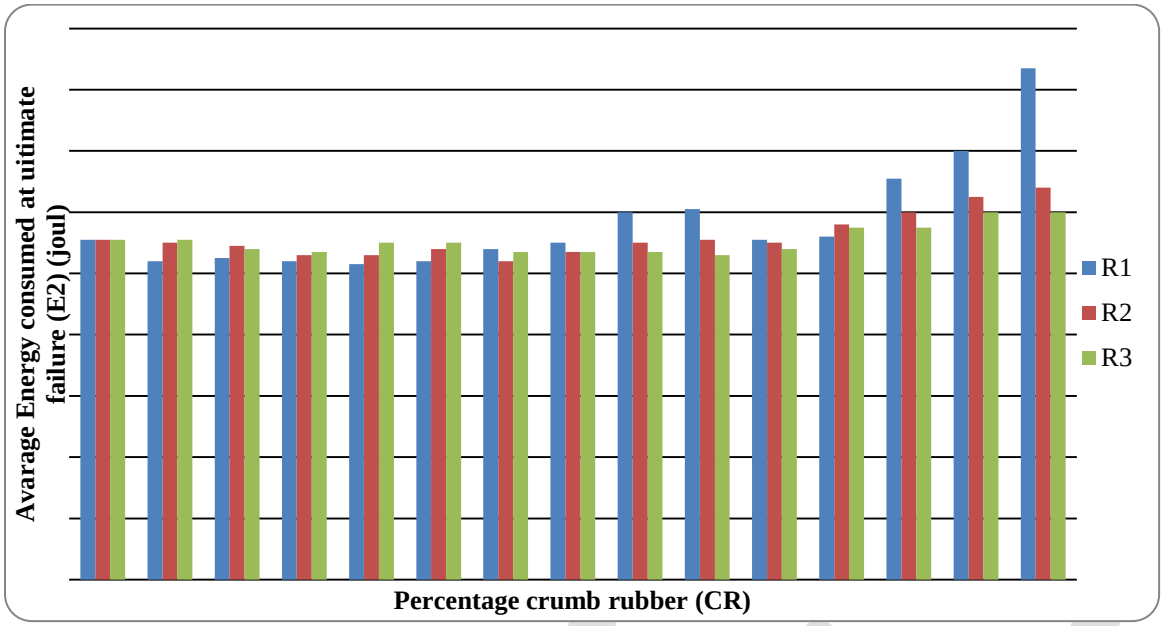

Fig.6 Percentage crumb rubber (CR) Vs Average Energy consumed at ultimate failure (E2) in joul

From the above result of impact test it was observed that, the average energy absorption capacity in R1 specimen increases upto 3% and after that it decreses, in R2 specimen average energy absorption capacity increases upto 4% and after that it decreses and in R3 specimen average energy absorption capacity increases upto 4.5% and after that it decreses upto 7%.

c) Ductility index:

Ductility index is defined as the ratio of energy consumed at failure to the energy consumed at first crack. From the result it was observed that, the ductility indices in R1 specimen increases up to 3 % CR replacement and after that it goes on decreasing, in R2 specimen up to 4 % CR replacement it goes on increasing and after that it decreases and in R3 specimen it increases up to 5% and after that it decreases

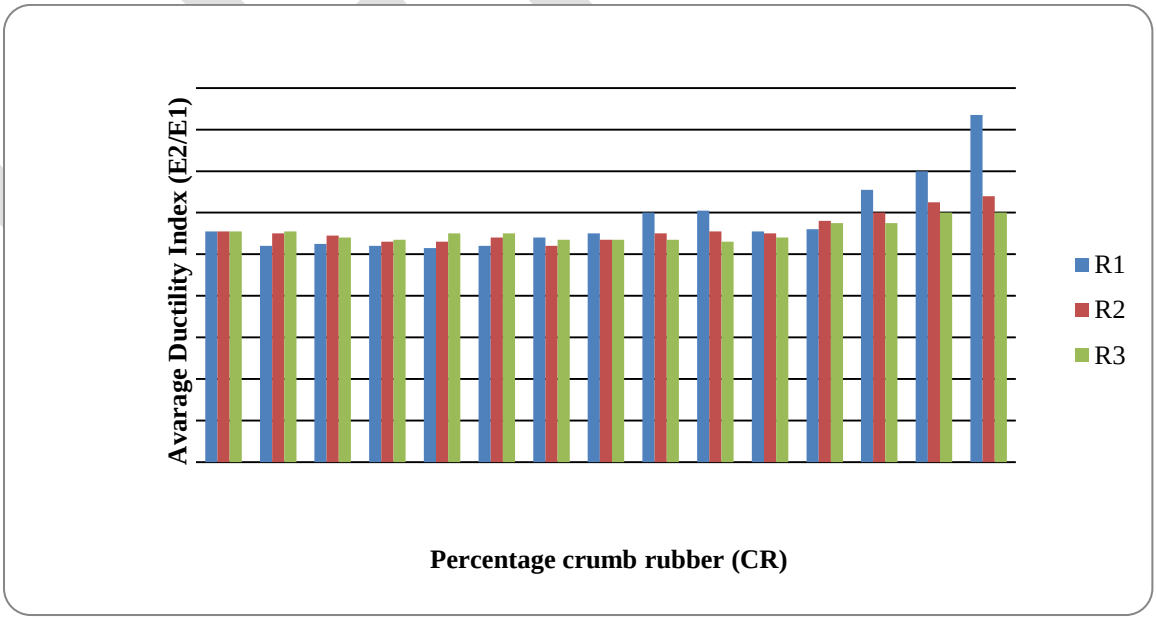

Fig.7 Percentage crumb rubber (CR) VS Ductility Index

VIII. ACKNOWLEDGMENT

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IX. CONCLUSION

This study represents the effect of waste tyre crumb rubber particle of varying sizes at different percentage replacement to the fine aggregate in concrete on impact strength. Based on experimental study on energy absorption capacity and ductility of concrete and by literature review following conclusion can be draw

- Use of smaller size waste tyre crumb rubber particles gives higher workability.
- Use of R1 type concrete gives higher value of energy absorption capacity. It is useful in road pavement or structure which is subjected to heavy shocks.
- Use of R3 type concrete gives good resistant to impact up to 5 % CR replacement. It is useful in structural members and joints where more deflection occurred. Also in seismic resistant structure

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