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Research Paper

BEHAVIOR OF PARTIAL REPLACEMENT OF FINE AGGREGATE WITH CRUMB RUBBER CONCRETE

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Concrete is one of the most widely used construction materials in the world. Cement and aggregate, which are the most important constituents used in concrete production, are then 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 the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources (such as aggregate) by using alternative materials which are recycled or waste materials. In this research, a study was carried out on the use of recycled rubber tires as a partial replacement for fine aggregates in concrete construction using locally available waste tires. The work was carried out by conducting tests on the raw materials to determine their properties and suitability for the experiment. Concrete mix designs are prepared using IS method for M20 grade of concrete. The specimens were cast with percentage replacements of the fine aggregate by 5, 10, 15 and 20% of rubber as fine aggregate. Moreover, control mixes with no replacement of the fine aggregate were cast to make a comparative analysis. The prepared samples consist of concrete cubes, cylinders and beams. Laboratory tests were carried out on the prepared concrete specimens. The lists of tests conducted are slump, compressive strength, split tensile strength and flexural strength tests. The data collection was mainly based on the tests conducted on the prepared specimens in the laboratory.

Keywords: Compressive strength, Flexural strength, Rubberized concrete, Split tensile strength and Workability

INTRODUCTION

Currently, waste materials resulting from various physical and chemical processes are the most important challenge in the industrial and developing countries. Extensive investigations on wastage recycling are being implemented to minimize the environmental damages. In this regard, construction investigators, like other recycling and production industries, have also achieved advances in using these waste materials. One

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of the non-recyclable materials enters the environment in automotive used tires.

Investigations show that used tires are composed of materials which do not decompose under environmental conditions and cause serious contaminations. It is estimated that 285 million tires are discarded annually in the United States and only 30% (97 million) are currently being used or recycled. The remaining 66% (188 million) contribute to the already alarming environmental waste problem. Based on examinations, another way is used the tires in concrete. This results in the improvement of such mechanical and dynamical properties as energy absorption, ductility and resistance to cracking. The replacement of fine aggregate with rubber particles may significantly comprise the compressive strength characteristic of concrete, localizing stresses and bonding problems between the rubber particles and the cement matrix.

CLASSIFICATION OF SCRAP TIRES

Scrap tires can be managed as a whole tire, as slit tire, as shredded or chopped tire, as ground rubber or as a crumb rubber product.

Slit Tires

These are produced in tire cutting machines. These machines can slit the tire into two halves or can separate the sidewalls from the tread of the tires.

Shredded or Chipped Tires

Tire shreds or chips involve primary and secondary shredding. The size of the tire shreds produced in the primary shredding process can vary from as large as 300 to 460 mm long by 100 to 230 mm wide, down to as small as 100 to 150 mm in length, depending on the manufacturer's model and condition of the cutting edges. Production of tire chips, normally sized from 76 mm to 13 mm, requires both primary and secondary shredding to achieve adequate size reduction.

Ground Rubber

Ground rubber may be sized to particles as big as 19 mm to as small as 0.15 mm. It depends upon the type of size reduction equipment and intended applications. Ground rubber particles are subjected to a dual cycle of magnetic separation, then screened and recovered in various sizes.

Crumb Rubber

It is the processing of the tire into fine granular or powdered particles using mechanical or cryogenic processes. The steel and fabric component of the tires are also removed during this process. Crumb rubber consists of particles ranging in size from 4.75 mm to less than 0.075 mm. Generally, these methods are used to convert scrap tires into crumb rubber. These methods are (i) cracker mill process, (ii) granular process, and (iii) micro mill process.

The cracker mill process tears apart or reduces the size of tire rubber by passing the material between rotating corrugated steel drums. By this process an irregularly shaped torn particles having large surface area are produced. The sizes of these particles vary from 5 mm to 0.5 mm and are commonly known as ground crumb rubber. Granular process shears apart the rubber with revolving steel plates, producing granulated crumb rubber particles, ranging in size from 9.5 mm to 0.5 mm.

MATERIAL INVESTIGATION

Ordinary Portland Cement (OPC)

Ordinary Portland cement is hydraulic cement. It is used in the making of concrete with property of setting and hardening, of which when the chemical properties react with water. OPC does not disintegrate in water as it sets and hardens in water in order to achieve the desired setting qualities in the finished product, a small quality of gypsum is added to the clinker and the mixture is finely ground to form the finished cement powder. Locally available 53 grade of cement used and their physical properties are presented in Table 1.

Fine Aggregate

Locally available free of debris and nearly riverbed sand is used as fine aggregate. Among various characteristics, the most important one is its grading coarse may be preferred as fine aggregate, increase the water demand of concrete and very fine sand may not be essential as it usually has larger content of thin particles in the form of cement. The sand particles should also pack to give minimum void ratio, higher voids content lead to requirement of more mixing water. Properties such void ratio, gradation specific surface and bulk density have to be assessed with optimum cement content and reduced mixing water. The physical properties are tested in the laboratory and presented in Table 2.

Coarse Aggregate

Coarse aggregate is chemically stable material in concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring an account of movement of moisture. Coarse aggregate contributes to impermeability of concrete, provide that is properly graded and the mix is suitably designed. Coarse

Table 1: Properties of Cement

S. No.	Description	Values	Remarks
1	Consistency	30%	Tested results are satisfactory
2	Initial setting time	45 minutes	
3	Final setting time	190 minutes	
4.	Specific gravity	3.25	
5.	Fineness of Cement	3%	
6.	Compressive strength of mortar cube at the		
	age of 3 days	29.8 N/ mm^2	
	age of 7 days	41.2 N/ mm^2	

Table 2: Properties of Fine Aggregate		
S. No	**Test analysis**	**Experimental Value**
1	Fineness modulus	3.2
2	Specific gravity	2.64
3	Bulk density	1.39
4	% of voids in sand	47.3

aggregate is conventional concrete contributes to the heterogeneity of the cement concrete and there is weak interface between cement mix and aggregate surface in conventional concrete. By restricting the maximum size of aggregate and cement becomes more homogeneous and there is a marked enhancement in the strength properties as well as durability characteristics of concrete. The physical properties are presented in Table 3.

Table 3: Properties of Coarse Aggregate		
S. No	**Test analysis**	**Experimental Value**
1	Fineness modulus	3.8
2	Specific gravity	2.58
3	Bulk density	1.41

Crumb Rubber

The tire rubber used in the experiments was applied in the following two size grading and it was obtained from Alagu Rubber Factory, Tutucorin. Crumb rubber for the replacement of fine aggregate in concrete. The size of the crumb rubber used is 20 meshes and presented in Figure 1. The physical properties of crumb rubber in Table 4.

Figure 1: Crumb Rubber

Crumb Rubber

Crumb Rubber Used in Concrete Mix

Table 4: Properties of Crumb Rubber		
S. No.	**Property**	**Tyre Rubber**
1	Specific gravity	1.16
2	Unit weight (Kg/m^3)	1150
3	Tensile strength	2000 Kg/cm^2
4	Elongation at break (%)	800
5	Water absorption	Small
6	Swelling in organic solvents	Large
7	Tackiness	Light
8	Useful temperature range	-40-100°C
9	Chemical resistance	much better
10	Elasticity	depends on °

EXPERIMENTAL INVESTIGATION

There were five type of mix considered of which one control mixture (without rubber) was designed as per Indian Standard Specification IS: 10262-2009 (1:1.46:3.09 W/C ratio = 0.5) to achieve target mean strength 27.6 MPa. The other four concrete mixes were made by replacing the fine aggregates with 5%, 10%, 15%, 20% for M20 grade concrete. The proportion of mix ingredients for 1m^3 of concrete are tabulated in Table 5.

Specimen Preparation and Testing

In order to prepare the recycled crumb rubber concrete specimens, fine aggregates were replaced by waste materials of crumb rubber in several percentages (0%, 5%, 10%, 15% and 20%) in separate concrete mixes.

The sand used was cleaned from all inorganic impurities and passed through 2.36 mm sieve and retained on 150 micron. For each mix, cubes of 150 x 150 x 150 mm, cylinders of 150 mm diameter by 300 mm height, and small beams of 100 x 100 x 500 mm were prepared. All specimens were fabricated and then cured in water for 7 and 28 days in accordance with Indian standard 10262. For each concrete mix, slump tests were performed and recorded at the casting time of specimens. After 24 hours of casting cubes, beams and cylinders were taken out from the mould and then submerged in water tank for curing. All tests were carried out at Krishnasamy College of Engineering and Technology, Cuddalore. Samples were weighed before testing in the compression testing machine (CTM) of 2000 kN. The load was applied until failure and the crushing load was noted.

Compressive strength = Crushing load/ Effective are

Experimental Program

A total of 30 specimens of cube, cylinder and beam were prepared with M20 mix for this study with 5, 10, 15, 20% of replacement of fine aggregate with crumb rubber.

Test on Fresh Concrete

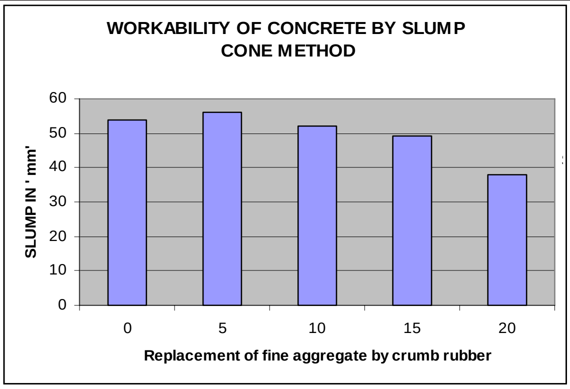
Workability

The slump factor is used to measure the horizontal free flow known as workability of concrete. The test has been carried out for M20 grade concrete and results are shown in Figure 2. From the illustration it has been identified all the rubber replaced with fine aggregate might behaved very close to the flow

Table: 5 Proportions of Mix Ingredients (For 1 m^3 of Concrete)

Crumb Rubber Replacement(%)	Cement (kg)	Crumb Rubber (kg)	Fine aggregate (kg)	Coarse Aggregate (kg)
0	2.848	-	4.159	8.802
5	2.848	0.207	3.950	8.802
10	2.848	0.416	3.743	8.802
15	2.848	0.624	3.535	8.802
20	2.848	0.832	3.327	8.802

Figure 2: Slump Factor for M20 Concrete with Various Rubber Replacement



of conventional concrete. Hence, it is preferred to make use of workability factor of 0.50 for M20 grade concrete from graphical representation.

Tests on Hardened Concrete

Compressive Strength

The specimens of size 150 x 150 x 150 mm for the various mix proportion for 5%, 10%,15% and 20% replacement of aggregate with rubber. The casted cubes are kept for curing for 7 days and 28 days. Then the cubes are tested in compression testing machine of capacity 2000 kN for both 7 and 28 days and results are presented in Table 6.

Table 6: Results of M20 Grade Concrete Average Compressive Strength

Cube Notation (%)	Compressive Strength N/Mm^2	
	7 Days	28 Days
0	25.33	32.43
5	19.15	26.56
10	13.44	21.94
15	9.88	9.69
20	8.39	8.01

A gradual reduction of the compressive strength can be observed. This was caused by the increased porosity or weakness points in the concrete mix. Due to a lack of bonding between rubber particles and the cement paste applied stresses are not uniformly distributed in the paste. As cement paste containing rubber particles surrounding the aggregates is much softer than hardened cement paste without rubber, the cracks would rapidly develop around the rubber particles during loading and causing rupture in the concrete.

Figure 3: Compressive Strength Test for Cubes

Split tensile Strength

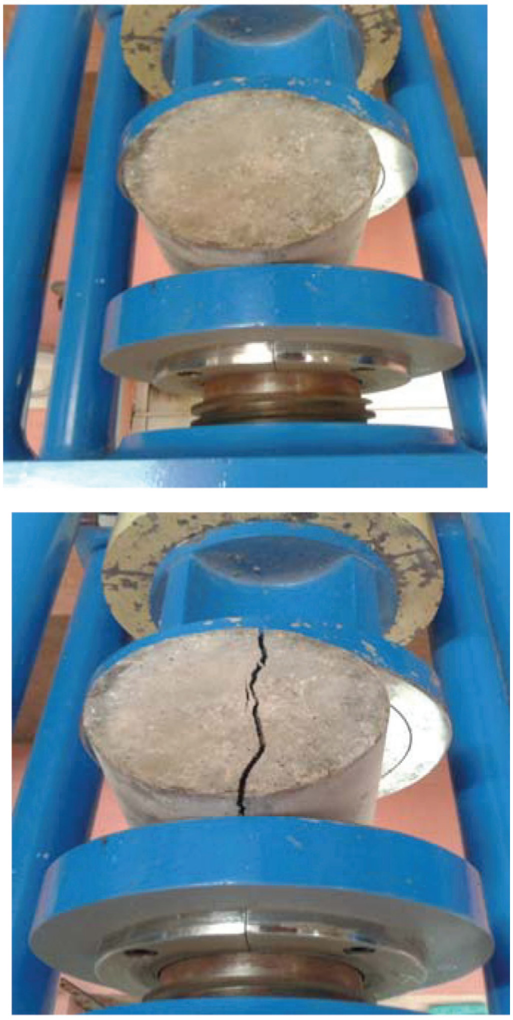
The split tensile test is done with a cylinder of size 150 mm diameter and 300 mm length specimens with 5%, 10%,15%, 20% replacement of fine aggregate with crumb rubber concrete mix. The cylinder is kept curing for 7 and 28 days. After curing the specimens are tested in compressive testing machine. Load is applied along the length and the load which the cylinder splits into two halves is noted. The split tensile stress is calculated using formula 2P/pDL where, P is load, L is the length of cylinder and D is diameter of cylinder and results are presented in Table 7.

Tensile strength of concrete was reduced with increased percentage of rubber replacement in concrete. The most important reason being lack of proper bonding between rubber and the paste matrix, as bonding plays the key role in reducing tensile strength carried out with cube specimen to find out the compressive strength of conventional and rubber replaced concrete using compression testing machine as presented in Figure 4.

Table 7: Results of M20 Grade Concrete Average Split Tensile Strength

Cylinder Notation	Compressive Strength N/Mm^2	
	7 Days	28 Days
Conventional	1.697	2.630
5	1.543	2.462
10	1.432	2.134
15	1.216	1.855
20	1.138	1.734

Figure 4: Split Tensile Strength Test for Cylinders



Flexural Strength

The flexural strength test was used to determine the flexural strength of concrete. The test was performed on prisms of dimensions 100 x 100 x 500 mm (Figure 5). Cured for 7 and 28 days by immersing under water. After 28 days the flexural strength was determined by the two point loading technique, computed by using the expression Fb = PL/bd2, where Fb is the flexural strength in MPa, P is the maximum load applied in N, L is the span length in m, b is the width of specimen in mm, and d is the depth of the specimen in m. The test is carried out with beam specimen to find out the flexural strength of conventional and rubber replaced concrete using flexural testing machine and the results are tabulated in Table 8.

Figure 5: Flexural Strength Test for Beams

Table 8: Results of M20 Grade Concrete Average Flexural Strength

Cube Notation	Compressive Strength N/Mm^2	
	7 Days	28 Days
Conventional	2.862	4.400
5	2.586	3.982
10	1.577	2.433
15	0.875	1.890
20	0.732	1.724

RESULTS AND DISCUSSION

For M20 grade of concrete when rubber replacement increases the compressive strength decreases. The performance of rubber replaced concrete is quite encouraging up to 10%. The tensile strength follows the same pattern of compressive strength. The decrease in the strength is due to non polar action of the rubber particles which attract air and repels water. The split tensile strength of the concrete decreases about 30% when 20% sand is replaced by crumb rubber. Failure of plain and rubberized concrete in compression and split tension shows that rubberized concrete has higher toughness.

CONCLUSION

Based on the above test results concluded the following:

1. Compressive strength decreases when the percentage of replacement of crumb rubber increases.
2. Split tensile strength decreases at the maximum of 25% when crumb rubber replaces upto 10% in fine aggregate.
3. Flexural strength of concrete increases when rubber crumbs increases upto 10%
4. It is identified that the grade of concrete plays the major role in the ductility performance of rubber replaced concrete.
5. Rubberized concrete showed ability at absorb a large amount of plastic energy and did not show brittle failure under compression or split tension loading.

6. 5% replacement of crumb rubber proves exceptionally well in compression, tensile and flexural strength and follow the curvature of the conventional specimens all the tests in M20 grade of concrete.
7. Finally by replacing fine aggregate by crumb rubber safeguard the environment.

REFERENCES

1. Manigandan H and Pannirselvam N (2011), "Evaluation of chloride ion permeability on chipped and crumb rubber concrete", Proceedings of the *National conference on advances in Earthquake resistant design and construction techniques*, pp. 140-150.
2. Mohammad Reza Sohrabi and Mohammad Karbalaie (2011), "Experimental study on compressive strength of concrete containing crumb rubber", *International Journal of Civil & Environmental Engineering IJCEE-IJENS*, Vol. 11, No. 3.
3. Senthil Vadivel T and Thenmozhi R (2012), "Experimental study on waste tyre rubber replaced concrete", *Journal of Applied Sciences Research*, Vol. 8, No. 6, pp. 2966-2973.
4. Tarun R Naik and Rafat Siddique (2002), "Properties of Concrete Containing scrap Tire Rubber – An Overview" Report No. CBU-2002-06 REP-459.
5. El-gammal A K Abdel-gawad and A Shalaby (2010), "Compressive strength of concrete utilizing waste tyre rubber concrete", *Journal of Emerging Trends in Engineering and Applied Sciences* (JETEAS), Vol. 1, No. 1, pp. 96-99.
6. Panda K C, Parhi P S and Jena T (2012), "Scrap-Tyre-Rubber Replacement for Aggregate in Cement Concrete: Experimental Study", *International Journal of earth and science Engineering* ISSN 0974-5904, Vol. 05, No. 06.
7. Parveen, Sachin Dass and Ankit Sharm (2013), "Rubberized Concrete: Needs of Good Environment (Overview)", *International Journal of Emerging Technology and Advanced Engineering* ISSN 2250-2459, ISO 9001:2008 *Certified Journal,* Vol. 3.
8. Mohd Mustafa Al BakriA, Syed Nuzul Fadli S A, Abu Bakar M D and Leong K W (2007) "Comparison of rubber as aggregate and rubber as filler in concrete", 1st *International Conference On Sustainable Materials* 2007_ICoMS.
9. Senthil Kumaran G, Nurdin Mushule and Lakshmipathy M (2008), "A review on construction technologies that enables environmental protection: rubberized concrete", *American Journal of Engineering and Applied Sciences,* Vol. 1, No. 1, pp. 40-44.
10. Eshmaiel Ganjian, Morteza Khorami, and Ali Akbar Maghsoudi (2009), "Scrap-tyre rubber replacement for aggregate and filler in concrete", *Construction and Building Materials,* Vol. 23, pp. 1828-1836.
11. Mahmut Ekenel and John J Myers (2009), "Use of recycled rubber tires as a partial

replacement for coarse aggregate in concrete construction", *Construction and Building Materials,* Vol. 24, pp. 2043-2051.

12. Barris C , Ll Torres, Turon A and Baena M (1994), "Investigation of crumb rubber concrete for blast", *Cement & Concrete Composites,* Vol. 16, pp. 287-298.

13. Erhan Gu neyisi, Mehmet Gesog lu and Turan O Zturan (2007), "Properties of rubberized concretes containing silica fume", *Cement and Concrete Research*, Vol. 34, pp. 2309-2317.

14. Toutanji H A (1996), "The use of Rubber Tire particle in concrete to replace mineral aggregates", *Cement & Concrete Composites,* Vol. 18, pp: 135-139 .

15. Piti Sukontasukkul (2008), "Use of crumb rubber to improve thermal and sound properties of pre-cast concrete panel", *Construction and Building Materials,* Vol. 23, pp. 1084-1092.