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Original Research Paper

Experimental Behaviour of Concrete with Waste Tyre Rubber as Coarse Aggregate

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ABSTRACT

In recent years waste handling and management is the primary issue faced by countries all over the world. It is very challenging and hectic problem that has to be tackled in an indigenous manner. On the basis of statistical data provided by the Environmental Protection Agency (EPA) 270,000,000 millions waste tyres are produced each year. The disposal of the waste tyres in landfills is a major issue handled by the local municipalities and government sectors. The statistical study gives an estimate that within the next decade the majority of the landfills used for the waste tyre disposal shall be closed and this poses the problem of need for lands for waste dumping. This new problem gave an idea of recycling of waste tyres instead of filling them in bare lands. Recycling of waste is a process adopted by any industry for efficient resource management. The discharge of waste tyres into expensive and the continuously decreasing numbers of landfills generates significant pressure to the local bodies identifying the potential application for these waste products. In this paper an experimental study is conducted to analyse the behaviour and failure characteristics of rubberized concrete where waste tyre rubber is partially replaced with coarse aggregate.

INTRODUCTION

Resource handling is the basic requisite for the proper functioning of any industry. Even though demand forecasting of the raw materials proves to be a preventive measure to avoid delay in the production, there are lots of other factors that disturb the normal functioning. The non-availability of sufficient raw materials and high transportation cost incurred in purchasing the same, the residue disposal provokes any industrialist to go for methods of recycling the waste obtained after the process. The optimal use of the resources has also added up to the adoption of recycling segment in an industry. Land filling of this non-degradable waste tyre rubber leads to reduction of water table and causes drought. The other ill effects are depletion of fertility of the soil and charring of rubber waste releases toxic gases like monoxides of carbon and dioxides of sulphur, which promotes global warming. These are the main factors that promote recycling of waste materials.

A large number of research papers based on solid waste policy and management have appeared in the published literature during the past decade. This research project investigates the use of certain waste products (e.g., tyres) in various aspects of construction. There has been a number of rubberized asphalt projects developed in all the corners of civil engineering. These projects can be characterized as dry process, wet process, trickle method, asphalt rubber technology, and rubber systems in road rehabilitation. There is very rare literature on usage of tyre rubber as a construction material in reinforced concrete elements. Amirkhanian & Arnold (2001) has tested the use of crumb rubber-asphalt concrete in road pavement at several areas to determine the economic and engineering feasibilities of these materials. The major objectives of the research study were to develop test procedures, specifications and construction methods for construction of rubberized asphalt mixes, and to monitor the test field section. They concluded that the road section paved using wet process has been performing satisfactorily to this point. The test result coring that it indicates the asphalt rubber mixture is producing higher wet indirect tensile strength and tensile strength ratios than control mixture. Fairburn & Larson (2001) investigated the use of concrete derived from shredded rubber from old tyres for resurfacing a cracked pavement. He found that the concrete was more slip resistant, highly elastic, lighter in weight, and could be used for fireproofing and insulation. Goulias & Ali (1998) used the granulated tyres as elastic aggregate with Portland cement modifying the brittle failure of concrete and increasing its ability to absorb higher amounts of energy during failure. The objective of the study is to evaluate the effects of rubber aggregate on Portland cement concrete properties. Results showed large deformation without full disintegration of concrete. Eldin & Senuci (2002) investigated the potential benefits of using rubber aggregate in Portland cement concrete and showed the ability of concrete to absorb large deformation. There is no literature that the waste tyre rubber used as

Table 1: Specific gravity test for sand and 20 mm metal.

S. No.	Observation	Results
1	Specific gravity for the cement	3.14
2	Specific gravity of sand	2.54
3	Specific gravity of 20 mm metal	2.54
4	Fineness modulus of Sand	2.38
5	Fineness modulus of metal	4.16
6.	Workability of concrete	0.84 CF

Table 2: Mix proportion for the concrete cube specimen.

S.No.	Grade of Concrete	Target Mean Strength (N/mm^2)	Water	Cement
1	M20	26.60	0.50	1:1.43:3.03
2	M25	31.60	0.45	1:1.21:2.71

Table 3: Rubber replacement details.

S.No.	Grade of Concrete	Replacement of rubber by percentage	Notations	Total quantity of coarse aggregatein (kg)	Quantity of coarse aggregate (kg)	
					20 mm metal	Rubber
1.	M20	0	R	151.24	151.24	00.00
		2	R1	151.24	148.22	03.02
		4	R2	151.24	145.19	06.05
		6	R3	151.24	142.17	09.07
		8	R4	151.24	139.14	12.10
		10	R5	151.24	136.12	15.12
2.	M25	0	R	135.32	135.32	00.00
		2	R1	135.32	132.61	02.71
		4	R2	135.32	129.91	05.41
		6	R3	135.32	127.20	08.12
		8	R4	135.32	124.49	10.83
		10	R5	135.32	121.79	13.53

Table 4: Specimen details.

Grades	Notations	7 Days	14 Days	28 Days
M20	Conventional	3	3	3
	R2	3	3	3
	R4	3	3	3
	R6	3	3	3
	R8	3	3	3
	R10	3	3	3
M25	Conventional	3	3	3
	R2	3	3	3
	R4	3	3	3
	R6	3	3	3
	R8	3	3	3
	R10	3	3	3
Total (36 + 36 + 36 = 108)		36	36	36

replacement for coarse aggregate in concrete. This experimental study proposes to attempt to evaluate the behaviour and failure characteristics of a concrete specimen replacing waste tyre rubber as coarse aggregate in different percentage by weight for different mix proportions.

MATERIAL INVESTIGATION

Material selection, utilization and effective management become the major part in any research work. So, it requires investigate and categorize material. In general, primary components, which are used in combination for casting the test specimen such as cement, fine and coarse aggregate, water and waste tyre rubber, need to be tested to find out their properties such as fineness modulus, specific gravity, workability, etc. The results of the tests are given in Table 1.

Physical properties of waste tyre rubber: Properties of scrap tyre rubber specimen 10-25 mm thick are given below.

Specific gravity (g/cc)	=	1.14 + 0.02
Tensile strength (kg/cm^2)	=	35 (minimum)
Elongation at break	=	200% or 2 L
Hardness shore	=	59 + 3
Mooney viscosity at 100°C	=	25 to 55

MIX DESIGN

Mix design is the process of selecting and determining the relative proportions of materials with the object of producing concrete of certain minimum strength and durability as economically as possible. The main objective is to stipulate the minimum strength and durability. Mix design was carried out as per Indian Standard Code Method (IS 10262 – 1982) for the test specimen. Mix proportion for the concrete cube specimen is given in Table 2.

REPLACEMENT RATIO SELECTION

The next step is to select the replacement of waste tyre rubber instead of coarse aggregate and decided accordingly by

Fig. 1: Waste tyre rubber replaced for coarse aggregate.

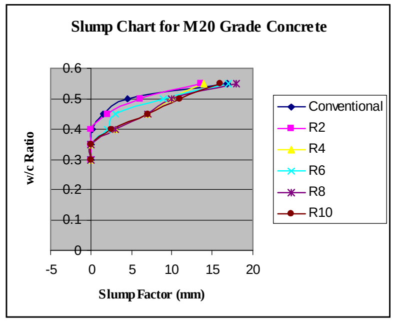

Fig. 2: Slump factor for M20 concrete with various rubber replacements.

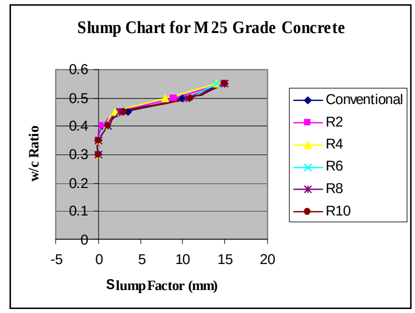

Fig. 3: Slump factor for M25 concrete with various rubber replacements.

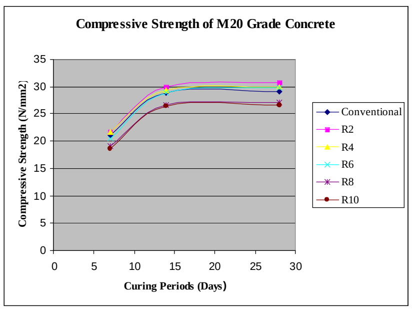

Fig.4: M20 grade concrete compressive strength.

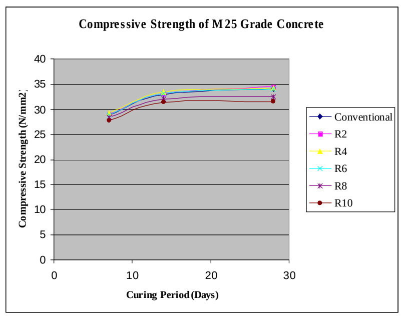

Fig.5: M25 grade concrete compressive strength.

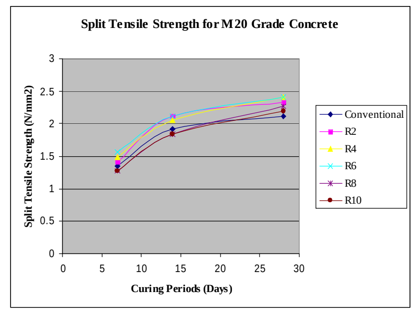

Fig. 6: M20 grade concrete split tensile strength.

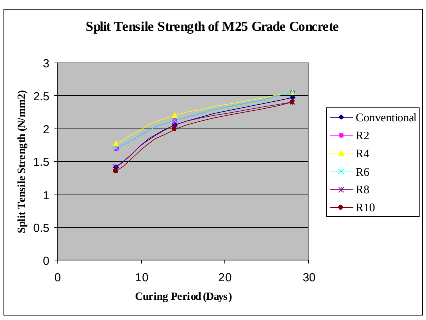

Fig. 7: M25 Grade concrete split tensile strength.

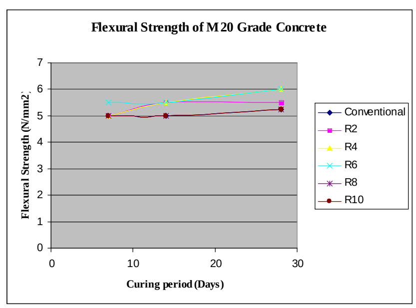

Fig.8: M20 Grade concrete flexural strength.

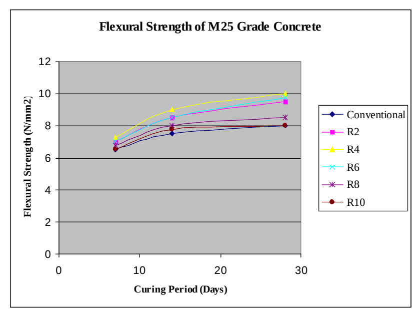

Fig.9: M25 Grade concrete flexural strength.

weight. Table 3 shows various replacements of waste tyre rubber with coarse aggregate by weight. Rubber is replaced as 2, 4, 6, 8 and 10 % in each grade with coarse aggregate. Fig. 1 shows waste tyre rubber for replacement as coarse aggregate.

TEST SPECIMEN CASTING

The test specimens were cast in two different mix proportions of M20 and M25 grade by weight with water cement ratios of 0.50 and 0.45 respectively. The sizes of the specimens were: cube 150 × 150 × 150 mm, cylinder 150 × 300 mm and beam mould 100 × 100 × 500 mm. The moulds were placed on an even surface and the materials were mixed in mixer machine. First, coarse aggregate and fine aggregate were added and mixed thoroughly in a dry condition, and then cement and water were added to get fresh concrete mix. Compaction was done for all the specimens using vibrating table. The mould is striped after 24 hours. The test specimens were cured for 7 days, 14 days and 28 days in a curing tank.

EXPERIMENTAL INVESTIGATION

A Total of 108 cubes, cylinders and beams were prepared with M20 and M25 mix for this study with 2, 4, 6, 8 and 10% of replacement of waste tyre rubber with coarse aggregate. The specimen details are given in Table 4.

Slump factor: The slump factor is used to measure the horizontal free flow of concrete. The test has been carried out for both M20 and M25 grade concrete and results are shown in Figs. 2 and 3. From the illustration it has been identified

Table 5: Results of M20 grade concrete average compressive strength.

S. No.	Cube Notation	7 Days Specimen		14 Days Specimen		28 Days Specimen	
		Collapse Load (KN)	Compressive Strength (N/mm^2)	Collapse Load (KN)	Compressive Strength (N/mm^2)	Collapse Load (KN)	Compressive Strength (N/mm^2)
1	Conventional	475	21.11	650	28.89	655	29.11
2	R2	490	21.78	675	30.00	690	30.67
3	R4	490	21.78	660	29.33	675	30.00
4	R6	460	20.44	650	28.89	670	29.78
5	R8	430	19.11	600	26.67	610	27.11
6	R10	420	18.67	595	26.44	600	26.67

Table 6: Results of M25 grade concrete average compressive strength.

S. No.	Cube Notation	7 Days Specimen		14 Days Specimen		28 Days Specimen	
		Collapse Load (KN)	Compressive Strength (N/mm^2)	Collapse Load (KN)	Compressive Strength (N/mm^2)	Collapse Load (KN)	Compressive Strength (N/mm^2)
1	Conventional	650	28.89	740	32.89	765	34.00
2	R2	652	28.98	745	33.11	775	34.44
3	R4	656	29.16	750	33.33	770	34.22
4	R6	650	28.89	745	33.11	765	34.00
5	R8	640	28.44	720	32.00	730	32.44
6	R10	625	27.78	705	31.33	710	31.56

Table 7: Results of M20 grade average split tensile strength.

S. No.	Cylinder Notation	7 Days Specimen		14 Days Specimen		28 Days Specimen	
		Collapse Load (KN)	Tensile Strength (N/mm^2)	Collapse Load (KN)	Tensile Strength (N/mm^2)	Collapse Load (KN)	Tensile Strength (N/mm^2)
1	Conventional	95	1.34	135	1.91	150	2.12
2	R2	100	1.42	150	2.12	165	2.34
3	R4	105	1.49	145	2.05	170	2.41
4	R6	110	1.56	150	2.12	170	2.41
5	R8	90	1.27	130	1.84	160	2.26
6	R10	90	1.27	130	1.84	155	2.19

Table 8: Results of M25 grade average split tensile strength.

S. No.	Cylinder Notation	7 Days Specimen		14 Days Specimen		28 Days Specimen	
		Collapse Load (KN)	Tensile Strength (N/mm^2)	Collapse Load (KN)	Tensile Strength (N/mm^2)	Collapse Load (KN)	Tensile Strength (N/mm^2)
1	Conventional	100	1.42	145	2.05	175	2.48
2	R2	120	1.70	150	2.12	180	2.55
3	R4	125	1.77	155	2.19	180	2.55
4	R6	120	1.70	150	2.12	180	2.55
5	R8	100	1.42	145	2.05	170	2.41
6	R10	95	1.34	140	1.98	170	2.41

Table 9: Results of M20 grade of average flexural strength.

S. No.	Beam Notation	7 Days Specimen Collapse Load (KN)	7 Days Specimen Flexural Strength (N/mm^2)	14 Days Specimen Collapse Load (KN)	14 Days Specimen Flexural Strength (N/mm^2)	28 Days Specimen Collapse Load (KN)	28 Days Specimen Flexural Strength (N/mm^2)
1	Conventional	10	5	10	5	10.5	5.25
2	R2	10	5	11	5.5	11	5.5
3	R4	10	5	11	5.5	12	6
4	R6	11	5.5	11	5.5	12	6
5	R8	10	5	10	5	10.5	5.25
6	R10	10	5	10	5	10.5	5.25

Table 10: Results of M25 grade of average flexural strength.

S. No.	Beam Notation	7 Days Specimen Collapse Load (KN)	7 Days Specimen Flexural Strength (N/mm^2)	14 Days Specimen Collapse Load (KN)	14 Days Specimen Flexural Strength (N/mm^2)	28 Days Specimen Collapse Load (KN)	28 Days Specimen Flexural Strength (N/mm^2)
1	Conventional	13	6.5	15	7.5	16	8
2	R2	14	7	17	8.5	19	9.5
3	R4	14.5	7.25	18	9	20	10
4	R6	14	7	17	8.5	19.5	9.75
5	R8	13.5	6.75	16	8	17	8.5
6	R10	13	6.5	15.5	7.75	16	8

that all the rubber replaced with coarse aggregate concrete might behave very close to the flow of conventional concrete. Hence it is preferred to make use of workability factor 0.50 for M20 Grade and 0.45 for M25 grade concrete from the graphical representation.

Compressive strength: The compression test is carried out with cube specimens to find out the compressive strengths of conventional and rubber replaced concretes using compression testing machine and the results are given in Tables 5 and 6, and Figs. 4 and 5.

SPLIT TENSILE STRENGTH

The split tensile test has been carried out and comparative results of conventional and rubber replaced concretes are given in Tables 7 and 8 and Figs 6 and 7.

FLEXURAL STRENGTH

The beam specimens were tested in flexural testing machine to compare the results of conventional and rubber replaced concretes and the results are given in Tables 9 and 10 and Figs. 8 and 9.

RESULTS AND DISCUSSION

From the comparison of various percentages of coarse aggregate replacement with waste tyre rubber and conventional concrete, it is clearly found that all the replacements prove higher ultimate compressive strengths than that of target mean compressive strength of both M20 and M25 grade concrete. The rubber replacements of 2, 4, and 6% show higher ultimate compressive strength compared with conventional concrete of both the grades of concrete. 10% replacement of rubber shows very minor deviation compared with conventional concrete i.e., 8.38% in M20 grade and 7.18% in M25 grade concrete that will not create any harm to the structure.

Accordance with the comparison of split tensile strength in M20 grade, all the percentages of replacements of tyre rubber with coarse aggregate confirm higher strength than that of conventional concrete specimens. In M25 grade, 2, 4 and 6% replacements prove higher strength, and 8 and 10% show very minor deviation of 2.82% than the conventional concrete.

The flexural strength comparison in both the grades indicate that 2, 4 and 6% replacements behave exceptionally well and show higher strength than the conventional concrete. 8% replacement establishes higher strength in M25 and equalizes in M20 grade conventional concrete. 10% replacement balances with conventional concrete in both the grades of concrete.

CONCLUSION

The results clearly show that the performance of 2, 4 and 6% replacements proved better in compressive strength of both the grades M20 and M25, and show greater than 92% accuracy in 8 and 10% replacements. In split tensile strength, 2, 4 and 6% replacements show excellent performance in M20 and M25 grade and more than 97% accuracy in 8 and 10% replacements. In flexural strength, all the replacements show exceptionally better performance. All the replacements of coarse aggregate with waste tyre rubber aggregate show gradual and strong improvement in both the grades of concrete in all the requisite strengths. But considering the safety factor, this research has been concluded that 6% replacement of waste tyre rubber aggregate with coarse aggregate will gives optimal and safest replacement in accordance with the clean high performance in all the indispensable strength.

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