Studies on Concrete Replaced with Waste Tyre Rubber as Fine Aggregate

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Abstract: Concrete is one of the most extensively used construction material in the world and the mineral aggregates used to make the concrete are a finite resource, which is fast dwindling. On the other hand, Waste tyre treatment is now a serious global threat. Waste tyre dumping, disposal of these materials or burning these tyres cause serious environmental and health problems. The public, governments and industry are all greatly interested in green environment and engineering approaches towards better sustainable development. At the same time, these studies can help to make the environment clean and minimize waste. An emerging use is the production of concrete, in which rubber tyre particles Partially replace natural coarse aggregates. One of the solutions suggested is the use of tyre rubber aggregates as additive in cement based material. Waste tyres are cut into small pellets of size matching the nominal aggregate size and are used to replace the coarse aggregate used in concrete. For comparative analysis, concrete mix of M20 grade is prepared for various concrete mixes by varying percentage replacement of mineral coarse aggregates by 4, 6, and 8 rubber aggregates and the mechanical properties of rubber concrete are compared with that of conventional concrete. Different combinations of crumb rubber with traditional coarse aggregate were evaluated based on compression strength and flexural strength tests were conducted according to Indian Standard.

I. INTRODUCTION

General

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. Concrete technology has made tremendous growth in the past decade. Concrete is no longer a material consisting of cement, aggregate, water and admixture but it is an engineered material with several new constituents. The concrete today can take care of any specific requirements under most of different exposure conditions. Thus there is a need for continuous study and research in the field of concrete technology. The American Concrete Institute (ACI) defines high performance concrete as "the concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients, normal mixing procedure and typical curing practices". High performance concrete therefore should have at least one outstanding property such as compressive strength, high workability, and enhanced resistance to chemical or mechanical stresses, lower permeability, durability etc. Millions of waste tyres are generated and stock piled every year in an uncontrolled manner causing a major environmental problem. The disposal of tyres in landfills is the major issue handled by local municipalities and government sectors. As tyres are non-biodegradable, they remain in dumpsites with little degradation overtime, presenting a continuing environmental hazard. Dumping or disposal of these materials causes environmental and 1health problems. Also it is estimated that more than 1.2 billion waste tyre are produced globally every year. This waste being non-biodegradable poses severe fire, environmental and health risks. So, waste tyre management is a serious global concern. Therefore, recycling of Waste materials plays a vital role in concrete. One of the solutions suggested is the use of waste rubber as partial replacement of coarse aggregates in concrete which has become highly expensive and also scarce. The utilization of waste tyres has been focused on waste minimization and for environmental management.

2. RUBBER MODIFIED CONCRETE

A mixture composed of ordinary concrete and rubber from the recycled tyres has been presented in technical literature under the name of "Rubber Concrete" or "Rubber Modified Concrete". The literature available also shows that workable rubberized concrete can be made with appropriate percentage of rubber tyre aggregates. Sara Sgobba etal, (2010), the study explores the ameliorative effects of rubber particles on some properties of concrete. The result presented shows that the incorporation of rubber aggregates in concrete, obtained from waste tyres, is a suitable solution to decrease the weight in some engineering manufactures. Though rubberized concrete has proven its applications in various construction fields, still a lot of research has to be done to measure the elastic constants and mechanical properties of rubberized concretes by adding rubber in different volume proportions, water-cement ratios, aspect ratios and in different forms such as fibre chips, powder form, etc. so that the appropriate strength can be explored. Here the study is conducted with varying percentage of scrap pieces of rubber in concrete 4%, 6% and 8%.

3. LITERATURE REVIEW

NATIONAL AND INTERNATIONAL STUDIES

1. M.Mavroulidou,J.Figueiredo,(2005)M.

Mavroulidou J. Figueiredo performed slump test to determine the workability of rubber concrete with 0, 10, 20, 30 and 40 percent of tyre rubber aggregate both fine and coarse rubber aggregate. They also made an experimental study to compare the variations in mechanical properties of 7thand 28th day rubber concrete with fine rubber aggregate and rubber concrete with coarse rubber aggregate. Finally they concluded that both cube compressive strength and Split Tensile strength of concrete with coarse rubber aggregate was higher than that with fine rubber aggregate. But the flexural strength test results showed that the strength of rubber concrete with fine rubber aggregate was higher than that with coarse rubber aggregate.

2.Liayaqat Ali Khan, Mr. Sourabh Lalotra, Shivani Bhardwaj

Experimental Study on Mechanical Properties of Concrete Using Chipped Rubber Aggregates and Silica Fume. Four different volume contents of rubber tire chips were used: 25, 50, 75 and 100%. The incorporation of rubber tire in concrete exhibited a reduction in compressive and flexural strengths, the reduction in compressive strength was approximately twice the reduction of the flexural strength

3. Abhijit singh Parmar

The use of Crumb Rubber as a Partial Replacement of Coarse aggregate in conventional concrete increases compressive strength getting highest strength at using minimum replacement at 5% of 20.12 N/mm2 . Maximum Flexural Strength 3.42 N/mm2 getting at minimum replacement of coarse aggregate by crumbed rubber.

4.S.M.Dumne

S.M.Dumne carried out the study using tests such as slump, unit weight and compressive strength on different concrete mixes in order to determine properties of concrete mix. For comparative analysis, concrete mix of M20grade was prepared for various concrete mixes by varying percentage replacement of mineral coarse aggregates by 0, 5, 10 and 15 rubber aggregates. The test results showed that rubberized concrete gave lesser unit weight in addition to the reduction in workability. It was also observed that there was a reduction in compressive strength of rubberized concrete which restrict its structural applications but it preserves some desirable characteristics. Overall, results of experimental test reflected that it is possible to use discarded rubber tyre aggregates in concrete as a partial replacement to mineral coarse aggregates but percentage replacement should be limited in order to restrict its application.

5. M.Priyadharshini, M. Naveen kumar, (1998)

They did an experimental study on crumb rubber with partial replacement of fine aggregate. Adding crumb rubber into concrete resulted in a significant decrease of the mechanical properties, but increased the durability. A 20% replacement of fine aggregate and a 5% replacement of the total mixture with crumb rubber met the safety strength requirements of concrete and had excellent durability.

6. Malathi R, Vime Gold V, Divya C

A Comparative Study on Rubber Concrete over Conventional Concrete Rubber concrete specimens were prepared by adding 5%, 10% and15% as increment of rubber aggregates replacing coarse aggregates in concrete and were cured for same curing period to make a comparative study. The Split Tensile strength of specimen with tyre rubber aggregate at the end of 7th,14th and 28th day reduced by about 8% for every 5% increment of tyre rubber aggregates respectively.

7. K.Nithya, R.Kalpana (2005)

K.Nithya, R.Kalpana performed a comparative study on early age concrete with waste rubber aggregate and the conventional concrete. The percentage of replacement of coarse aggregate was 0%, 10% and 12% and the curing was done with acids like HCl and HS2O4. Compressive strength, Splittensile strength and Flexural strength for specimens with normal curing and acid curing were compared. The test results showed that acid curing and percentage increase of rubber aggregate the compressive strength. However the rubber concrete reduces the environmental pollution and wastage of natural resources. Despite the loss in strength, this type of concrete was acceptable for various applications requiring medium to low compressive strength.

8.. Ganjianin, E., Khorami, M., and Maghsoudi, A.A., (2009),

Their study confirmed the decrease in compressive strength for increase rubber content. However, they obtained a slight increase in compressive strength when 5% of chipped rubber replaced the coarse aggregates due to better grading of the mixture.

9. Eldin et al.,

Conducted an experimental study on rubberized Concrete in year 1989behaviour, discarded vehicle tyres constitute one important part of solid waste, which had historically been disposed of into landfills. An emerging reuse is the production of concrete, in which waste-tyre rubber particles in part replace the natural aggregates. This has an additional advantage of saving the natural aggregates used in concrete making. Recycled waste-tyre rubber is a rising material in the construction industry due to its low weight, elasticity, energy absorption, heat and sound proofing characteristics. Waste-tyre rubber can be used as chipped (20-30mm) or crumbed (3-10mm) or ash rubber(less than1mm). The waste-rubber tyre particles cut into 20mm size. Its benefits are numerous such as reduction of the cost of aggregates and disposal, prevention of environmental degradation, and increase in life span of landfill areas. Concrete pavements are made of high strength mixtures, which lack sufficient flexibility. By partial replacement of fine and coarse aggregates with rubber, sufficient flexibility can be achieved and thermal changes can also be reduced. It is reported that use of waste-rubber tire particles as partial replacement of aggregates in concrete leads to loss of its strength.

10.R. Nagalakshmi

Conducted an experimental study on Coconut Shell Concrete in year 1987to assess the strength characteristics on M 25 concrete with partial replacement of cement with fly ash and coarse aggregate with coconut shell. The 20% of fly ash is replaced with cement and simultaneously by replacing 10%, 20% and30% of coconut shell as coarse aggregate for concrete of grade M 25.Examinedstrength characteristics such as compressive strength, splitting tensile strength and flexural strength of concrete mix are found for 28 days of curing period, results are analyzed and compared with the regular mix. The results found were comparable with that of conventional mix. The result concludes that the compressive strength, splitting tensile strength and flexural strength of the concrete reduced with increasing percentage of the coconut shell replacement.

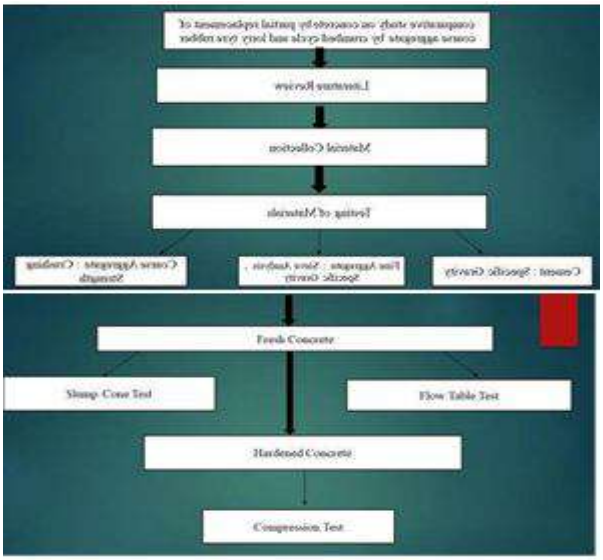
5. METHODOLOGY

INDIAN SCENARIO

In the absence of suitable standardized test methods it is necessary to examine critically the existing test methods and identify or, when necessary develop test methods suitable for acceptance as Indian standards. According to professor Dr.Peter JM Bartos, Director University of Paisely," Unless this work is carried out without delay, there will be a real danger of each country adopting more or less different test methods, making any further harmonization very difficult. Standardization of test capable of dealing with the key property of see is urgently required. Thereby we can come to a conclusion that there are no proper codal provisions for this innovative concrete material in India.

MATERIALS USED

1) Cement: OPC 43 grade cement is used for the experimental purpose and is investigated as per Indian Specifications IS: 12269-1987.
2) Fine Aggregate: Fine sand having size
4.75 mm as maximum is used as fine aggregate.
3) Coarse aggregate: Crushed stone with maximum 20 mm size is used as coarse aggregate.
4) Water: Water used in the experimental work is conformed to IS: 456-2000 for mixing as well as curing of Concrete specimens.
5) Waste tire: Crumb rubber having size between 0.075 mm to 4.75mm is used in the concrete being made for the experiment.
6) Silica fume: Silica fume used is of diameter less than 1 m. It is used as an admixture in the concrete.
7) Mix design: Mix design can be defined as the process of gathering the required ingredients in the required quantities in order to mix them in proper ratio to get the concrete having desirable strength, durability and workability. In this experimental investigation I have prepared a concrete having mix proportions of M-30 which is tabulated below:



Mix Composition

The mix design was prepared with constant quantities of cement, aggregate and water. Controlled mix design was prepared as per IS: 10262-2009 to have 28days compressive strength of 28.66 N/mm2. After that the fine aggregate was replaced with 5%, 10% and 15% crumb

Content	M-1 (0%CR)	M-2 (5%CR)	M-3 (10%CR)	M-4 (15%CR)
Cement(kg/m³)	434.8	434.8	434.8	434.8
Fine aggregate (kg/m³)	843.42	801.25	749.078	716.907
Crumb rubber	0	42.17	94.34	126.51
Coarse aggregate (kg/m³)	1074.008	1074.008	1074.008	1074.008
Water (kg/m³)	170	170	170	170
W/C ratio	0.31	0.31	0.31	0.31
Mineral admixture (kg/mm³)	3.319	3.319	3.319	3.319
Slump (mm)	90	85	80	80

Preparation and Details of Test Specimens

In the present experimental investigation, the total numbers of specimens casted were 72. The cubes casted were totally 24 in number, of which each set of 6 cubes were meant for each percentage of crumb rubber (i.e.0%, 5%, 10% and 15%). Out of 6 cubes, 3 cubes were tested after 7 days, and the other 3 cubes were tested after 28 days. Similarly 24 beams and 24 cylinders were casted, of which each set of 6 beams and 6 cylinders were meant for each percentage of crumb rubber. In these, every 3 beams and every 3 cylinders having different crumb rubber percentage were tested after 7 day strength and 28 day respectively.

Tests on Hardened Concrete

Compressive Strength

Compressive strength is defined as the capacity of a material or structure to resist compression when a load is applied on it, in order to push it together. In other words, we can say compressive strength of a material can also be defined as the minimum amount of load required at which that particular material breaks down. In this experiment we have tested all the cubes that we had casted with different ratios of crumb rubber for their compressive strengths. Cube specimen of size 150 mm were casted as per the Indian Standard specification IS: 516-1959. After finishing, the samples were covered with sheets to minimize the loss of moisture. The specimens were de-molded after 24 hours and then kept in water for curing. The compressive strength test was carried out after 7 and 28 days.

Calculations

The formula used for the calculation of the compressive strength was:

$\Sigma\sigma$	=	P / A		
Where,		$\Sigma\sigma$	=	Compressive Strength (N/mm²)
		P	=	Maximum load (N)

Split Tensile Strength

Split tensile strength is defined as the tendency of a material to oppose an applied force trying to pull it apart. The tensile strength of a material can be defined as the minimum amount of force that is required to split that specific material apart. The cylinders of size 150 mm by diameter and 300mm by length that we have casted were compacted in vibrators and then after de-molding and curing them, the tests were conducted on them after 7 and 28 days respectively to check there split tensile strengths.

Calculations

The formula used for the calculation of the Split tensile strength was: fct = 2PJI I D Where, P=maximum load in Newton applied L=length of the specimen (in mm), and D=cross sectional dimension of the specimen

Flexural Strength

Flexural strength is defined as the tendency of the material to oppose its deformation when a specific amount of load is applied on it. It is also known as bend strength and fracture strength. The beams of size 10 × 10 × 50 cm that we have casted were compacted in vibrators and then after de-molding and curing them the tests were conducted on them after 7 and 28 days respectively to check there flexural strengths.

Calculations

The flexural strength of the sample is expressed as the modulus of rupture fb, which, if 'a' equals the distance from the line of fracture to the nearer support. Fb=p.2 When 'a' is greater than 20.0 cm for 15.0 cm sample, or greater than 13.3 cm for a 10.0 cm specimen, or fb = 3p.a b.d2 when 'a' is less than 20.0 cm but greater than 17.0 cm for 15.0 cm sample, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm sample. Where: b = measured width in cm of the sample d = measured depth in cm of the sample at the point of failure, l = length in cm of the span on which the sample was supported, and p = maximum load in kg applied to the sample. If 'a' is less than 17.0 cm for a 15.0 cm sample, or less than 11.0 cm for a 10.0 cm sample, the results of the test shall be discarded.

RESULTS AND DISSCUSSIONS

Results of Controlled Concrete Sample

1) For the concrete containing crumb rubber, the test results shows that with the addition of crumb rubber there is decline in the value of compressive strength, flexural strength and split tensile strength.

2) The decline in the compressive strength value observed is ranging from 10% to 27%.

3) In case of split tensile strength there is reduction in strength and is about 8% to 25%. However there is little lesser reduction in split tensile strength comparing to compressive strength.

Property	7 Days	28 Days
Compressive strength(N/mm2)	27.97	28.68
Split tensile strength(N/mm2)	7.85	9.21
Flexural strength(N/mm2)	10.14	11.39

Results of Concrete Samples Containing Crumb Rubber

Property	Mix	7 Days	28 Days
Compressive strength (N/mm²)	5% CR	26.24	28.02
	10% CR	24.03	26.05
	15% CR	18.36	20.67
Split tensile strength(N/mm²)	5% CR	6.08	7.35
	10% CR	5.68	6.44
	15% CR	5.35	6.01
Flexural strength(N/mm²)	5% CR	9.70	10.03
	10% CR	8.91	9.83
	15% CR	7.03	8.49

4) In case of flexural strength there is reduction in strength like compressive strength and it was about 20% to 30%.

CONCLUSION

According to the experimental investigation, the utilization of rubber tire as partial replacement of fine aggregates has been used in three different proportions 5%, 10% and 15% with silica fumes as mineral admixture. Based on the results, following conclusions are drawn:

1. As the percentage of crumb rubber is increased, eventually the workability of the concrete also increases.
2. In comparison to the previously done
3. experimental investigations with crumb rubber in the absence of silica fumes, this research has shown comparatively better adhesive and bonding properties and hence comparatively better values for compressive, tensile and flexural strength.
4. The increase in the workability also shows decrease in the voids due to the betterment in the compaction but due to the decrease in the other properties it is not significant.
5. For larger percentage of rubber in concrete, the decline rate of compressive strength is higher than normal concrete.
6. Better results were obtained when 5% of rubber is used for substituting the natural aggregate in the rubberized concrete.

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