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RESEARCH ARTICLE

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HYBRID CONCRETE BY PARTIAL REPLACEMENT OF ALL INGREDIENTS OF CONCRETE

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ABSTRACT

Aggregate is one of the main ingredients in producing concrete. It covers 75% of the total for any concrete mix. The strength of the concrete produced is dependent on the properties of aggregates used. However, the construction industry is increasingly making higher demands of this material and is feared to accommodate the many requests at one time. Hence need for an alternative coarse aggregate arises.

The volume of tyre rubber and construction waste is increasing at a fast rate. At present the disposal of these waste materials is becoming a major waste management problem in the world. Similarly there is problem for the disposal of fly ash. Using the waste materials as aggregate conserves virgin aggregate, reduces the impact on landfills, decreases energy consumption and can provide cost savings. Recycled aggregates are the materials for the future. In India the disposal of waste tyre and waste construction material in landfills is a major issue handled by local municipalities and government sectors. Using this waste material in concrete can solve these problems. The use of recycled coarse aggregate and tyre rubber as partial aggregate along with fly ash in concrete has great potential to positively affect the properties of concrete in a wide spectrum and result in economy.

This experimental study is conducted to analyze the behavior of concrete when fine aggregate is partially replaced with crumbed tyre rubber. Compressive strength is measured in concrete mixes with 5%, 8% and 10% substitution of natural fine aggregate by crumbed rubber along with partial replacement of cement and coarse aggregate by fly ash and recycled aggregates respectively.

KEY WORDS: Technology, Rubber Concrete, Economy, Partial Replacement


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INTRODUCTION

In India, the total production of fly ash is nearly as much as that of cement. But our utilization of fly ash is only about 5% of the production. Therefore, the use of fly ash must be popularized for more than one reason The use of fly ash in concrete not only extends technical advantage to the properties of concrete but also contribute to the environmental pollution control. In India alone, we produce75 million tons of fly ash per year, the disposal of which is a serious environmental problem. The effective utilization of fly ash in concrete making is, therefore attracting serious considerations of technologists and government departments

Central Pollution Control Board reported in 2004 that solid waste generation in India was about 48 million tons/annum and more than 25%of this is from construction industry which consists of about 7-8 million tons of concrete and brick waste. The waste quantities are estimatedto reach to level of at least 85 million by 2013. RCAs is particularly very promising source of aggregates as 75 per cent of any typical concrete ismade of aggregates. RCAs present a unique solution to the problems oflarge scale demolitions occurring now-a-days in India. This recycling industryfor waste concretes helps reducing management/maintenance costs of dumpsites/ landfills and transportation costs.

Millions of waste tyres are generated and stock piled every year, often in an uncontrolled manner, causing a major environmental problem. Timely action regarding recycling of used tyres is necessary in view to solve the problem of disposal of used tyres keeping in view the increasing cost of raw material, resource constraints and environmental problems associated with the stockpiles of the used tyres.

Tyre disposal to landfills is problematic, as waste rubber is not easily biodegradable. Stockpiled tyres present many health, environmental and economic risks through air, water and soil pollution. They pose health hazards including diseases due to rodent and mosquito infestation and pollution to land, water, and air.

An emerging field for the reuse of scrap tyres is in the production of concrete, where tyre rubber can be used as a partial replacement to natural aggregates. This has the additional advantage of saving in natural resources.

Previous research conducted show dramatic changes in the mechanical properties of concrete when rubber is introduced to the mix [2-11].The use of crumbed rubber as aggregate in concrete has not given results that could indicate the possibility of its use as structural material. It is thought that the main cause of the decrease of strength in rubber concrete is due to the weak bond between the recycled rubber particles and the cement. Sodium hydroxide (NaOH), also known as lye or caustic soda, is a caustic metallic base [13] due to its causticity; it is a perfect substance to modify the surface of rubber in order to improve the interfacial transition zone (ITZ) in the concrete matrix.

Previous research has shown that replacing the fine aggregate more than 5% by crumbed rubber leads to major changes in concrete properties. As well, it is found that30% of cement and 40% of coarse aggregate can be replaced by fly ash and recycled aggregate respectively without any comparable reduction in compressive strength.

This investigation intent to explore this issue by comparing an OPC control mix with three mixes with different amount of natural fine aggregate replacement (5%, 8% and 10%) by treated crumbed rubber along with partial replacement of cement and coarse aggregate by fly ash (30%) and recycled aggregate (40%) respectively.

Investigations carried out so far reveal that tyre waste concrete is specially recommended for concrete structures located in areas of severe earthquake risk and also for applications submitted to severe dynamic actions like railway sleepers. This material can also be used for non-load-bearing purposes such as noise reduction barriers. Investigations about rubber waste concrete show that concrete performance is very dependent on the waste aggregates

Literature Review

Some of the previous researches on rubberized concrete:

Eldin N.N and Senouci A.B.(1993)noted that rubberized concrete did not perform as well as normal concrete under repeated freeze-thaw cycles. It exhibited lower compressive and tensile strength than of normal concrete but unlike normal concrete, rubberized concrete had the ability to absorb a large amount of plastic energy under compressive and tensile loads.

Toutanji,H.A (1996) noted that the specimens which contained rubber tyre aggregate exhibited ductile failure and underwent significant displacement before fracture. The test revealed that high toughness was displayed by specimens containing rubber tyre chips as compared to control specimens.

Khatib Z.K and Bayon F.M (1999) has developed "Rubberized portland cement concrete" to conduct experimental program in which two types of rubber fine Crumb Rubber and coarse tyre chips were used in Portland cement concrete (PCC) mixtures. Rubberized PCC mixes were developed by partially replacing the aggregate with rubber and tested for compressive and flexural strength in accordance to ASTM standards. It is suggested that rubber contents should not exceed 20% of the total aggregate volume.

Serge et al [2000] in their study concluded that the rubber particles treated by NaOH shows better cohesion with cement paste. Their results indicated that there was an improvement in flexural strength by this procedure, but a 33% decrement occurred in compressive strength.

Experimental Program

The experimentation consisted of four concrete mixes: one control mix with no replacement of any type and three mixes with 5%, 8% and 10% replacement of natural fine aggregate by recycled crumbed tyre rubber.In all the three mixes other than control mix,40% replacement of natural coarse aggregate by recycled concrete aggregate and 30% replacement of cement by fly ash is done as shown in Table-1.

Table-1: Percentage replacement of various materials.

Material Partially Replaced	Material Replacing	Percentage of Replacement
Cement	Fly Ash	30%
Natural Aggregate(Coarse)	Recycled Concrete Aggregate	40%
Fine Aggregate (Sand)	Crumbed Rubber Aggregate	Varying Percentages (5%,8%,10%)

A. Materials used

Materials used to make concrete specimens were fine aggregate, coarse aggregate, cement, fly ash, crumbed tyre rubber, recycled aggregate and water.

1. Cement

The cement used for research work was ordinary Portland cement of 43 gradesconforming IS-8112.

2. Coarse Aggregate

The coarse aggregate was selected from natural stone, which was maximum 20 mm in size. The stone used had 2.87 specific gravity in saturated surface state and 0.80 % water absorption. The grades distribution curves for coarse and fine aggregate are given.

3. Fine Aggregate

Sand of Zone-II as per IS: 383-1970 was used as fine aggregate. It had the specific gravity of 2.75 and 0.70% water absorption.

4. Fly Ash

Fly ash used for research work conforming grade IS-3812 (Part- I).

5. Crumbed Rubber

Crumbed Rubber was taken from the scrap tyre recycling industries in Bhopal. The recycled crumbed tyre used is treated for surface modification by sodium hydroxide (NaOH) solution. The treatment consisted of soaking the recycled tyre particles in a NaOH solution for a period of 20 minutes, and then it was washed under running water and left to air dry at room temperature. It had 0.98 specific gravity and 0.00 % water absorption.

6. Recycled Aggregate

The recycled aggregate was obtained from the demolished concrete structure, from the remains of beams and columns. It was 20 mm graded aggregates as per IS: 383-1970.It had 3.20specific gravity in saturated surface state and 1.40 % water absorption.

7. Water

Clean water conforming to IS-456(2000) standards is taken.

B. Mix Proportion

Mix design of the concrete is done strictly as per the specification of the IS 10262 (2009). According to IS code specification mix of M40 grade is designed.In this study four different types of mixes or combination are being considered and designed as per Indian Standard Specification IS: 10262(2009).

A standard control mix was prepared in conformation with IS code. The other three concrete mixes were made by replacing the fine aggregates with 5%, 8% and 10% of crumbed tyre rubber by volume. The partial substitution of coarse aggregate by recycled aggregate (40%) and cement by fly ash (30%) was done by volume in the three mixes.

Water cement ratio- The water cement ratio of all the prepared mixes was kept at an optimum value of 0.4 according to the grade of concrete chosen and mix design that was done.

The designation of all the mixes is given in Table-2. The composition and proportions for all the mixes and the quantities are shown in Table-3.

C. Casting and Curing

Mixing and casting of cubic test specimens was performed in accordance with IS Code 516-1959. All specimens were wet cure by submersion in water.

9 cubes of 150 x 150 x 150 mm size of each mix were cast for 7-days,14 days 28 days testing. A thin layer of oil was applied on all the faces of the mould. The concrete sample was filled into the cube moulds in layers approximately 5 cm deep. Each layer was compacted by means of a suitable vibrating table until the specified condition was attained. The casted cubes were stored under shed at a place free from the vibration at a temperature 220C to 330C for 24 hours covered with wet gunny sacking.The cubes were removed from the moulds at the end of 24 hours and were immersed in clean water at a temperature 240C to 300C till the 7, 14 or 28-days age of testing.

D. Testing

Test on fresh concrete

Slump Test - The workability of all concrete mixtures was determined through slump test utilizing a metallic slump mould. The difference in level between the height of mould and that of highest point of the subsided concrete was measured and reported as slump. The slump tests were performed according to IS 1199¬-1959.The slump of the mixes is shown in Table-5.

Test on hardened concrete

Cubes were tested for compressive strength at an age of 7, 14, and 28 days from the first day of immersed curing. A constant loading rate of 140 kg/cm2/min was employed until the resistance of the specimen to the increasing load broke down and no greater load could be sustained. The maximum load applied to the specimen was recorded. The quoted strength values are the averages of three cubes per test in accordance with IS 516-1959 standard test method.

Tests on Materials

Analysis of the physical properties of the natural aggregates was done according to IS standards. All aggregates met the specification of IS standard 383. Table-4 shows results of analysis of the physical properties of natural coarse and fine aggregates; recycled aggregates and crumbed rubber aggregate used in all test mixes.

Table-2: Designation of various mixes.

Mix Designation	Percentage replacement of fine aggregate by crumbed rubber
CC (Control Concrete)	0%
CR5	5%
CR8	8%
CR10	10%

Table-3: Composition of various mixes per m^3 of mix.

	CC	CR5	CR8	CR10
Water to cement Ratio	0.4	0.4	0.4	0.4
Size of Coarse Aggregate	4.75 mm-20 mm	4.75 mm-20 mm	4.75 mm - 20 mm	4.75 mm - 20 mm
Size of Fine Aggregate	90 μ-2 mm	90 μ-2 mm	90 μ- 2 mm	90 μ- 2 mm
Water	156 l	156 l	156 l	156 l
Cement	390 kg	273 kg	273 kg	273 kg
Fly ash	-	117 kg	117 kg	117 kg
Coarse Aggregate (gravel)	1308 kg	775.12 kg	775.12 kg	775.12 kg
Recycled Coarse Aggregate	-	574.44 kg	574.44 kg	574.44 kg
Fine Aggregate (sand)	703.79 kg	338.58 kg	327.89 kg	320.76 kg
Crumbed Rubber Aggregate	-	6.35 kg	10.16 kg	12.7 kg
Ordinary Portland Cement	OPC43 Grade	OPC43 Grade	OPC43 Grade	OPC43 Grade

*Note- The design of various mixes is done as per IS Code IS 10262 (2009)

Table-4: Physical properties of aggregates.

Property	Aggregate			
	Coarse	Fine	Recycled	Crumbed Rubber
Specific Gravity	2.87	2.75	3.20	0.98
Absorption	0.80	0.70	1.40	0.00
Moisture Content	0.30	0.10	0.20	0.00
Grading Zone	-	2	-	2

RESULTS& DISCUSSION

The introduction of recycled rubber tyres to concrete increases the slump and workability. All concrete mixes were designed to have a slump of 25mm; however all of the mixes had a slump of much more value. It was noted that the slump value was increased as the percentage of rubber was increased. The mix consisting of 5% rubber had a slump of 25mm, followed by the 8% rubber mix having a 120mm. slump while the mix with 10% replacement of aggregate by rubber had a slump of 135mm. In general, as the percentage amount of rubber increased the amount of energy required for casting specimens decreased substantially. Workability increases with increasing percentage of rubber in concrete.

Table-5: Slump Values.

Mix	Slump Value
CC	25 mm
CR5	25 mm
CR8	120 mm
CR10	135 mm

Results show a significant decrease in the compressive strength as the rubber replacement amount increases (Figures 1 and Figure 2) shows the variation.

Upon examination of broken blocks containing recycled tire, it could be seen that the pieces of concrete tested tend to stay together linked through the rubber particles.In general, forall testing the specimens did not shattered as the OPC control mix, the rubber containing specimens cracked but the cracks were arrested by the rubber fibers.

Table-6 shows the compressive strengths of various mixes at 7days, 14 days and 28 days from the day of curing and figure-1 shows the compressive strength of concrete verses age of concrete graph..Table-7 shows the percentage change in compressive strength for each mix and age.

Table-6: Compressive strength test results.

Mix	Compressive Strength (in N/mm^2)		
	7 days	14 days	28 days
CC	26.78	28.77	30.04
CR5	17.62	28.21	36.24
CR8	14.64	21.09	24.47
CR10	13.55	19.56	22.52

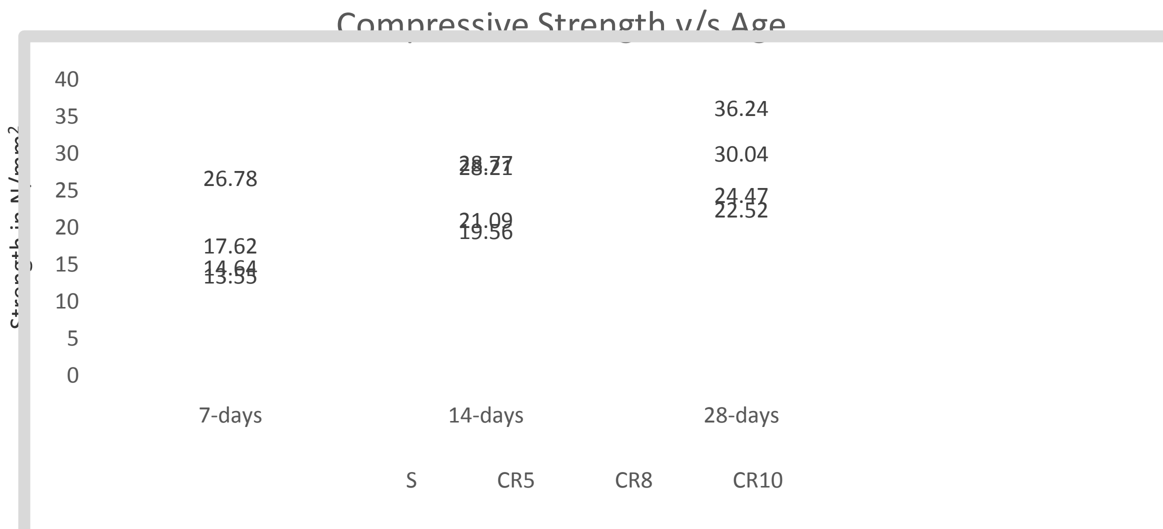

Figure 1: Compressive Strength versus Age.(*Note- Age is from the day of beginning of curing of concrete cubes.)

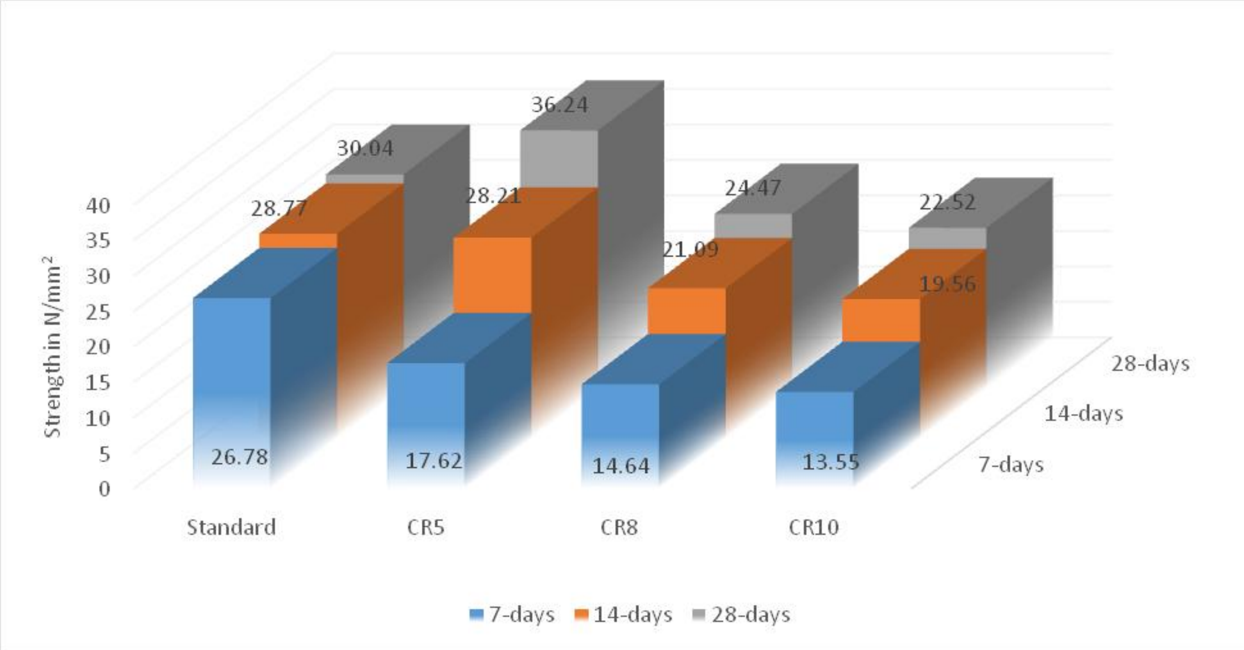

Figure 2: Comparison of compressive strength according to percentage aggregate substitution

Table-7: Percentage decrease of compressive strength for concrete mixes.

Age (days)	Percentage Decrease of Compressive Strength		
	CR5	CR8	CR10
7	-37.68	-54.03	-55.29
14	-43.59	-55.17	-61.57
28	-38.58	-53.87	-59.22

CONCLUSION

Research on the usage of waste materials is very important because,waste materials is gradually increasing with the increase in population and increasing urban developments.Utilization of rubber tyres and recycled aggregate in concrete will eradicate the disposal problem of these waste materials and essay to be environment friendly, thus paving way for greener concrete. The reason that many investigations and analysis had been made on recycled aggregate and crumb rubber is because, they are easy to obtain and the cost is cheaper than natural aggregate. Natural aggregates need to mine but these aggregate can ignore this process.

After detailed study of the result and analysis the following conclusions were made.

[1]The slump value increases with the increase in percentage of crumb rubber as our experiment shows therefore we can say that workability of concrete increases with increase in rubber percentage.

[2] Use of rubber doesn't have positive effect on compressive strength instead compressive strength decreases with increase in crumbed rubber percentage.

[3]Recycled rubber tyres use as aggregate could be successful in its use as lightweight concrete in non-structural applications, and itrepresents a viable alternative to recycle tyres helping the conservation of the environment in the process.

[4] Utilization of crumb rubber and recycled aggregate in concrete can turn out to be economical as they are easily available at some places and at cheaper cost as compared to natural one.

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