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Study on the Strength Properties of Concrete using Industrial Waste

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Abstract **-Efficient waste management and using it as replacement for concrete components is yet a field not fully tapped to its potential. The paper highlights the double positives of using wastes as alternatives by not only reducing stress on environment but also cutting down on the cost of concrete manufacture while preserving its quality, leading to sustainable economic development.Numerous projects have been conducted on replacement of aggregates by crumb rubbers but scarce data are found on cementitious filler addition in the literature. In this research the performance of concrete mixtures incorporating 2.5%, 5% and 10% of discarded tire rubber as sand, aggregate and cement replacements was investigated. Hence to examine characteristics of tire crumb-containing concrete, three sets of concrete specimens were made. In the first set, different percentages by weight of chipped rubber were replaced for coarse aggregates and in the second set scrap-tire powder were replaced for cement and in the third set, different percentages by weight of crumb rubber. Selected mechanical test were performed and the results were analyzed. The mechanical tests included compressive strength and tensile strength. The results showed that with up to 2.5% replacement, in each set, no major changes on concrete characteristics would occur, however, with further increase in replacement ratios considerable changes were observed.**

Keywords - Rubber, concrete, replacement

I. INTRODUCTION

Increasing environmental concerns and health risks related to the construction industry have come under great scrutiny by both, the government as well as environmental activists. The cement and concrete industry is a large consumer of aggregates, sand, clinker and fuel in the form of resources [1]. The main issue here is regarding waste production, which has increased tremendously, necessitating effective disposal. The vast majority of industrial and agricultural wastes are by-products of fuel incineration, slag, bagasse, fly ash, and large scale manufacture of a range of products. Such wastes, being produced in massive amounts, if not discarded properly can pose problems such as pollution and leaching of chemicals like arsenic, beryllium, boron, cadmium, chromium, chromium (VI), cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, especially when dumped in landfills, quarries, and water bodies [2]. Since concrete production is energy intensive and has a high capital demand, the use of alternate materials to replace some of its standard components solves two problems, the first one being the effective disposal of such wastes, in a safe as well as economic manner. Secondly, the incorporation of such additives in concrete can provide several advantages related to its mechanical properties and durability [3-5].

Studies indicate that several agricultural and industrial by-products can be utilized in concrete structures in certain optimum amounts. Agro-wastes, such as bagasse ash, have pozzoloanic properties, where amorphous silica combines with lime to forms cementitious material [6]. However, the major problem with its usage is negligible reactivity. Often, processes employed for ash generation have minimum control over combustion temperatures of wastes and the method of cooling, tending to produce ashes lacking in hydraulic conductivity [7]. In the first experiment, the material considered for replacement of sand in concrete, is Sugarcane bagasse ash (SCBA). A specific percentage of fine aggregate (sand) in concrete has been replaced with SCBA and its effects on the resultant compressive strength have been documented. The lowered direct and indirect cost, along with its reduced impact on the environment, adds to the advantages over conventional materials while still maintaining an acceptable performance profile with respect to durability, safety and strength.

The second experiment is based on the usage of scrap rubber. The global demand of automobiles has generated massive stockpiles of used tires. Scrap tire is not biodegradable, and has detrimental effects on the environment. A useful method of simultaneous disposal and utilisation is their use in the concrete industry. Significant research and development has been carried out for the use of tire crumbs in asphaltic pavement layers in Iran [8]. Results have shown that such layers had better skid resistance, reduced fatigue cracking and longer design life than their conventional counterparts [9, 10]. To take it a step further, the replacement of different components of concrete, by various forms of tire scrap has been carried out and its effect on the resultant compressive strength, observed.

The final experiment focuses on coconut shell as the replacement material. Coconut is grown in more than 86 countries worldwide, with a total production of about 54 billion coconuts every year. India ranks high in the production of coconuts, with an annual production of 13 billion coconuts [11]. Limited research has been carried out on the mechanical properties of concrete with coconut shells as a replacement for aggregate [12, 13]. Consequently further research is needed for a better understanding of the behaviour of coconut shells as aggregate in concrete, and their suitability for the role.

II. EXPERIMENTAL INVESTIGATION

2.1 Materials and Mix Proportion

The materials used in the specimen preparation confirms to the properties as described above in the introduction part. The physical properties of the cement are shown in the table below. The details of the physical properties of various cements tested in accordance with **IS: 12269 : 1987.**

Table no. 2.1 Physical Properties of Cement

Physical Property	*Results*
Fineness Modulus(retained on 90μm sieve)	8.0
Normal Consistency	28%
Initial Setting Time(minutes)	60
Final Setting Time(minutes)	420
Specific Gravity	3.15

The properties of the coarse aggregates and the fine aggregates are also shown in the table below [2]. The physical properties of fine aggregate such as specific gravity, fineness modulus, porosity, void ratio etc., were determined in accordance with IS: 2386-1963

Table no. 2.2 Physical Properties of Coarse and Fine Aggregates

Physical Tests	*Coarse Aggregates*	*Fine Aggregates*
Specific Gravity	2.67	2.66
Fineness Modulus	6.86	2.32
Bulk Density	1540	1780

The concrete mix was proportioned on weight basis. Till now the only supplementary material added in the mix is rubber. Their percentage was varied as 0, 2.5, 5.0, and 10.0. The mix proportions used for the specimen preparation are as follows.

Table no. 2.3 Conventional Concrete Strength Test for M15

Title	*For 7 Days*	*For 14 days*	*For 28 days*
Compressive Load (kN)	170 190	215 185	220 240
Avg. Compressive Strength (N/mm^2)	18	20	23

Table no. 2.4 Cement Replacement (Percentage by Weight)

Sr. No.	*W/C Ratio*	*Cement*	*Ground Rubber*	*Sand*	*Aggregate*
1	0.5	97.5%	2.5%	100%	100%
2	0.5	95%	5%	100%	100%
3	0.5	90%	10%	100%	100%

Table no. 2.5 Sand Replacement (Percentage by Weight)

Sr.No.	*W/C Ratio*	*Cement*	*Crumb Rubber*	*Sand*	*Aggregate*
1	0.5	100%	2.5%	97.5%	100%
2	0.5	100%	5%	95%	100%
3	0.5	100%	10%	90%	100%

Table no. 2.6 Aggregate Replacement (Percentage by Weight)

Sr.No.	*W/C Ratio*	*Cement*	*Shredded Rubber*	*Sand*	*Aggregate*
1	0.5	100%	2.5%	97.5%	100%
2	0.5	100%	5%	95%	100%
3	0.5	100%	10%	90%	100%

III. SPECIMEN PREPARATION

The concrete constituents were mixed in an electrically operated revolving drum type concrete mixer. The ingredients were initially mixed in dry condition and then water was added. Table 3.2 lists the size of specimens that were utilized in order to evaluate the performance of the different curing techniques. The moulds were filled in two layers and vibrated until the consolidation of concrete, indicated by the formation of a thin sheen of mortar on the surface.

3.1 Testing

The different specimens after the completion of the respective time period of their curing were tested for their compressive strength by compression testing machine. The specimens were kept at the centre of the machine and load was applied uniformly at the specimens. Small amount of fly ash was also placed at the top of specimen, so that it may get compressed if there is any deformation in loading. This was done just to ensure that the specimen was loaded equally from all the sides.

Table no. 3.1 Compressive Strength after 7 days test

S. No.	*Date of Casting*	*Percentage of Replacements*	*Date of Testing*	*Compressive Load (KN)*	*Average Compressive Strength in 7 days (N/mm^2)*
1	20/03/13	2.5%	27/3/13	188 282	23.5
	20/3/13	5%	27/3/13	181 126	15.35
	20/3/13	10%	27/3/13	130 106	11.8
2	21/3/13	2.5%	28/3/13	169	18.85
				208	
	21/3/13	5%	28/3/13	157 163	16
	21/3/13	10%	28/3/13	141 138	13.95
3	31/3/13	2.5%	7/4/13	255 270	26.25
	31/3/13	5%	7/4/13	227 195	21.1
	31/3/13	10%	7/4/13	186 178	18.2

Table no. 3.2 Compressive Strength after 28 days test

S. No.	*Date of Casting*	*Percentage of Replacements*	*Date of Testing*	*Compressive Load (KN)*	*Compressive Strength in 28 days (N/mm^2)*
1	20/03/13	2.5%	17/4/13	251 240	24.55
	20/3/13	5%	17/4/13	235 173	20..4
	20/3/13	10%	17/4/13	147 131	13.9
2	21/3/13	2.5%	18/4/13	286 270	27.8
	21/3/13	5%	18/4/13	201 189	19.5
	21/3/13	10%	18/4/13	205 165	18.5
3	31/3/13	2.5%	28/4/13	275 292	28.35
	31/3/13	5%	28/4/13	220 192	20.6
	31/3/13	10%	28/4/13	207 180	19.35

Table no. 3.3 Split Tensile Strength on Cylindrical Cube after 28 Days test

S. No.	*Date of Casting*	*Percentage of Replacements*	*Date of Testing*	*Compressive Load (KN)*	*Split Tensile Strength in 28 days (N/mm^2)*
1	20/03/13	2.5%	17/4/13	85	2.71
	20/3/13	5%	17/4/13	51	1.62
	20/3/13	10%	17/4/13	48	1.53
2	21/3/13	2.5%	18/4/13	84	2.68
	21/3/13	5%	18/4/13	82	2.61
	21/3/13	10%	18/4/13	70	2.23
3	31/3/13	2.5%	28/4/13	80	2.55
	31/3/13	5%	28/4/13	73	2.32
	31/3/13	10%	28/4/13	58	1.84

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The results of tests and measurement values taken in the laboratory, and their analysis are given below.

4.1. Compressive strength test

The results of 7-days and 28-days compressive strength tests for concrete mixtures are shown in Figs. 1 and 2. As expected, in line with the findings of other researchers, in general, the strength of concrete mixtures containing chipped rubber was reduced. As it can be seen in Figs. 1 and 2, with 2.5% powder rubber replacement, the compressive strength was reduced by only about 5% when compared to control mixture despite 5% reduction in cement content by weight. Replacements of 5% and 10% of powder rubber reduced the strength by 10–23%, respectively. These were mainly due to reduction in the cement content in these mixtures. The reasons for reduction in the compressive strength of concrete when rubber was used were more related to differing properties of rubber particles and aggregates. These factors include:

I) 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 expand quickly throughout the matrix, and eventually causing accelerated rupture in the concrete.

II) Due to a lack of proper bonding between rubber particles and the cement paste (as compared to cement paste and aggregates), a continuous and integrated matrix against exerted loads is not available. Hence, applied stresses are not uniformly distributed in the paste. This is causing cracks at the boundary between aggregates and cement.

III) During casting and vibrating test specimens, rubber particles tend to move toward the top surface of the mould, resulting in high concentration of rubber particles at the top layer of the specimens. This is because of the lower specific gravity of the rubber particles and also due to lack of bonding between rubber particles and the concrete mass. This problem is manifested more clearly in the second mixture. Non-uniform distribution of rubber particle at the top surface tends to produce non-homogeneous samples and leads to a reduction in concrete strength at those parts, resulting to failure at lower stresses.

IV) Lower strength of the second mixture, when compared to the first mixture, is due toreduction in the quantity of cement used as adhesive (i.e. cementing) materials.

V) As rubber has lower stiffness compared to aggregates, presence of rubber particles in concrete reduces concrete mass stiffness and lowers its load bearing capacity. The slight increase in compressive strength of sample containing 5% chipped rubber can be due to improvement of the coarse and fine aggregates grading.

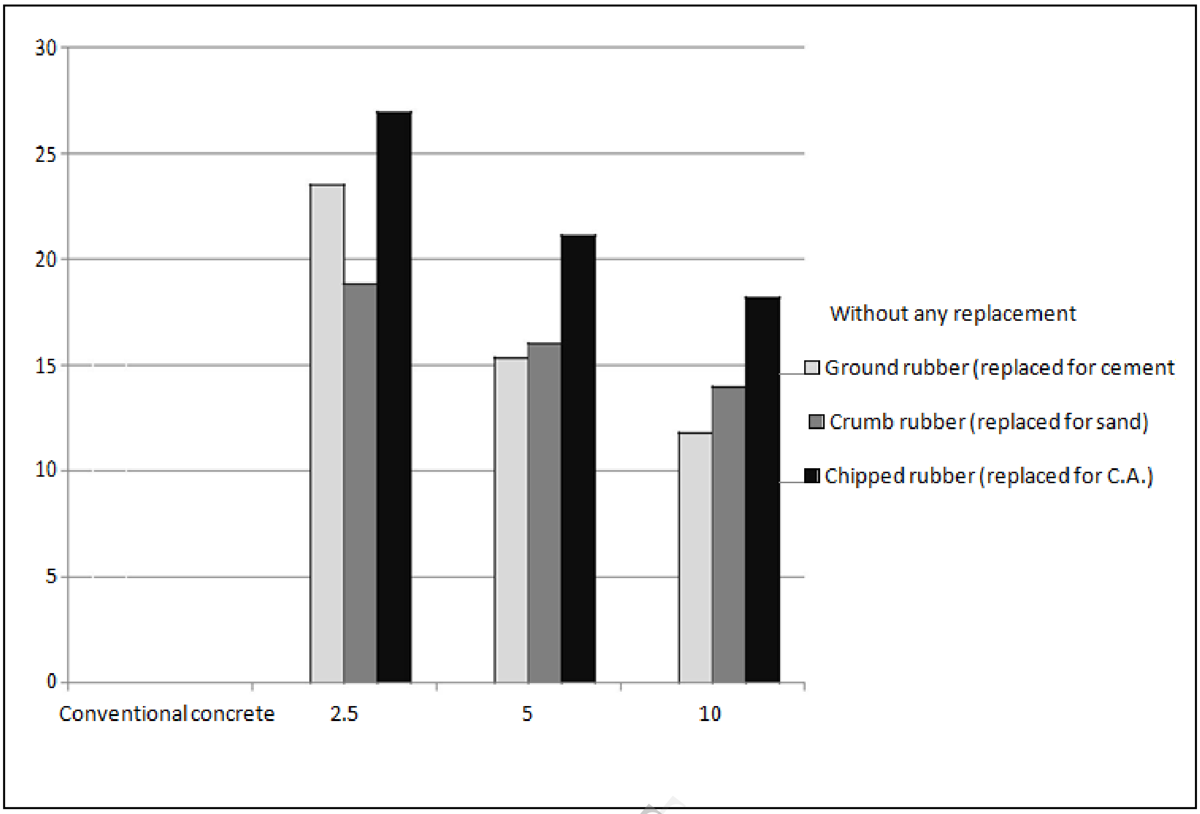

Fig.1 Comparison between Compressive Strength (N/mm^2) of 7 days and Replaced (Percentage by weight)

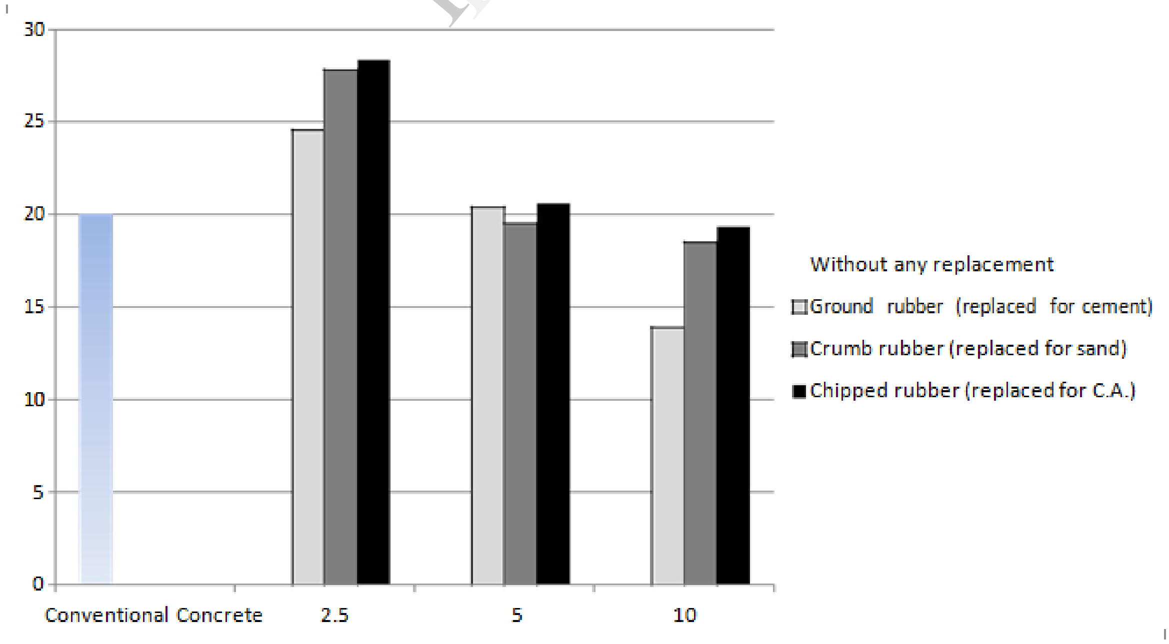

Fig.2 Comparison between Compressive Strength (N/mm^2) of 28 days and Replaced (Percentage by weight)

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4.2 Tensile Strength

The results of tensile strength test are given in Fig 3. Tensile strength of concrete was reduced with replacement of rubber in both mixtures. The percent reduction of tensile strength in the first mixture was about twice that of the second mixture for lower percentage of replacements. Tire rubber as a soft material can act as a barrier against crack growth in concrete. Therefore, tensile strength in concrete containing rubber should be higher than the control mixture. However, the results showed the opposite of this hypothesis.

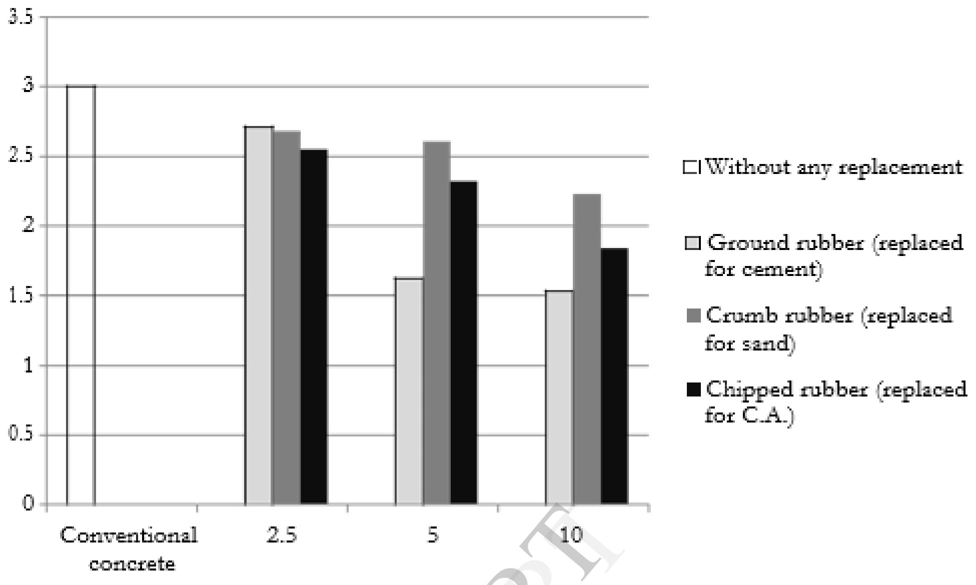

Fig.3 Comparison between Split Tensile Strength (N/mm^2) of 28 days and Replaced (Percentage by weight)

For M15 grade of concrete target compressive strength achieved 23N/mm^2 for conventional concrete. The compressive strength of concrete with replacement of cement, sand and coarse aggregates with 2.5% of ground rubber, crumb rubber and chipped rubber respectively gives better result than conventional and other percentage of replacements. If we increase the percentage of replacements in concrete with rubber waste strength will decrease. The split tensile strength of concrete also gives the better results with replacement of 2.5% of rubber waste.

V. CONCLUSION

The following general findings are based on the laboratory study reported in this report. The specific conclusions that can be drawn from this study are as follows:

- Compressive strength of concrete depended on two factors: grain size of the replacing rubber and percentage added. In general, compressive strength was reduced with increased percentage of rubber replacement in concrete, though with 2.5% replacement of coarse aggregate, sand or cement by rubber, decrease in compressive strength was low (less than 2.5%) without noticeable changes in other concrete properties.
- 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. Tensile strength of concrete containing chipped rubber (replacement for aggregates) is lower than that of concrete containing powdered rubber (for cement replacement).
- From this experimental investigation we found that compressive strength and tensile strength gives better result by replacement of cement, sand, coarse aggregate with 2.5% of rubber.

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