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Partial Replacement of Fine Aggregate by Waste Tyre Crumb Rubber in Porous Concrete

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ABSTRACT

This paper eventually shows the experimental study on the appropriate consumption of refuse tyre crumb rubber in concrete as a replacement for fine aggregate in different percentages along with the use of silica fumes as mineral admixture to alter the bonding properties of the rubberized concrete in a positive way. The use of waste rubber tyre which leads to the protection of environment and also it aids in preserving the natural aggregates. In this study the waste tyre crumb rubber was used as a replacement for natural fine aggregates and was tested for the mechanical properties of M30 grade concrete as per IS 10262-2009. Three different properties of rubberized concrete were tested namely compressive strength, flexural strength and split tensile strength. According to the test results it was noticed that there is decrease in the compressive strength, split tensile strength and flexural strength when the percentage of rubber content is increased as compared to the nominal mix. The percentage replacement of natural fine aggregate with crumb rubber was 5%, 10% and 15%.

***Key words**: Crumb Rubber, Mechanical Properties, Fine Aggregates, Waste Tyre.*

INTRODUCTION

The excess dumping of the waste material is one of the key issues in the whole world. The dumping of the waste tyres is a major matter because this material is very difficult to degrade even after a long time. Waste rubber is also used as raw material for rubber goods. Concrete is made by means of the composition of cement, coarse aggregate and fine aggregate. Among all kinds of construction materials concrete is the most frequently used material. Due to which there is decrease in the natural aggregates. There are several techniques which were proposed for the consumption of waste tyre, one of them is the use of crumb rubber in the concrete as full or partial replacement of coarse aggregates or fine aggregates. But only limited researches have been done till now on the use of waste tyre crumb rubber in concrete [1].

Alteration of building materials has an important role in the building sector. Various numbers of attempts have been thus made in the construction material field to get into use refused waste products like damaged used tyres, into valuable and gainful items. Success in this case will have a great contribution towards the decline of waste material dumping problems by utilization of the waste materials as a raw matter for other construction requirements. As dumping and burning of waste and discarded rubber tyres is a very difficult and pollution producing process [2].

Cement mixture consisted of rubber may be proved sensible to use for basic and nonstructural purpose, for example, lightweight concrete dividers, building exteriors and compositional parts. The consumption of crumb rubber in flimsy concrete is viewed as conceivably critical road. The use of crumb rubber with concrete will be advancement in the structuring of the wall as it will work as shock as well as sound absorber [3]

Need

In the developmental procedures a lot of waste is being produced in which, there lies two categories degradable and non degradable while the rubber tyres falls in the non degradable category thus they cannot be decomposed easily. People however try to decompose this material by dumping them in the ground but this method works only for a limited duration as after sometime they come out of the landfills and get on the top of the surface of land while some people try to decompose them by burning which is even worst as they emit a lot of carbon while burning which results in the increased air pollution [4]. So it is better to put them for the reuse, one of the best way to reuse them is by using them in construction industries as a building material. They can be mixed with concrete to build various structures which will make the disposal of rubber tyres easy as well as productive. The structures made by this composite are good in resisting the ultrasonic waves which highly reduces the damage factor as the rubber particles of the composite act as absorbers. Globally 15 million tonnes of waste is being generated every year , out of which India contribute a million tones ,that's why there is huge need of proper management of these wasted tyres and reusing is the best possible option we have got [5]. Reusing it in the construction companies is the best way to mange this non degradable stuff and get some benefits out of the waste, which is a good sign for mother earth as well [6].

Objective

The process requires a broad laboratory for studying the proportion of crumb rubber in the preparation of rubberized concrete .The motive of the study was to know the strength behavior that is change in compressive, flexural strength and Split tensile strength of rubberized concrete with different percentage of crumb rubber along with the use silica fume as a mineral admixture Parameters varied in investigation as shown below:

1) Firstly, replacement of fine aggregate is done by 5% in the concrete.
2) Then, replacement of fine aggregate is increased to 10% in the concrete.
3) And, At last, 15% fine aggregate is replaced with crumb rubber in the concrete.

Aim

To know the effects on the varying volume of rubber on

1) Compressive Strength
2) Split Tensile Strength
3) Flexural Strength

LITERATURE REVIEW

Eldin and Senouci (2003), on the premise of experimental outcomes, demonstrated that there was around 85% reduction in compressive strength and half reduction in rigidity when the total course was completely replaced by coarse rubber chips. In any case, examples lost up to 65% of their compressive strength and up to half of their rubberity. He likewise demonstrated that when stacked in pressure examples carrying rubber did not show fragile disappointment. The continuous disappointment was watched, both of a part (coarse tire chips) or a shear mode (fine morsel rubber). It was contended that since the bond glue is significantly weaker in strain than in pressure the rubber treated example containing coarse tire chips would begin flopping in strain before it achieves its pressure confine The produced pliable anxiety focuses at the top and base of the rubber totals result in numerous pliable small scale breaks that frame along the tried example. These smaller scale splits will quickly proliferate in the concrete glue. Until they experience and rubber total. On account of their capacity to withstand expansive pliable distortions, the rubber particles will go about as springs deferring the broadening of splits and anticipating whole crumbling of the concrete mass. The constant utilization of compressive load will cause an era of more splits and in addition augmenting of existing ones. Amid this procedure, the coming up short example is equipped for engrossing noteworthy plastic vitality and withstanding expansive miss happenings without full breaking down. This procedure will proceed until the burdens beat the bond between the concrete glue and the rubber totals [7-12].

Neil N. Eldin (2003) 2, broke down the after effects of compressive and part rigid qualities in rubber treated cement following 7 and 28 days curing and watched that there was slightest change in the compressive and rubber qualities between the 7th and 28th day, when the coarse total were supplanted by rubber chips with an expansive volume that is for the examples carrying 75% and 100% tire chips. The decrease of up to 85% of compressive and half of rubberity has been observed when the coarse total was supplanted by rubber. A little decrease was observed when sand was supplanted with piece rubber. The examples showed high limit with regards to retaining plastic vitality under both pressure and strain loadings [13-14].

Topcu (1995) 3, investigated the consequences of pressure tests led on normal and rubber treated concrete. He also observed that the compressive strength of standard cement gotten from 3D shape tests is higher than that acquired from barrel tests. In any case, the outcomes regarding rubber treated cements out of the blue demonstrated the turn around15. This shows the mechanical strength of rubber treated mixture is extraordinarily influenced with the size, extent, surface of rubber particles and the sort of concrete utilized as a part of such mixture [15-17].

Goulias and Ali (1997) 9,on premise of test outcomes utilizing diverse parameters, it was discovered that dynamic moduli of flexibility and inflexibility diminished with an expansion of the rubber substance, demonstrating that a less concrete and less fragile material was acquired. The damping limit of cement (a measure of the capacity of the material to diminish the adequacy of free vibrations in its body) appeared to diminish with an expansion of the rubber substance [16].

On the other hand, Topcu and Avcular (1997a) and Fatuhi and Clark (1996) suggested utilizing rubber treated cements in conditions where vibration damping is required, for example, in structures as a tremor stun wave safeguard, in establishment cushions for apparatus, and in railroad stations. After effects of Poisson's proportion estimations showed that barrels with 20% rubber had a bigger proportion of horizontal strain to the comparing pivotal strain than that of 30% rubber concrete chambers (Goulias and Ali 1997a). It was additionally discovered (Goulias and Ali 1997) that the higher the rubber substance, the higher the proportion of dynamic modulus of flexibility to the static modulus of versatility [17]. The dynamic modulus was then found with compressive strength, giving a high level of relationship between's the two parameters. This recommends nondestructive estimations of the dynamic modulus of versatility might be utilized for evaluating the compressive strength of rubber treated [18-19]. A decent relationship between's compressive strength and the damping coefficient figured from transverse recurrence was additionally discovered, demonstrating that the damping coefficient of rubber treated may moreover be utilized for anticipating the compressive strength [20]. Consequently more research is required before such suggestions can be made.Topcu and Ozcclikors (1991) demonstrate that 10% rubber chips expansion expanded the strength of cement by 23%.They likewise researched the workability of rubber treated mixture [21-22]. They watched a reduction in droop with expanded rubber substance by aggregate total volume. Their outcomes demonstrated that at rubber substances of 40% by aggregate total volume, the droop was close to 0 and the concrete was not workable by hand. Such type of mixture must be compacted utilizing a mechanical vibrator. Mixture containing fine piece rubber was, in any case, more workable than mixture containing either coarse tire chips or morsel rubber or a mix of them [23-24].

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 1μm. 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:

Table 1 Mixing Proportion

Units of batch	Water (lts)	Cement (kg)	F.A (kg)	C.A (kg)	Mineral admixture (kg)
Cubic meter	170	434.8	843.42	1074.08	3.319
Ratio	0.31	1	1.94	2.47	0.0076

Table 2. Mix Composition for Different Percentages of Crumb Rubber

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

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/mm^2. After that the fine aggregate was replaced with 5%, 10% and 15% crumb rubber by weight of fine aggregates. The detailed description is in the table 2.

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/mm^2)
		P	=	Maximum load (N)

A = Cross section area of cube (mm^2)

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 = 2PЛ l 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

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/mm^2)	5% CR	26.24	28.02
	10% CR	24.03	26.05
	15% CR	18.36	20.67
Split tensile strength(N/mm^2)	5% CR	6.08	7.33
	10% CR	5.68	6.44
	15% CR	5.35	6.01
Flexural strength(N/mm^2)	5% CR	9.70	10.03
	10% CR	8.91	9.83
	15% CR	7.03	8.49

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.
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

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.

3) 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.
4) For larger percentage of rubber in concrete, the decline rate of compressive strength is higher than normal concrete.
5) Better results were obtained when 5% of rubber is used for substituting the natural aggregate in the rubberized concrete.

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