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Experimental Behaviour of Waste Rubber Replaced in Hollow Block

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Abstract— Our environment is subjected to many hazards and pollutants which is expanding and polluting in a very serious manner. One such thing is disposal of non-degradable waste on the environment. It has been stated that volume of polymeric wastes like rubber tyres and PET bottles [Polyethylene Terephthalate] is rapidly increasing in recent times. Waste rubber tyres is one among the crucial environmental hazard due to rapid increase of automobile production, leading in accumulation of waste of used rubber tyres. They are recycled rarely and others are just land-filled or stockpiled. For this reason, various efforts have been made to recognize the unrealized, application of rubber obtained from the waste tyres in civil engineering innovations. Interestingly, these rubber materials are made into pieces and are used as an aggregate replacement. By incorporating them as building material, it has an added benefit of saving the aggregates obtained naturally which are used in greater amounts for producing concrete, creating scarcity of aggregates. On this note, our study aims in usage of rubber tyres as partial aggregate replacement. This paper reviews the performance of the hollow block made by integrating the pieces of discarded rubber tyres as aggregate replacement in various proportions. A great number of projects are available on aggregate replacement by rubber in concretes, but this paper deals with the rubber replacement in hollow block. Thus, different percentage of replacement of rubber are casted and tested for its compressive strength after they are cured for 3 days,7 days and 28 days. The test results were recorded and analyzed when they are subjected to aggregate replacement by rubber. After series of examinations and discussions, their results are concluded.

Keywords: Environment, aggregate replacement, hollow blocks, rubber tyres.

I. Introduction

In recent times, the disposal and handling of non-biodegradable waste has become a chaotic problem in waste management process. And one such material is rubber waste which include worn out tyres and other rubber materials. Based on the data provided by the Environmental Protection Agency (EPA), it states that almost 270,000,000 million waste tyres are produced each year. All these wastes will ultimately come into the landfills and dumps which are very exorbitant and less in number in recent days. The rubber tyres are bulky with void space of almost 75%, which makes them difficult to compress thereby making the landfill unstable and ultimately break their covers. They also affect the groundwater table and reduce their level. Therefore, the dumping of these wastes into the landfills generates a remarkable pressure among the local government bodies while handling them.

Rubber has excellent durability, elasticity and flexible properties which makes them an ideal material to manufacture tyres. Interestingly, these properties also make them difficult to breakdown and decompose. Hence, there is a need of finding an alternative way instead of dumping them in landfills.

Transforming these rubber tyres in a beneficial product will be a righteous way to the environment we live in. This involves the shredding of rubber types into various different forms such as shreds, chips and crumbs. The scarp rubber tyres are classified into many types such as Asphalt Rubber, Asphalt Rubber Blend, Granulated Crumb Rubber Modifier, Crumb Rubber Modifier and Vulcanized Rubber. These products can be used as fillers but they are bounded to low percentages thus they are used only in low-end products. An attempt to recover the constituent part in these rubber products by thermal decomposition process was found, but they were ultimately dropped because their commercial scale method was not resolved satisfactorily.

After analyzing all the results, the recycling was the best method for utilizing these rubber wastes. It is the process where the worn out products and their effluents are collected and treated for making a new product. The non-availability of sufficient raw material, greater transportation cost in their purchase, any industrialist will opt for ways to recycle the waste obtained after the process. Thus the recycling process reduces the shortage of raw materials and also provides us a healthy environment, free from pollution.

Hollow blocks have increased in popularity due to their properties to reduce construction cost, good bonding of mortar and plaster due to their rough surface, more durable and so on. In today's modern world we aim on sustainable development which uses the variety of materials from the industrial wastes and other wastes in the construction industry. There are many types of system available, which can be categorized depending on the flexibility and resistance to cracking such as Rubber Filled Concrete (RFC), Stress Absorbing Membrane (SAM), Stress Absorbing Membrane Inter layer (SAMI), Two-layer system, Three-layer system.

The recycled rubber from waste is a potential material in construction field due to its properties which include sound and heat insulating properties, light weight, elasticity, energy absorption, they are replaced for the fine and coarse aggregate by weight using different percentage. [1] In the concrete containing high ratio of rubber replacement of coarse aggregate, the examination of deforming agent is done. The results states that, although the deforming agent reduce air to a greater extent, increase in compressive strength was not found. [2] The statistical data proved that despite a huge loss in strength, they still can be used for the areas where medium to low compressive strength is required. Therefore, the use of rubbers from the scrap tyres in the concrete is an additional way for used tyres. [3] The rubber replaced concrete's compressive strength depends on the quantity and size of the added rubber materials. The results also concluded that compressive strength gets reduced when the size of rubber particles are small and the quantity of rubber added is high. The compressive strength reduces with higher rubber waste content and smaller rubber particle size. The porosity of matrix shows an increase when the addition of rubber waste additive to cement matrix. [4]

II. Materials Used

A. Cement

The type of cement used for this hollow block manufacturing is locally available Ordinary Portland Cement (OPC). OPC are classified into three types namely grade 33,43 and 53, depending upon their strength they achieve at the end of 28 days. In this experimental analysis, grade 53 cement is used. The cement was tested to match the properties proposed by the Indian Standards, IS: 4031–1988 and IS: 12269–1987. The various properties test result was shown in Table. 1.

Table 1. Properties of Cement

Properties	Value
Specific gravity	3.25
Fineness	2%
Standard consistency	34%
Initial setting time	35 min
Final setting time	6 hours

B. Waste tyre rubber:

The scrap tyres are obtained from the local recycling units where scrap tyres where the source of rubber is readily available. The rubber obtained from the scrap tyres are not identical in their dimensions. Therefore, they are made into similar and homogeneous sizes before they are used in casting of hollow blocks. The obtained rubber can be categorized into three main categories-ground rubber, crumb rubber and chipped rubber. In the above mentioned categories the chipped or shredded rubber are used here as partial replacement of the coarse aggregate in the hollow blocks. Initially, the rubber particles are made into sizes with high irregularity. The further processing of the rubber particles allows them to produce in the desired sizes, which ranges from 0.426-4.75 mm. Figure 1 shows the rubber obtained from the scrap tyres and Figure 2 shows the required size of the rubber which ranges about 4.75mm.

Figure 1. Waste tyre rubber

Figure 2. Size of rubber 4.75mm

Table 2 and Table 3 conveys the physical and chemical properties of the waste tyre rubber respectively.

Table 2. Physical Properties of waste tyre rubber

Properties	Range
Specific Gravity	1.06-1.1
Specific Heat	0.28-0.35 cal/gr/°C
Molecular Weight	$3x10^5$ - $1x10^5$
Hydraulic conductivity	0.2-0.85 cm/s
Thermal Expansion	5.9 - $7.9x10^4$ /°C
Thermal Conductivity	$0.330\text{-}0.515x10^3$g-cal/s/cm/°C
Dynamic Viscosity	500-250000mPa
Ductility	80-158mm
Flammability	582°F
Thermal insulation	0.0838-0.147 cal/m-hr-°C
Moisture absorption	2-4 %
Stability temperature	200°C
Heat temperature	150-316°C
Density	7.51 bs/cu.foot

Table 3. Chemical properties of waste tyre rubber

Properties	Range
Angle of friction	15-32°
Cohesion	349-394 N/mm^2
Total Organic Carbon	22.7-3.1 ppm
Turbidity	254-00 NTU
Gradation	50-300 mm
Softening Point	38-125°C
Breaking Point	12-30°C
Colour	Black
Penetration	15-25000.1 mm
Chemical Degradation	100-300°C
Mechano-Chemical Desperation	100-200°C

III. MIX DESIGN

The raw materials involved in the fabricating the waste tyre rubber hollow blocks are OPC Cement, Crusher powder, Waste tyre Rubber, Fine and Coarse Aggregate and water. Table 4 shows the various mix proportion for different percentage of replacement is tabulated below.

Table 4. Mix Proportion for various percentage of replacement of tyre

Ingredients	Mix Proportion(%)						
Crusher chips	55	50	45	40	35	30	25
Crusher Powder	35	35	35	35	35	35	35
Cement	10	10	10	10	10	10	10
Tyre	0	5	10	15	20	25	30

The size of the hollow block is 400x200x200mm.The ratio of mix proportion adheres to 1:1.506:3.27. This mix ratio enables us to obtain any desired number of blocks in single moulding process. Primarily, the crusher powder, crusher chips and the cement are mixed together with preferred water-cement ratio. The waste rubber is also used as partial replacement of coarse aggregate in desired percentage (i.e., 5%,10%,15%,20%,25% and 30%).The varying ratio of waste rubber material used in this mix design is shown in the Table 5.

Table 5. Ratio for the replacement of the fine aggregates

Percentage of rubber replaced on fine aggregate	Volume of rubber material (Kg/m3)	Volume of crusher powder (Kg/m3)	Volume of crusher chips (Kg/m3)	Volume of cement (Kg/m3)
0	0	3	4.00	0.50
5	0.05	2.875	4.00	0.50
10	0.10	2.75	4.00	0.50
15	0.15	2.50	4.00	0.50
20	0.20	2.425	4.00	0.50
25	0.25	2.35	4.00	0.50
30	0.30	2.25	4.00	0.50

A total of 21 number of blocks out of which three are conventional hollow blocks are casted and are cured. The conventional hollow blocks are casted to compare the differences in the strength and material properties of conventional hollow bricks to the bricks obtained by the replacement of the waste tyre rubber.

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete works. One of the purposes of testing hardened concrete is to confirm that the concrete used at the site has developed the required strength.

IV. Results and Discussion

A. Compressive Strength

The minimum compressive strength of the hollow bricks as stated by the BIS is about 3.5 N/mm2.This compressive strength of the hollow blocks is determined by using the compressive testing machine, having a capacity of 2000kN.Rate of loading used for concrete specimen is 315 KN/min (5KN/sec) as per IS:516. Constant rate of loads are applied by the machine to the hollow blocks until failure occurs. Scrutinize the loads and note the maximum load at failure.
Compressive strength of bricks = maximum load (n) / average area of samples (mm2).
The hollow bricks are tested for the compression in are the bricks which have undergone curing for 3days,7 days and 28 days to record the strength at different curing stages. Table 6,7 and 8 shows the compressive strength of the hollow bricks of varied ratio of rubber replacement at the end of 3 days,7 days and 28 days respectively.

Table 6. Compressive strength of the hollow bricks at the end of 3 days of curing

Percentage in replacement (in %)	Age of test (day)	Compression Load at failure (kN)	Compression Strength (N/mm^2)
0	3	115	1.43
5	3	114	1.42
10	3	110	1.37
15	3	107	1.33
20	3	104	1.30
25	3	101	1.26
30	3	98	1.22

Table 7. Compressive strength of the hollow bricks at the end of 7 days of curing

Percentage In Replacement (%)	Age of Test (day)	Size of Cube (mm)	Compression Load at Failure (KN)	Compression Strength (N/mm2)
0	7	400x200 x200	135	1.69
5	7	400x200 x200	134	1.68
10	7	400x200 x200	130	1.62
15	7	400x200 x200	128	1.60
20	7	400x200 x200	123	1.54
25	7	400x200 x200	117	1.46
30	7	400x200 x200	114	1.42

Table 8. Compressive strength of the hollow bricks at the end of 28 days of curing

Percentage in Replacement (%)	Age of Test (day)	Size of Cube (mm)	Compression Load at Failure (KN)	Compression Strength (N/mm^2)
0	28	400x200x200	157	1.96
5	28	400x200x200	155	1.94
10	28	400x200x200	150	1.87
15	28	400x200x200	146	1.82
20	28	400x200x200	141	1.76
25	28	400x200x200	138	1.72
30	28	400x200x200	135	1.68

Regular results to be described at 7 and 28 days the compressive strength of the bricks was found to be 1.68 N/mm2 and 1.90 N/mm2 respectively. Three samples were tested for each compound the average of the three results of each combination is considered for comparison of results.

Figure 3. Compression test on hollow blocks

From the analysis of the result of compressive strength of various proportions of hollow blocks are:
The 5% replacement of rubber in fine aggregate in the hollow block responded well in compressive strength. It is very much equal to the conventional hollow block.
The 10% replacement of rubber in fine aggregate in the hollow block shows minor variation in compressive strength to the conventional hollow block.
The 15% replacement of rubber in fine aggregate, the hollow block shows the10% declination in compressive strength to the conventional hollow block.
The 20% replacement of rubber in fine aggregate, the hollow block shows the 12% declination in compressive strength to the conventional hollow block.
The 25% replacement of rubber in fine aggregate, the hollow block shows the 15% declination in compressive strength to the conventional hollow block.
The 30% replacement of rubber in fine aggregate, the hollow block shows the 20% declination in compressive strength to the conventional hollow block.
Figure 4,5 and 6 shows the variation of compressive strength attained by the hollow blocks containing rubber at various proportions after 3 days,7 days and 28 days of curing respectively.

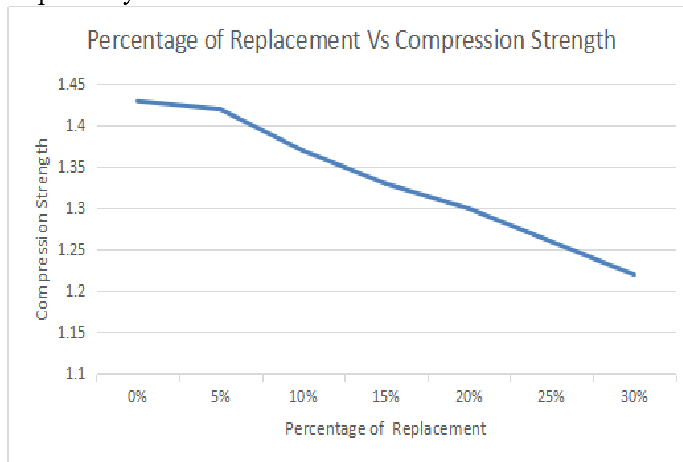

Figure 4. Graph showing the variation of compressive strength after 3 days of curing

The 5% replacement of rubber in fine aggregate in the hollow block responded well in compressive strength. It is very much equal to the conventional hollow block.
The 10% replacement of rubber in fine aggregate in the hollow block shows minor variation in compressive strength to the conventional hollow block.

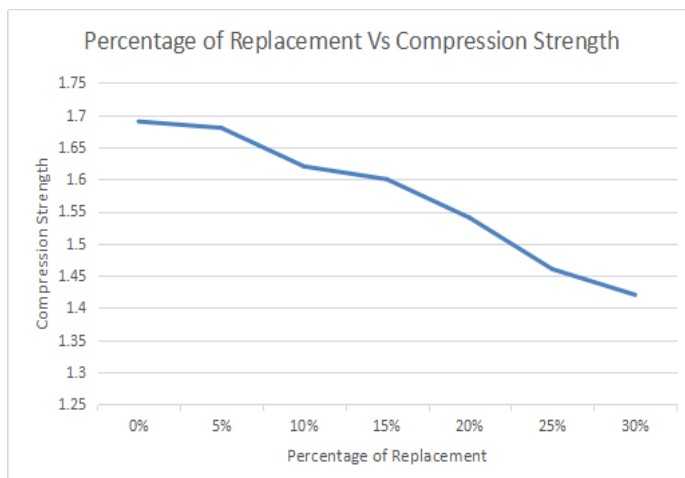

Figure 5. Graph showing the variation of compressive strength after 7 days of curing

The 15% replacement of rubber in fine aggregate, the hollow block shows the10% declination in compressive strength to the conventional hollow block.
The 20% replacement of rubber in fine aggregate, the hollow block shows the 12% declination in compressive strength to the conventional hollow block.
The 25% replacement of rubber in fine aggregate, the hollow

block shows the 15% declination in compressive strength to the conventional hollow block.

The 30% replacement of rubber in fine aggregate, the hollow block shows the 20% declination in compressive strength to the conventional hollow block.

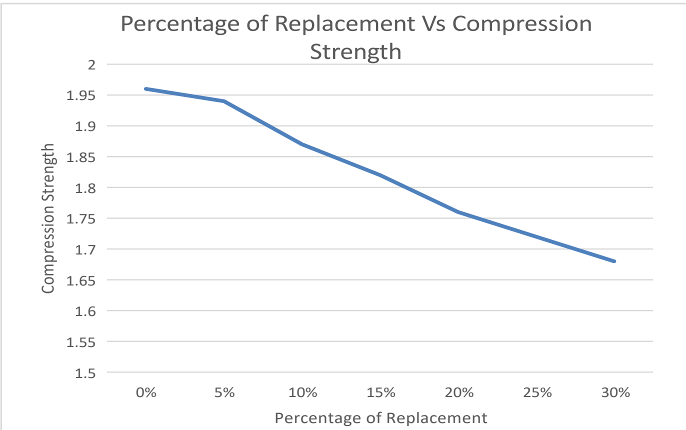

Figure 6. Graph showing the variation of compressive strength after 28 days of curing

Replacing waste tyre rubber up to 5% in the fine aggregate of hollow block masonry is affordable. Thus it can be used for both load bearing and non load bearing structures.

Replacing 10% in the fine aggregate is suggested for minor loaded area and recommended for non-load bearing walls.

Replacing 15% to 30% is not comfortable for load bearing structures and hence it can be used for compound walls, flooring for the ground and pavements for garden.

V. Conclusion

Out of all the tests that were conducted and the analysis of the obtained statistics, replacing the rubber obtained from the scrap tyres up to 5% in the fine aggregate is highly appreciable. They show the best results and also make the hollow block masonry very affordable. Replacing 5% of fine aggregate with the rubber suits for both load bearing and non-load bearing structures. When we replace them for 10%, the test results shows that they are not ideal for load bearing structures. They are suggested for non-load bearing walls and areas where the applied load is minimum. Results state that replacing the rubber for more than 10% is not capable for load bearing structures. So, replacement percentage ranging from 15% -30% are much preferred in the construction of compound walls, pavements for garden and for flooring the ground. From all the above data, it can be concluded that by adopting the percentage of replacement ranging from 5-10% is highly efficacious. In addition to the above achieved properties, they also reduce the production cost of the hollow blocks, thereby making them very affordable. On that account, utilizing the rubber obtained from waste tyres will be very great and effective approach to produce hollow blocks in a most economical and environmental-friendly way.

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