

Potential Pathway of using Rubber Tyre as a Fine Aggregates in Manufacture of Hollow Blocks

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Abstract— Numerous risks and pollutants are present in our environment, and they are seriously expanding and polluting it. The effects of disposing of non-biodegradable waste are one example. The amount of polymeric wastes, including rubber tyres and PET bottles (Polyethylene Terephthalate), has reportedly been rising quickly in recent years. Waste rubber tyres are one of the most serious environmental hazards because of the quick rise in automobile production, which causes an accumulation of waste from used rubber tyres. Rarely are they recycled, and others are simply disposed of or piled up. Due to this, numerous initiatives have been made to recognise the untapped potential of rubber made from used tyres in new developments in civil engineering. The interesting thing about these rubber materials is that they are cut into pieces and used to replace aggregate. By using them as building materials, it also has the added advantage of conserving the naturally obtained aggregates, which are in short supply because they are used in greater quantities to make concrete. In light of this, our study will examine the use of rubber tyres to replace some of the aggregate. The performance of the hollow block produced by incorporating scraps of used rubber tyres as aggregate replacement in varying ratios is examined in this paper. Although there are many projects on replacing aggregate in concrete with rubber, this paper focuses on replacing rubber in hollow blocks. As a result, after curing for 3, 7, and 28 days, various percentages of replacement rubber are cast and tested for their compressive strength. When aggregate was substituted for rubber, the test results were noted and analysed. The findings are reached after a series of tests and discussions.

Keywords: Environment, aggregate replacement, hollow blocks, rubber tyre waste

I. INTRODUCTION

In recent times, the disposal and handling of non-biodegradable waste has become a chaotic problem in the waste

management process. And one such material is rubber waste, which includes 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 tonnes of waste tyres are produced each year. All of these wastes will eventually end up in landfills and dumps, which are extremely expensive and have been decreasing in number in recent years. The rubber tyres are bulky, with a void space of almost 75%, which makes them difficult to compress, thereby making the landfill unstable and ultimately breaking their covers. They also affect the groundwater table and reduce its level. As a result, the dumping of these wastes into landfills creates a significant amount of pressure on the local government bodies in charge of handling them.

Rubber has excellent durability, elasticity, and flexibility properties, which makes it an ideal material to manufacture tires. Interestingly, these properties also make them difficult to breakdown and decompose. Hence, there is a need to find an alternative to dumping them in landfills.

Transforming these rubber tyres into useful products is a moral way to protect the environment in which we live. This involves the shredding of rubber types into various different forms, such as shreds, chips, and crumbs. There are several types of scarp rubber tyres, including asphalt rubber, asphalt rubber blend, granulated crumb rubber modifier, crumb rubber modifier, and vulcanised rubber. These products can be used as fillers, but they are bound to low percentages, so they are used only in low-end products. An attempt to recover the constituent parts in these rubber products by thermal decomposition was found, but they were ultimately dropped because their commercial scale method was not resolved satisfactorily.

After analysing all the results, recycling was the best method for utilising these rubber wastes. It is the process where worn-out products and their effluents are collected and treated for use in

making a new product. Because of the scarcity of raw materials and the higher transportation costs associated with their acquisition, any industrialist will look for ways to recycle the waste generated by the process. Thus, the recycling process reduces the shortage of raw materials and also provides us with a healthy environment free from pollution.

Hollow blocks have increased in popularity due to their properties to reduce construction costs, the good bonding of mortar and plaster due to their rough surface, being more durable, and so on. In today's modern world, we aim for sustainable development, which uses a variety of materials from industrial waste and other waste in the construction industry. There are many types of systems available, which can be categorised depending on the flexibility and resistance to cracking, such as rubber-filled concrete (RFC), stress-absorbing membranes (SAM), stress-absorbing membrane interlayers (SAMI), two-layer systems, and three-layer systems.

The recycled rubber from waste is a potential material in the construction field due to its properties, which include sound and heat insulating properties, light weight, elasticity, and energy absorption. They are replaced for the fine and coarse aggregates by weight using different percentages[1-4]. The defoaming agent is examined in concrete with a high ratio of rubber replacement in the coarse aggregate. The results state that, although the defoaming agent reduced air to a greater extent, an increase in compressive strength was not found[5-9]. The statistical data proved that despite a huge loss in strength, they can still be used in areas where medium-to-low compressive strength is required. As a result, using rubber from scrap tyres in concrete is another application for used tyres[10]. The rubber-replaced concrete's compressive strength depends on the quantity and size of the added rubber materials. According to the findings, compressive strength decreases when rubber particles are small and there is a lot of rubber added. With increasing rubber waste content and smaller rubber particle size, the compressive strength declines. The cement matrix's porosity is increased by the addition of rubber waste as an additive [11-13].

II. MATERIALS USED

A. Cement

The cement used in the production of these hollow blocks is a locally available ordinary Portland cement (OPC). OPC are classified into three types, namely grades 33, 43, and 53, depending upon the 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). Table 1 displays the results of the various property tests.

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:

Scrap tyres are obtained from local recycling units, where they are readily available as a source of rubber. The rubber obtained from the scrap tyres is not identical in its dimensions. Therefore, they are made into similar and homogeneous sizes before they are used in the 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, chipped or shredded rubber is used here as a 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 the desired sizes, which range from 0.42 to 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 around 4.75 mm [14-15].



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	3×10^5 - 1×10^5
Hydraulic conductivity	0.2-0.85 cm/s
Thermal Expansion	$5.9 - 7.9 \times 10^4$ /°C
Thermal Conductivity	$0.330-0.515 \times 10^3$ 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 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 proportions for different percentages of replacement.

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

Ingredients	Mix Proportion (%)						
	55	50	45	40	35	30	25
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 hollow block measures 400x200x200mm. The ratio of mix proportions adheres to 1:1.506:3.27. This mix ratio enables us to obtain any desired number of blocks in a single moulding process. Primarily, the crusher powder, crusher chips, and cement are mixed together with the preferred water-cement ratio. The waste rubber is also used as a partial replacement of coarse aggregate in the 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 Table 5.

Table 5. Ratio for the replacement of the fine aggregates

Percentage of rubber replaced on fine aggregate	Volume of rubber material (Kg/m ³)	Volume of crusher powder (Kg/m ³)	Volume of crusher chips (Kg/m ³)	Volume of cement (Kg/m ³)
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 blocks are casted and cured, three of which are conventional hollow blocks. The conventional hollow blocks are cast to compare the differences in the strength and material properties of conventional hollow bricks to the bricks obtained

by the replacement of waste tyre rubber[16-18].

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, which has a capacity of 2000 kN. The rate of loading used for a concrete specimen is 315 kN/min (5 kN/sec) as per IS 516. The machine applies a constant rate of loads to the hollow blocks until failure occurs. Scrutinize the loads and note the maximum load at failure.

The compressive strength of bricks is equal to the maximum load (N) divided by the average area of the samples (mm²).

The hollow bricks that are tested for compression are the bricks that have undergone curing for 3 days, 7 days, and 28 days to record the strength at different curing stages. Tables 6, 7, and 8 show the compressive strength of the hollow bricks with a 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/mm ²)
0	7	400x200x200	135	1.69
5	7	400x200x200	134	1.68
10	7	400x200x200	130	1.62
15	7	400x200x200	128	1.60
20	7	400x200x200	123	1.54

25	7	400x200x200	117	1.46
30	7	400x200x200	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



Figure 4. Compression test on hollow blocks

The following are the results of the compressive strength analysis of various proportions of hollow blocks:

In terms of compressive strength, the 5% rubber replacement in fine aggregate in the hollow block performed well. It is very much equal to the conventional hollow block. The 10% replacement of rubber in fine aggregate in the hollow block shows a minor variation in compressive strength compared to the conventional hollow block. With the 15% replacement of rubber in fine aggregate, the hollow block shows a 10% decline in compressive strength compared to the conventional hollow block. With a 20% replacement of rubber in fine aggregate, the hollow block shows a 12% declination in compressive strength compared to the conventional hollow block. With a 25% replacement of rubber in fine aggregate, the hollow block shows a 15% declination in compressive strength compared to the conventional hollow block. With the 30% replacement of rubber in fine aggregate, the hollow block shows a 20% declination in compressive strength compared 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.

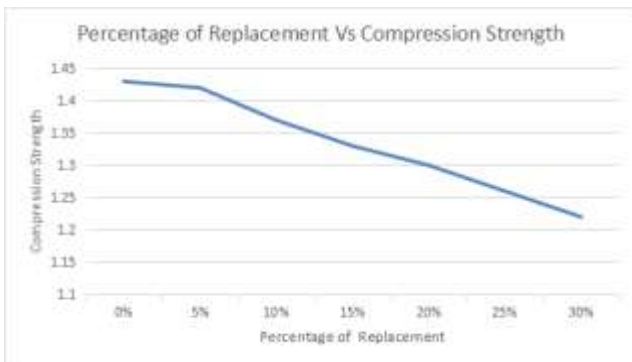


Figure 5. Graph showing the variation of compressive strength after 3 days of curing

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 [19].

The 10% replacement of rubber in fine aggregate in the hollow block shows minor variation in compressive strength to the conventional hollow block.

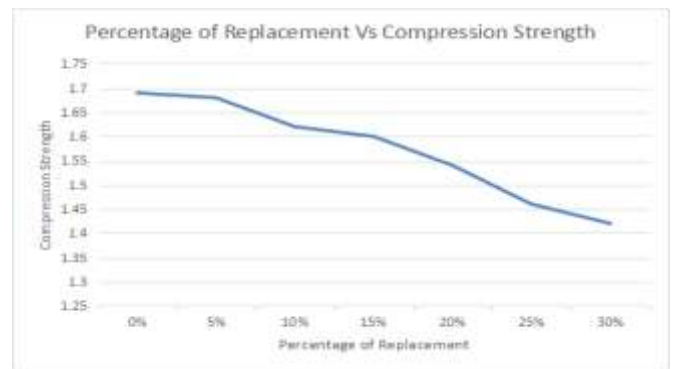


Figure 6. Graph showing the variation of compressive strength after 7 days of curing

The 15% replacement of rubber in fine aggregate, the hollow block shows the 10% 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.

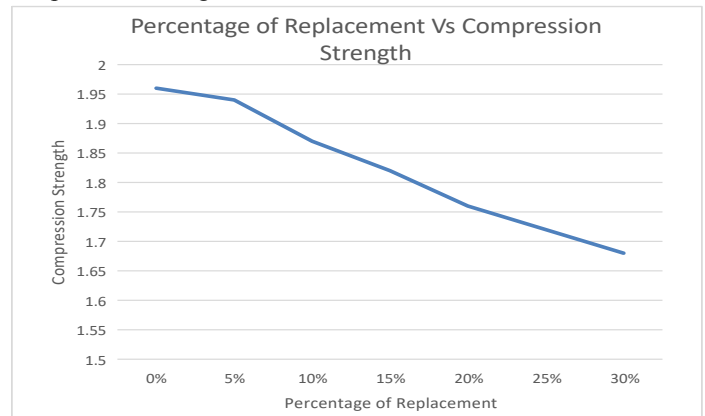


Figure 7. Graph showing the variation of compressive strength after 28 days of curing

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 [20].

V. CONCLUSION

Out of all the tests that were performed and the statistics that were analyzed, replacing the rubber obtained from scrap tyres up to 5% in the fine aggregate is highly commendable. They show the best results and also make hollow block masonry very affordable. Replacing 5% of the fine aggregate with the rubber suits is appropriate for both load-bearing and non-load-bearing structures. When we replace them with 10%, the test results show that they are not ideal for load-bearing structures. They are suggested for non-load-bearing walls and areas where the applied load is minimal. Results state that replacing the rubber by more than 10% is not capable of supporting load-bearing structures. So, replacement percentages ranging from 15%–30% are much preferred in the construction of compound walls, pavement for gardens, and flooring for the ground. Based on the data presented above, it is possible to conclude that a replacement percentage of 5-10% is highly effective. In addition to the above-mentioned properties, they also reduce the production cost of the hollow blocks, thereby making them very affordable. As a result, utilising the rubber obtained from waste tyres will be a very good and effective method of producing hollow blocks in a cost-effective and environmentally friendly manner.

REFERENCES

- [1] Balaji G, Vetturayasudharsanan R (2019) "Experimental investigation on flexural behaviour of RC hollow beams", *Materials today: proceedings* 2019, <https://doi.org/10.1016/j.matpr.2019.05.461>.
- [2] Vetturayasudharsanan R, Balaji G (2019) "Feasibility study on triangular perfo-bond rib shear connectors In composite slab ", *Materials today: proceedings* 2019.
- [3] Ali Alsaman, Canh N. Dang, Gary S. Prinz, and W. Micah Hale (2017) "Evaluation of modulus of elasticity of ultra-high performance concrete", *Construction and Building Materials*, Vol. No. 153, pp 918–928.
- [4] Andrew Fahim, Edward G. Moffatt and Michael D.A. Thomas "Performance of high-volume fly ash concrete in marine environment", *Cement and Concrete Research*, Vol. No. 102 pp, 127–135.
- [5] Birgit Funk, Reinhard Trettin, and Henning Zoz (2017) "From slag to high performance concrete – Manufacturing FuturBeton", *Materials Today: Proceedings* 4, pp S81–S86.
- [6] Chen.J.J, Ng .P.L, Li .L.G and Kwanc .A.K.H (2017) "Production of high-performance concrete by addition of fly ash microsphere and condensed silica fume", *Procedia Engineering* Vol. No. 172, pp 165 – 171.
- [7] Hor Yin, Wee Teo, and Kazutaka Shirai (2017) "Experimental investigation on the behaviour of reinforced concrete slabs strengthened with ultra-high performance concrete", *Construction and Building Materials* Vol. No. 155, pp 463–474.
- [8] IS: 383-1970, "Specifications for Coarse and Fine aggregate from Natural Sources for Concrete", Bureau of Indian Standards, New Delhi, India.
- [9] IS: 456-2000, "Indian Standard Code for Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, India.
- [10] IS: 516-1959, "Indian Standard Code for Practice- Methods of Test for Strength of Concrete", Bureau of Indian Standards, New Delhi, India.
- [11] IS: 10262-2000, "Recommended Guidelines for Concrete Mix Design", Bureau of Indian Standards, New Delhi, India.
- [12] IS: 12269-1987, "Specifications for 53-Grade Portland Cement", Bureau of Indian Standards, New Delhi, India.
- [13] Jacek Gołaszewski and Tomasz Ponikiewski (2014) "The influence of high-calcium fly ash on the properties of fresh and hardened self-compacting concrete and high performance self-compacting Concrete", *Journal of Cleaner Production* Vol. No. 72, pp 212-221.
- [14] Maha M.S. Ridha, Nagham T.H. Al-Shafi, and Milad M. Hasan (2017) "Ultra-high performance steel fibers concrete corbels: Experimental investigation", *Case Studies in Construction Materials* 7, pp 180–190.
- [15] Miao Ren, Tiefeng Chen and Xiaojian Gao (2018) "Effects of autoclave curing and fly ash on mechanical properties of ultra-high performance concrete", *Construction and Building Materials* Vol. No. 158, pp 864–872.
- [16] Govindan, B., Ramasamy, V., Panneerselvam, B., & Rajan, D. (2022). Performance assessment on bamboo reinforced concrete beams. *Innovative Infrastructure Solutions*, 7(1), 1-13.
- [17] Balaji, G., & Dineshkumar, R. (2020). Experimental Investigation on High Performance Concrete with Silica Fume and Combination of Coconut Shell and Egg Shell Ash as Mineral Admixture. *ADALYA JOURNAL*, 9(1), 403-407.
- [18] Balaji, G. (2016). ArivuThiravida Selvan V and Maniarasan SK (2016), 'Study on Structural Behaviour of RC Hollow Beams'. *International Journal of Innovative Research in Engineering Science and Technology*, Special Issue, 38-43.
- [19] R. Vetturayasudharsanan, G. Balaji, P. Balamurugan, and R. Dineshkumar, "Analytical study of triangular perfo-bond shear connectors," *Innovative Infrastructure Solutions*, vol. 6, no. 2, p. 115, 2021.
- [20] Balaji G and Vetturayasudharsanan R (2018), 'Experimental Study on Fly Ash Based slurry Infiltrated Fiber Concrete Beam Incorporate with Lathe Waste', *International Journal of Emerging Trends in Science and Technology*, Volume 4, Issue 2, pp 5-8.