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Influence of the Partial Sand Replacement with Crumb Rubber in Masonry Blocks

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Research Article

Abstract

This study used rubber crumbs conforming to ASTM D5603 and D5644 specifications, which were sourced from Fagor LGA, Kano State, Nigeria. Adhere to BS standard specifications, using a 1:4 mix ratio and a 0.5 water-to-cement ratio, batching and mixing took place. According to BS 1881 Part II 1983, at 0%, 3%, 6%, and 9% displacement, the compressive strengths of the test blocks on day 7 and day 28 were 3.40, 3.00, 2.73, and 2.51 N/mm^2, respectively, and 5.21, 4.19, 3.73 and 3.46 N/mm^2. The values obtained were all within the acceptable strength range required for the blocks, i.e., the average compressive strength of the medium, medium weight, hollow, or solid concrete blocks ranged from 2.5 N/mm^2 to 7.5 N/mm^2. At the replacement rates of 0%, 3%, 6%, and 9%, the weights of the test blocks at seven days were: 1629.7, 1591.9, 1551.9, and 1469.9 kg, respectively. Likewise, on day 28, the body weights became 1575.1 kg, 1476.9 kg, 1366.7 kg, and 1297.6 kg at replacement rates of 0%, 3%, 6%, and 9%, respectively. Both results show that the weight of the block is significantly reduced at reduced cost and sufficient strength. Therefore, waste rubber chips can replace expensive sand and gravel aggregates.

Keywords
Cement; Crumb Rubber; Masonry Block; Sand; Strength.

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1. Introduction

The traditional brick production method has produced significant environmental pollution due to vast emissions of greenhouse gases, resulting in different climate changes such as smog, air pollution, acid rain, and global warming (Al-Fakih *et al.*, 2018). Moreover, the concrete industry is having difficulty finding a sufficient supply of fine natural aggregates and is actively researching alternatives, such as replacing fine aggregates with waste materials in concrete manufacturing (Khalid *et al.*, 2021). For this reason, frequent cracking and collapsing of buildings have been widespread in recent days because of the adoption of inappropriate constructional materials. On the other hand, waste tire disposal is a major environmental issue worldwide. The exponential rise of the automotive industry has recently resulted in increased demand for tires, which has resulted in massive tire waste at the end of their usable life. (Thakur *et al.*, 2020). The volume of waste tires manufactured is expected to exceed 1.2 billion tons per year by 2030, thanks to the significant increase in vehicles every day. Because they are large, non-biodegradable, and a great breeding ground for insects and rats, as well as flammable elements, scrap tires continue to cause substantial environmental, health, and aesthetic problems. Several initiatives have been to appropriately utilize and manage scrap tires (Mohammed *et al.*, 2017). However, waste rubber is not readily biodegradable, even after a long time; therefore, accumulating discarded tires has been a serious worry (Thakur *et al.*, 2020). Because of the high volume produced, the tire's endurance, and the environmentally hazardous tire components, these tires are a problematic source of waste. Tires take up valuable landfill space since they are long-lasting and non-biodegradable. Waste tires can also be a breeding ground for disease and mosquitoes, posing a threat to the environment and human health. Recycling wastes like building materials appears to be a realistic solution for the environment and the challenge of cost-effective building design. The technique of reusing discarded tires that are no longer viable for use on automobiles owing to wear or irreparable damage is known as recycling tires. The popularity of adopting ecologically friendly, low-cost, and lightweight construction materials in construction is growing (Thakur *et al.*, 2020).

Sand concrete bricks are manufactured in various block industries and are used to construct buildings as load and non-load-bearing units that serve as shelter for individuals. To get suitable bricks, it is necessary to determine the quality of concrete blocks produced in various block industries. Due to inadequate curing time, some blocks result in an insufficient compressive strength; thus, they are not adequate for building. Scrap tires can be turned into crumb rubber in various particle sizes and quality levels. Cement, aggregate, water, and crumb rubber make up Crumb Rubber masonry block. Crumb rubber is collected from discarded tires after processing and blended with gravel, cement, and water in specific proportions. Tipping fees paid to collect raw materials, sales of variously sized crumb products to various end-user markets, and potential sales of scrap metal and fiber contained within the tires are all part of the revenue stream (Parasivamurthy *et al.* (2007)). Several research works have shown that crumb rubber is very effective as a partial replacement for sand and has some structural importance, such as dampness reduction. For instance, Sukontasukkul *et al.* (2004) show that concrete acting as a binder mixed with crumb rubber can make concrete blocks more flexible and soften the surface. In a similar work, Siddique *et al.* (2004) presented a conservative approach of harnessing vandalized tires as crumb rubber and showed that a workable rubberized concrete mixture could be made with scrap-tire rubber. Thakur *et al.* (2020) partially employed waste rubber tires to substitute fine aggregate in the development of bricks. They found that as the amount of rubber powder in the mixture increases, the slump and water absorption increase linearly. The energy absorption of the crumb rubber concrete was found to be 3.66 times higher than that of the conventional concrete, and the compressive/tensile strength of the brick was found to decrease with increasing rubber powder content. Al-Fakih *et al.* (2018) and Aiswarya *et al.* (2021) successfully developed bricks using rubber waste material and fly as aggregates. The fly ash replaced the cement in this case, and rubber chips partially replaced the sand. They found the developed bricks to exhibit sufficient compressive and tensile strength; hence, they can be employed as structural elements for construction works. Mohammed *et al.* (2012) measured the essential properties of bricks made with different rubber content and found that they exhibit superior thermal, acoustic, and electrical qualities than standard hollow blocks; hence, they become suitable for load-bearing and lightweight applications in the construction industry. Intaboot and Kanbua (2022) also found that increasing the amount of crumb rubber in a concrete block decreases the density, compressive strength, static modulus of elasticity, and thermal conductivity; however, the water absorption increases. Al-Fakih *et al.* (2021) also revealed that as the ratio of rubber powder to fine aggregates is increased, the compressive strength and density of the bricks reduce, while the water absorption increases; however, the physical and mechanical qualities are generally acceptable for use in the construction of load-bearing structures. Al-Tamimi *et al.* (2020) revealed that the crumb rubber modified bricks have higher thermal insulation (by 71%) lower thermal conductivity (up to 40%) when compared to the standard hollow bricks, including those already on the market; thus, these bricks can reduce air conditioning energy consumption and carbon emissions in our society. Khalid *et al.* (2021) found that the water absorption increases with increasing crumb rubber content, while the compressive strength and density reduce. Recently, Rana *et al.* (2014) Rubber enhances workability, decreasing the density, compressive, and tensile strengths, mainly when the crumb rubber is larger. This has also been pointed out previously by Lark *et al. (*1996), in which it was shown that density and compressive strength of various mixes decrease with increasing crumb rubber in the mixture. Although the prior study has looked into the effectiveness of partially replacing sand with crumb rubber in the brick sector, there is still a lot to learn about Nigerian-made concrete aggregates. This is because most of the previous research works deal with the aggregate used in countries from Asia, Europe, and the Middle East. Therefore, this project aims to partially replace fine sand with crumb rubber in masonry blocks, investigates its feasibility as a potential building (or constructional) material in Nigeria, and compares its cost and properties with conventional blocks.

2. Materials

The following materials were used in the course of this research work:

2.1 Cement

The cement used was Ordinary Portland cement of Dangote 3X brand obtained from a dealer at the main gate of Kano University of Science and Technology Wudil, Wudil Local Government Area, Kano State.

2.2 Fine Aggregates

The fine aggregate used was river sand obtained from a nearby River Wudil in the Wudil local government of Kano State, Nigeria.

2.3 Water

The water used in this research work was clean and potable water obtained from the laboratory tap water tanks in the Department of Civil Engineering, Kano University of science and technology Wudil, Kano, Nigeria.

2.4 Waste Tyre Rubber granules

The crumb rubber granules used were obtained by shredding discarded heavy truck tires into sizes ranging from 4mm to 4.75mm after the wires and fibers were removed from them. The tires were sourced from Fagge L.G.A Kano State-Nigeria.

The masonry block was constructed from a mixture of cement, fine sand aggregate, water, and scrap (crumb) rubber. Ordinary Portland cement of the Dangote 3X brand was purchased from a vendor near Kano University of Science and Technology Wudil's main gate in Wudil Local Government Area, Kano State. River sand from Wudil local government in Kano State, Nigeria, was used as the fine aggregate. The water used in this study came from the Department of Civil Engineering's laboratory tap water tanks in Wudil, Kano, Nigeria. After shredding a used heavy truck tire into diameters ranging from 4mm to 4.75mm, the crumb rubber granules needed were obtained.

3. Method

The research will be limited to using a 1:4 mix ratio for the blocks. The percentage replacements will be used: 0%, 3%, 6%, and 9%. The curing period to be considered is 7, 14, 21, and 28 days.

3.1 Masonry block making

Using BS 1881-part II 1983, Batching of materials was done by weight. This was done to determine the proportion that would give the most optimum result. The percentage replacements of fine aggregates by rubber granule were 0%, 3%, 6%, and 9%. The 0% replacement was to serve as a control for other samples. The concrete was mixed manually with the aid of a shovel. Dry mixing of the sand, rubber granule, and cement were carried out, and water followed this. The materials were thoroughly mixed until they had a suitable consistency and uniform color. The size of formwork adopted was 450 x 225 x 150mm. The concrete was mixed, placed, and compacted in three layers. The samples were remolded after compaction and kept in a curing system for 7, 14, 21, and 28 days as required. Curing of the block is maintaining adequate moisture content and temperature of blocks at early ages so that it can develop the properties it was designed to achieve.

The samples were cured by spraying the water into the block twice a day at the morning and afternoon periods and A total of 64 blocks were cast four pieces per % replacement and tested for strength after 7, 14, 21, and 28 days.

3.2 Compressive strength tests

The blocks were dried by air, weighed, and axially placed in the crushing machine with two sides of the block in contact with the platen of the testing machine. The device was powered on, and the block was subjected to a compressive strength test. The crushing strength was determined at 7, 14, 21, and 28 days of curing. The compressive strength is determined according to BS 1881: Part II: 1983, and the compressive strength was calculated using (1),

$$S = \frac{N}{A} \qquad (1)$$

Where S is the compressive strength (N/mm^2), N is the failure load (N) and A is the effective surface area of block (mm^2).

3.3 Unit weight measurement

To find the unit weight of the block, the dried block was put on an electronic weight balance and measured the weight of sandcrete hollow block samples. Unit weight was determined at 7, 14, 21, and 28 days of curing. The unit weight was calculated by using Equation 2.0: according to BS 1881: Part II: 1983,

$$W = \frac{w}{V} \qquad (2)$$

Where W is the unit weight of block (kg/mm^3), w is the weight of block (kg), and V is the volume of block (mm^3).

4. Results and Discussion

4.1 Compressive Strength of Blocks

Because crumb rubber is a ductile material that is not stronger than river sand that has toughness behaviour, all of the results found are for 6-inch blocks only. This showed that the compressive strength of the blocks increases as the days of curing age increases and that the compressive strength of the blocks decreases as the percentage replacement of sand with crumb rubber increases.

Tables 1-4 illustrate the failure loads and compressive strength of hollow concrete blocks made with a 1:4 mix ratio and cure times of 7, 14, 21, and 28 days using a 0.5 % w/c ratio.

Table 1: Compressive strength of blocks at 7 days curing duration

Percentage replacement %	**Failure loads**			**Average Failure load (KN)**	**Compressive strength (N/mm^2)**
	A	B	C		
0	163	161	165	163	3.40
3	142	146	143	144	3.00
6	130	133	129	131	2.73
9	110	109	112	110	2.51

Table 2: Compressive strength of blocks at 14 days curing duration

Percentage replacement %	**Failure loads**			**Average Failure load (KN)**	**Compressive strength (N/mm^2)**
	A	B	C		
0	177	175	179	177	3.69
3	157	153	153	154	3.23
6	138	136	137	137	2.85
9	130	127	133	130	2.71

Table 3: Compressive strength of blocks at 21 days curing duration

Percentage replacement %	**Failure loads**			**Average Failure load (KN)**	**Compressive strength (Nmm^2)**
	A	B	C		
0	193	198	197	196	4.08
3	171	176	169	172	3.58
6	156	159	154	156	3.26
9	144	145	145	145	3.02

Table 4: Compressive strength of blocks at 28 days curing duration

Percentage replacement %	**Failure loads**			**Average Failure load(KN)**	**Compressive strength (N/mm2)**
	A	B	C		
0	251	249	250	250	5.21
3	204	199	201	201	4.19
6	180	179	178	179	3.73
9	164	168	166	166	3.46

Figures 1-4 show the Failure loads and compressive strength of concrete hollow blocks that partially replaced the sand with crumb rubber for 1:4 mix ratio and 7, 14, 21, and 28 curing days using a 0.5% w/c ratio graph behaviour.

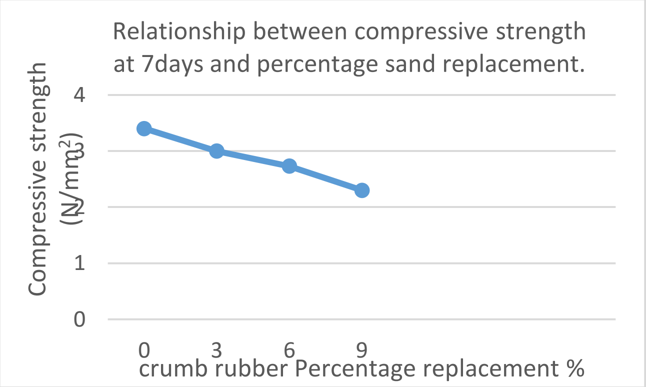

Figure 1: Relationship between compressive strength at 7days and percentage sand replacement graph.

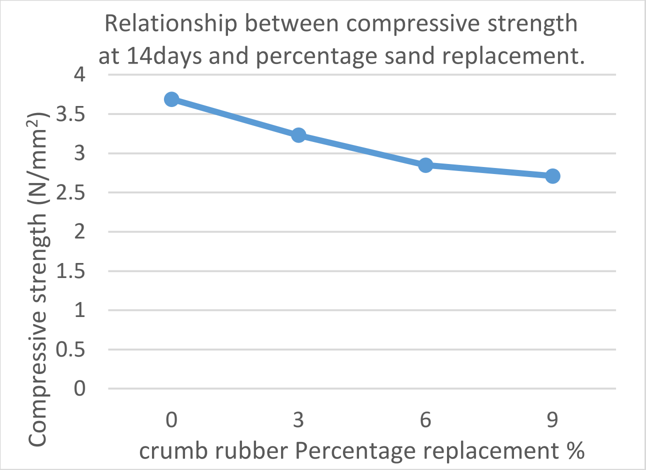

Figure 2: Relationship between compressive strength at 14days and percentage sand replacement graph.

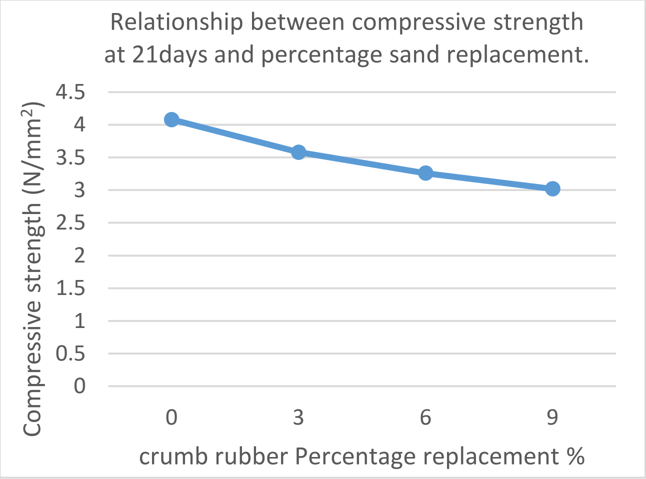

Figure 3: Relationship between compressive strength at 7days and percentage sand replacement graph.

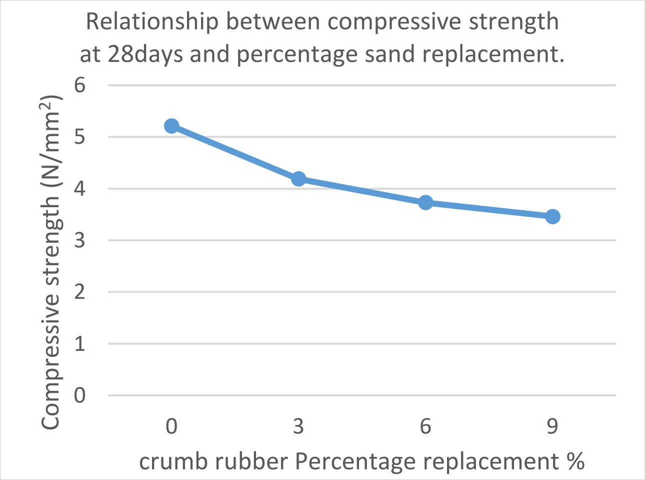

Figure 4: Relationship between compressive strength at 28days and percentage sand replacement graph.

The result obtained shows that the compressive strength of sandcrete hollow block decreases by replacing some percentage of sand with crumb rubber. Generally, the compressive strength of the block increases by the increment of curing days.

4.2 Unit Weight of Block

Table 5-8 shows the unit weight of 6 inches block that partially replaced the sand with crumb rubber at 7,14, 21, and 28 curing days. It was observed that the unit weight of sandcrete hollow block is decreasing by increasing the curing days, and also both the weight and unit weight of the blocks is reduced by the increment of crumb rubber that replaced some percentage of sand in block mix.

Table 5: Unit weight at 7 days of curing age

Percentage Replacement (%)	Average weight of block (kg)	Unit weight of block (kg/m^3)
0	17.601	1629.7
3	17.193	1591.9
6	16.761	1551.9
9	15.875	1469.9

Table 6: Unit weight at 12 days of curing age

Percentage Replacement (%)	Average weight of block (kg)	Unit weight of block (kg/m^3)
0	17.211	1593.6
3	16.020	1483.3
6	15.004	1389.3
9	14.305	1324.5

Table 7: Unit weight at 21 days of curing age

Percentage Replacement (%)	Average weight of block (kg)	Unit weight of block (kg/m^3)
0	17.011	1575.1
3	15.951	1476.9
6	14.760	1366.7
9	14.014	1297.6

Table 8: Unit weight at 28 days of curing age

Percentage Replacement (%)	Average weight of block (kg)	Unit weight of block (kg/m^3)
0	17.430	1613.9
3	16.450	1523.1
6	15.050	1393.5
9	15.000	1388.9

After critical observation and research, it was found that the unit weight of sandcrete hollow block is decreased by increasing the amount of crumb rubber as a partial replacement of sand because the density of crumb rubber is less than the density of the sand.

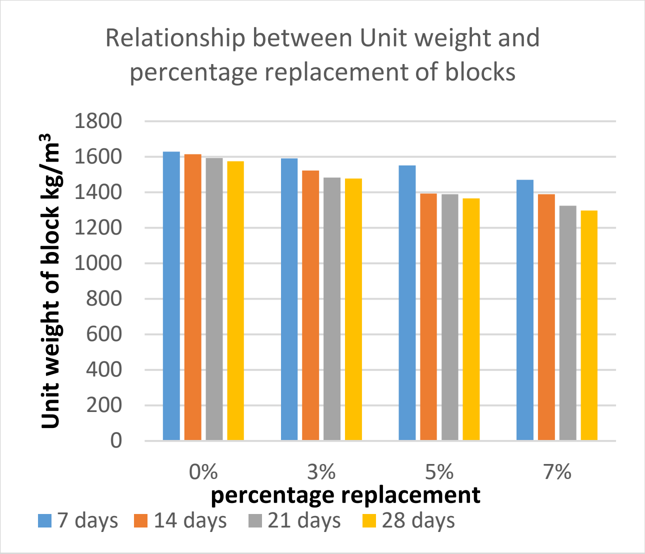

Figure 5: Relationship between Unit weight and percentage replacement of blocks Chart.

5. Conclusion

Rubber crumbs according to ASTM D5603 and D5644 requirements were purchased from Fagor LGA in Kano State, Nigeria, for this study. Using a 1:4 mix ratio and a 0.5 water-cement ratio, adhere to BS standard standards for batching and mixing. According to BS 1881 Part II 1983, the compressive strengths of the test blocks on day 7 and day 28 were 3.40, 3.00, 2.73, and 2.51 N/mm^2, respectively, at 0%, 3%, 6%, and 9% displacement. The results were all within the permitted strength range for the blocks, i.e. the average compressive strength of the medium, medium weight, hollow, or solid concrete blocks varied from 2.5 to 7.5 N/mm^2. The weights of the test blocks at 7 days were 1629.7, 1591.9, 1551.9, and 1469.9 kg, respectively, at replacement rates of 0%, 3%, 6%, and 9%. Similarly, on day 28, the body weights were 1575.1 kg, 1476.9 kg, 1366.7 kg, and 1297.6 kg, with replacement rates of 0%, 3%, 6%, and 9%, respectively. Both results suggest that the block's weight can be greatly lowered while maintaining appropriate strength. As a result, leftover rubber chips can be used in place of costly sand and gravel aggregates.

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