



## Investigation of Crumb Rubber Proportion on Compressive strength and Water Absorption of Crumb Rubber Mortar

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### ABSTRACT

The increasing environmental challenges and threat posed by Waste tyre have over the years received growing concern all over the world, the option of burning is ruled out for fear of environmental pollution. Hence, many devoted efforts through research have been dedicated to utilising waste tyre in the form of Crumb Rubber (CR) in the construction industry by way of incorporating it in cementations composite. The effort to reuse waste tyre in the form of crumb rubber concrete as well as mortar has been widely investigated. Despite the wide range study on Crumb Rubber Mortar (CRM) no enough study on water absorption. Thus, this paper aims to fill this gap by investigating the influence of the varying percentage of CR on the water absorption as well as density and compressive strength of CRM. In this regard, mortar containing 0 %, 5 %, 10 %, 15 %, 20 %, 25 % and 30 % CR as a replacement for fine aggregate were investigated. Results from the study indicate a reduction in flow (slump) with an increase in the percentage of CR. However, the increase in compressive strength was only recorded with 5% CR replacement followed by subsequent decline with an increase in CR. On the hand, the increase in the percentage of CR results in an increase in water absorption property with the corresponding decrease in density. This infers that the inclusion of CR above 5% is not encouraged.

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### INTRODUCTION

Waste tyre is one of the major environmental problems today. The increasing volume of used tyre being dumped into the landfills is making the problem even worse (Yilmaz and Degirmenci 2009). The disposal of waste tyres was found to be of environmental concern because waste tyres resist degradation. One option to reduce this environmental concern is for the construction industry to consume a high amount of recycled tyres accumulated in stockpiles (Muhammadi, 2014). By the year 2030, the number of discarded tyres would increase to 1200 million tyres yearly (Aiello

and Leuzzi. 2010). Senin *et al.*, (2016) studied the properties of cement mortar containing rubber ash as a sand replacement, and their findings revealed that the density of the cement mortar specimen decreased with the presence of rubber ash, while the compressive strength of the cement mortar specimens decreased with the presence of rubber ash at the early stages. However, at 28 days only the specimen with 5% rubber ash showed an increase in compressive strength. They finally concluded that the usage of rubber ash should not be beyond 5% replacement. Faraz *et al.*, (2015) carried out a study on the effect of crumb rubber



material on the concrete mix, the results showed that the addition of rubber crumb resulted in an increase in workability, compressive strength of concrete at the first stage and then it reduces. On the other hand, the addition of rubber crumbs resulted in the reduction of the weight of the concrete.

Hilal, (2011) carried out a research on the effect of crumb tyres rubber on some properties of foamed concrete, and the result indicated that the compressive strength, tensile strength, flexural strength, density and impact resistance of rubberized foamed concrete decreased as the crumb rubber tyres content in the mixture increased. He also stated that the water absorption of the rubberized foamed concrete increased as the crumb rubber content increased. Abdulla *et al.*, (2010) carried out a study on cement mortar properties contain crumb rubber treated with alkaline materials, and the result showed that crumb rubber treated with NaOCL increases the compressive strength, flexural strength, modulus of elasticity more than NaOH, while using detergent powder gave negative effect. Noor *et al.*, (2015) stated that addition of 10% silica fume improved the resistance of rubberized concrete against chloride ion penetration due to the dense cement matrix hence reducing the pore of cement paste. They also noted that the compressive strength reduction of 43% was observed in 20% crumb rubber. It was said that a high content of rubber reduced as high as 90% of the compressive strength of rubberised concrete compared to control samples of concrete without rubber (Youssf and Elgawady 2013).

According to Muhammadi, (2014), adding more rubber into the mix series decreases concrete bleeding index significantly. Also, test results indicated that introducing 30% or more rubber into concrete results in difficulty with finishing of

the pavement surface and should be avoided. Sofi, (2017) stated that the compressive strength and flexural strength values were gradually decreasing with an increase in the amount of crumb rubber in concrete. Gesoglu and Guneyisi (2007) reported a progressive increase in the chloride-ion penetration on partial replacement of coarse aggregate and fine aggregate by crumb rubber and rubber chips respectively. The penetration was found to decrease in the addition of silica fume to the concrete mixture. Bravo and de Brito. (2012) have reported that the water absorption (by the process of immersion) of rubberized concrete increases as the percentage of rubber and the particle size of rubber increases.

Hence, the main aim of this paper is to investigate the effect of crumb rubber on some properties of cement mortar (compressive strength, workability, water absorption, and Density).

## MATERIALS AND METHODS

### Materials

Material used in this study include, cement, sand, crumb rubber

### Crumb Rubber

The crumb rubber was sourced from a mill located at Dele Abuja Nigeria. It was processed with a grinding machine and a granulator having a 4.75mm nominal maximum size, then treated by sieving in other to get gradation close to that of typical sand.

### Sand

The sand was sourced from Samaru campus of Ahmadu Bello University Zaria, Nigeria. It was thoroughly flushed with water to reduce the level of impurities and organic matter and then sun-dried, it conformed to the requirement of BS 882(1982).



### Cement

Cement used in this study is Dangote Cement brand, a local OPC manufactured by the Dangote Company Limited in Nigeria. It is purchased from a local dealer in Samaru, Zaria.

### Water

Portable water was used which is free from any acid, inorganic compounds, and it conformed to BS 3148(1980).

### Methods

#### Prescribe mortar mix design

The constituents proportion used are presented in Table 1 below.

**Table 1:** Mortar constituent proportions

% replacement	Weight of Cement (kg)	Weight of fine Aggregate (g)	Weight of Crumb Rubber (g)
0	1000	2750.0	0
5	1000	2612.5	59.9
10	1000	2475.0	119.8
15	1000	2337.5	179.7
20	1000	2200.0	239.6
25	1000	2062.5	299.5
30	1000	1925.0	359.4

### Fine aggregates

The tests conducted on the fine aggregates are: specific gravity (BS 812-1995), sieve analysis (BS 812-103.2) analysis, Bulk density and moisture content

### Test on cement paste

#### Standard Consistency Test

This test was done to determine the quantity of water required to produce a cement paste of standard consistency based on BS EN 197-1:2009 standard. When the plunger penetrates the paste to a point 5 to 7mm above the bottom of the mould, the paste is considered to be at "normal consistency".

### Initial and Final Setting Times Test

The test was conducted to evaluate the initial setting time and final setting time of cement paste in accordance to BS EN 196 part 3:1995. The time (min) when the plunger penetrates 5-7 mm above the mould soffit was considered as the initial setting time and the final setting time (min) was

when the annular of the needle doesn't make an impression on the paste.

### Soundness

This soundness of cement paste was measured in accordance to BS EN 196-3: 1995.

### Flow (Slump) Test

The ease at which the fresh mortar flows was assessed using the flow or slump test in accordance with BS EN 12350-2:2009 standard.

### Water Absorption

The water absorption on hardened mortar after 28 days of curing was conducted in accordance to BS 812 Part 2.

### Casting of Mortar Cubes

The prescribed mortar mix of 1:3 in table 1 and water-cement ratio 0.5 were used to assess the effect of crumb rubber in mortar. A total of ninety (90) cubes were cast for compressive strength and water



absorption. The moulds were oiled before casting and clamped to the vice, castings of mortar were done in three layers, and each layer has given 25 blows of tamping rod. The specimens were left in the laboratory covered at room temperature for 24 hours to harden. Then they were de moulded, weighed and transferred to the curing tank for curing. Samples were taken for testing at 3, 7, 14 and 28 days.

#### *Compressive Strength Test*

The mortar cubes were removed from the curing tank and allowed to be surface dried and weight of each cube was recorded. However, the cubes were crushed using the Avery Denison Compression Machine of 2000 kN load capacity and a

constant rate of 15 kN/s. The cubes were inserted axially into Avery Denison Compression Machine in such a way that two of its faces were in contact with the top and bottom plates of the machine. The load was applied to the cube by turning the loading handle clock wisely. Then after, the cube had failed the failure load readings were taken.

## **RESULTS AND DISCUSSION**

### ***Physical properties of materials***

Physical properties of cement, fine aggregate and CR used are presented in this section. Table 2 shows the physical properties of cement which are satisfied according to BS EN 196-3 (1995).

**Table 2:** Physical properties of cement

Tests	Results
Initial Setting Time	130 (mins)
Final Setting Time	170 (mins)
Consistency	6.8 mm
Soundness	3.5 mm

Table 3 show properties of CR and Fine aggregate.

**Table 3:** Some physical properties of crumb rubber and fine aggregate

Materials	Moisture Content (%)	Bulk Density (Kg/m <sup>3</sup> )	Specific Gravity
Fine Aggregate	5.61	1409.03	2.71
Crumb Rubber	6.72	409.90	1.54

Bulk density and Specific Gravity of fine aggregate are higher than that of CR which is reasonable due to the possibility of existing void in the CR.

### ***Sieve Analysis***

Sieve analysis was conducted in accordance with BS 882, Part 2. Figure 1 and

Figure 2 show particle size distribution plots of fine aggregate and crumb rubber respectively. Both are classified as zone 1 based on BS 882, Part 2, grading limits.

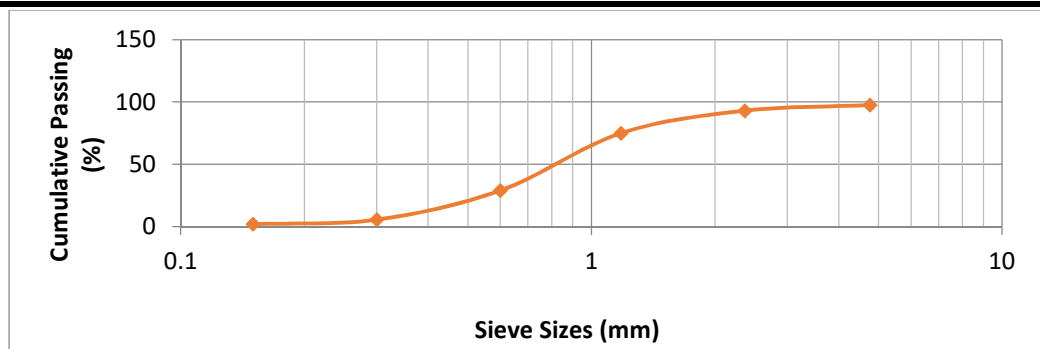


Figure 1: Sieve Analysis for fine aggregate

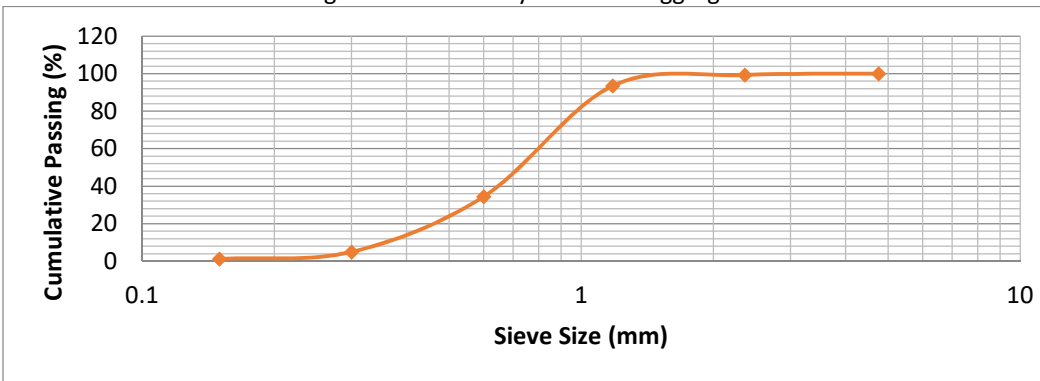


Figure 2: Sieve Analysis for Crumb Rubber

### Slump Test

The results of the (flow) slump test conducted on 1:3 cement/sand mortar with different percentage of crumb rubber are shown in Figure 3. Percentage increase in CR was found to cause a decrease in slump value decreases, the same pattern was

exhibited by Muyen *et al.*, (2019). This may be attributed to a high specific surface of CR for constant water content. And at 0% replacement, the slump is 4.5mm, while at 5% replacement the slump decreases to 4 mm that is 11.11%. So, the lowest slump was found to be 0.5 mm at 30%.

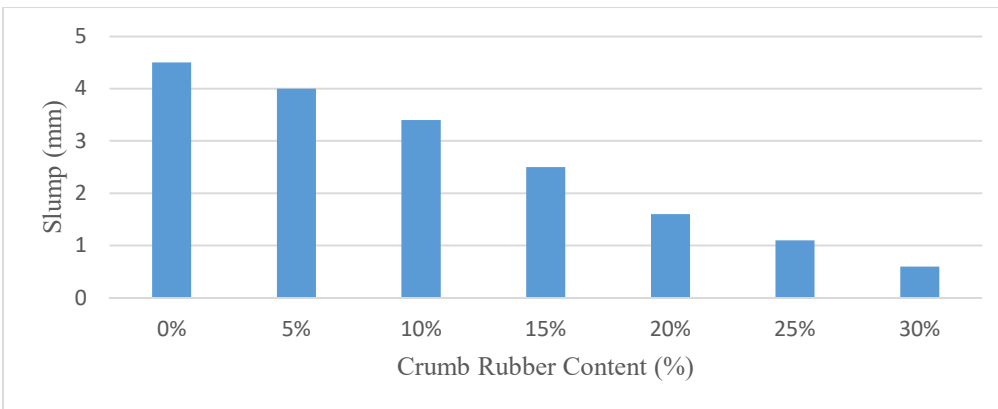
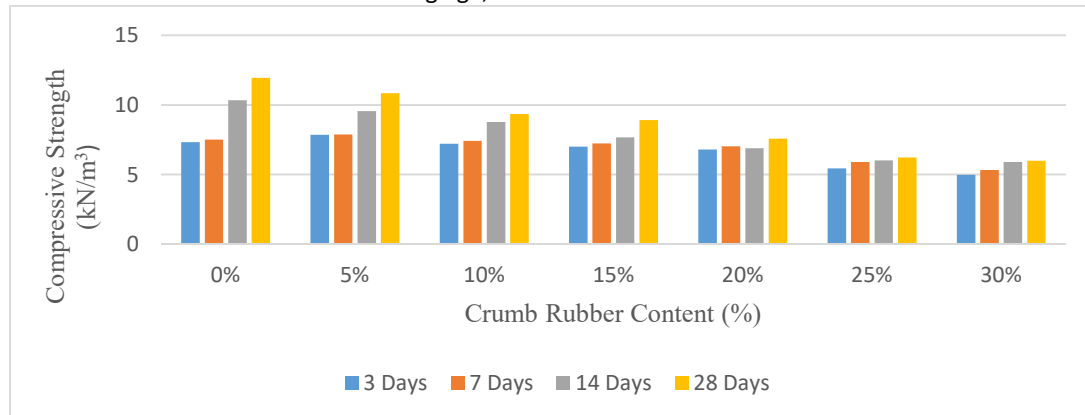


Figure 3: Effect of varying percentage of CR on Slump of Crumb Rubber Mortar (CRM)

### Compressive Strength of Crumb Rubber-Mortar

The result of compressive strength of CRM at 3 days, 7 days, 14 days and 28 days is presented in figure 4. It was observed that the compressive strength of mortar increased with an increase in the curing age,

on the other hand, the compressive strength of mortar decreased as the percentage replacement of crumb rubber content increased, this is in agreement with (Samuel and Emmanuel, 2013). And the same pattern was reported by Muyen *et al.*, (2019).

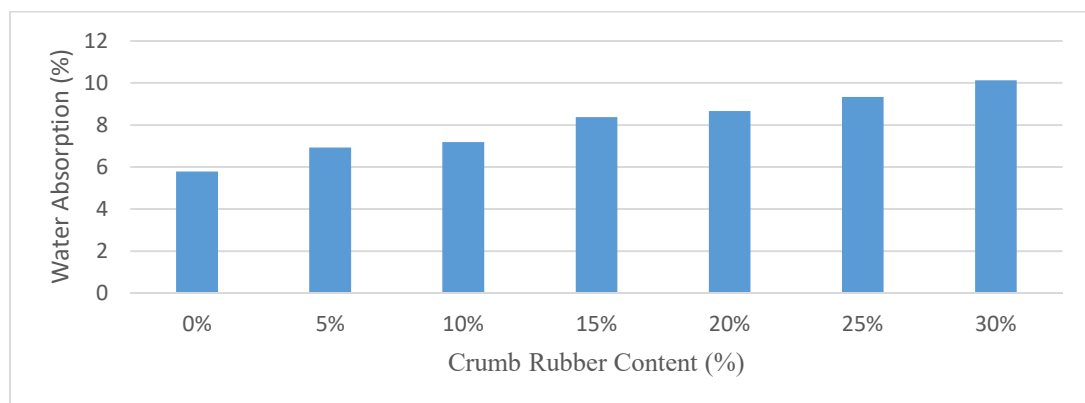


**Figure 4:** Compressive strength versus various % replacement of crumb rubber.

### Water Absorption

The relationship between the mean percentage of water absorbed and the percentage replacement of Crumb Rubber is presented in figure 5. It was noted that as the percentage of Crumb rubber content increased, the amount of water absorbed increased, this is in agreement with Ganjian *et al.*, (2009) who also observed an increase in water absorption with Crumb rubber as coarse aggregate. The increase may be due

to the fact that as more and more rubber chips were added to the mix, more voids were created and hence they became more permeable to water as explain by Muyen *et al.*, (2019). However, it is due to porous nature of Crumb rubber which resulted to higher water absorption compared with fine aggregate, the mean percentage of water absorbed at 0 % Crumb rubber is 5.78% while at 30 % Crumb rubber is 10.12%.



**Figure 5:** Water absorption versus percentage replacement of crumb rubber

### Density of Hardened Mortar

The relationship between the mean density of mortar and the percentage replacement of Crumb Rubber is presented in figure 6. The density of the mortar decreased as the percentage of Crumb rubber content increased, this may be as a

result of the low specific gravity of Crumb rubber. The mean density at 0 % Crumb rubber content is 2285.33 kg/m<sup>3</sup> while at 30% is 2106.67 kg/m<sup>3</sup>. This also confirmed that Crumb rubber can be used to produce lightweight structural elements.

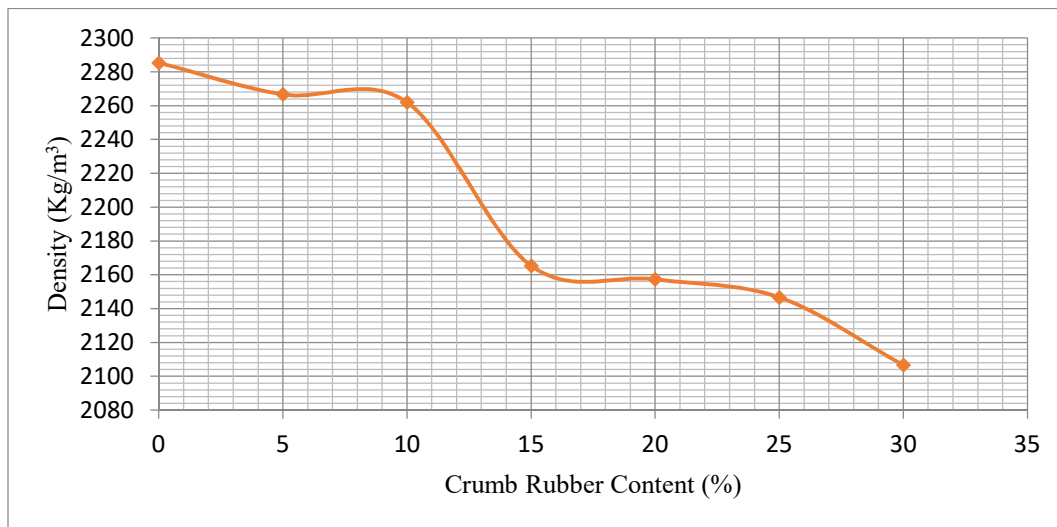


Figure 6: Density versus percentage replacement of crumb rubber.

### CONCLUSIONS

A detailed experimental investigation on the proportion of CR on water absorption and compressive strength of mortar was conducted using percentage of 0%, 5%, 10%, 15%, 20%, 25% and 30%. Based on the results presented the following conclusion can be drawn:

- 1) Inclusion of CR as a replacement for fine aggregate reduces the flow (slump) of mortar but steps-up the water absorption.
- 2) Increase in compressive strength of CRM was only recorded at 5% CR followed by a subsequent decline in the strength. Hence, it is recommended to limit the percentage replacement to 5%.
- 3) The Density of CRM decreases with an increase percentage of CR.

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