USE OF CRUMB RUBBER AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN MORTAR

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Abstract

This research aims to determine the possibility of using "crumb rubber" as a partial replacement of fine aggregate (sand) in 1:2.75 cement sand mortar and to find the effect on compressive strength, workability, water absorption and density of mortar. Different % of crumb rubber (0%, 5%, 10%, 15%, 20%, 25% and 30%) were replaced to the mortar mixes. A 0.5 water-cement ratio was used to form the mortar mixes. Workability results show a decrease in workability as the % replacement by crumb rubber increases. Furthermore, the test for compressive strength showed an increase in compressive strength for mortar up to 5% replacement by crumb rubber; then, the strength decreases with the further increase of crumb rubber replacement. The compressive strength at 28days for 5% replacement by crumb rubber was found to be 9.47N/mm^2, which is greater than the strength of the control mortar, 8.33N/mm^2. The water absorption test also showed a reduction of water absorbed at 5%, and it then pounces back and continues to increase as the % replacement by crumb rubber increases. Therefore, it can be concluded that the optimum use of Crumb rubber as a partial replacement for fine aggregate can be made up to 5%. The research also showed that crumb rubber could be used to reduce the water absorption rate and improve the compressive strength of mortar.

Keywords: Crumb rubber, Partial replacement, Fine aggregate, Mortar

INTRODUCTION

The manufacturing of mortar primarily consists of its ingredient; cement, water and fine aggregate. The primary source of natural sand is river sand. There is a shortage of these natural resources due to excessive usage, which leads to massive exploitation of natural resources, and therefore other sources must be found. The use of manufactured sand has similar properties as that of natural sand. This material is environmentally safe and imposes no threat to humans (Phani, 2013). Researchers have indicated that it is now possible to make aggregate from almost anything provided it possesses attributes that will eventually be tailored so that required or desirable property will be realized in concrete/mortar. Aggregate occupied three-quarters of the volume of the mortar, indicating a higher proportion than their constituent materials required for mortar/concrete works (Mortar-Civil Engineering). A rubber tire is not only used for automobiles but is also used as a construction material. The popularity of rubber tires as construction materials is due to their availability (Pierce & Blackwell, 2003).

While manufacturing rubber tires, some are used for cars, trucks etc. These tires are turned into waste products and usually dumped in waste yards or burnt, which causes environmental pollution. The United States Environmental Protection Agency indicated that the manufacture of rubber tires for automobiles increased by 14 percent from 1960-1988. Currently, approximately 280 million waste tires are discarded annually in the United States alone; from this large number, only a few tires are recycled. When Rubber Manufacturers Association (RMA) began its scrap tire effort in 1990, about 11 percent of the scrap tires generated every year were sent to an end-user market. One billion scrap tires were in stockpiles across the country. Today, the RMA notes that only 100 million stockpiled scrap tires remain, and the number continues to decline, and more than an 80percent of scrap tires are consumed annually. If its properties are adequate for mortar production, it could be significant in the construction industry, especially in offsetting vast amounts of money spent on aggregate. The material, therefore, usually presents some disposal problems and may become an input material for mortar production. The growing amount of waste produced from tires has been a significant concern in the last decades because tires represent large non-biodegradable refuse with the danger of fire and proliferation of rats and insects in the stocked refuse mass. The need for recycling strategies is so imperious. Various waste materials have been suggested as additives to mortar materials due to the intake of resources for the production and to improve some performances of mortar with economic and technological advantages. Furthermore, the other part of the need is that aggregate construction production continuously leads to the depletion of natural resources. This research investigates the effects of crumb rubber as a partial replacement of fine aggregate in mortar production.

LITERATURE REVIEW

Solid Waste Management is one of the significant environmental concerns in the world. Each year thousands of tires are added to stockpiles, landfills, and illegal dumps across the West Bank of the Gaza strip, which causes extensive environmental and hazardous problems. Waste tire stockpiles are dangerous due to potential environmental threats and fire hazards and create breeding grounds for rats, mice, vermin and mosquitoes (Naik & Singh, 1991). Over the years, the disposal of tires has become one of the severe problems for the environment. Landfilling is becoming unacceptable for waste tires because of the rapid depletion of available sites for waste disposal.

Civil Engineering Applications of Recycled Rubber from Scrap Tires

Crumb rubber is a finely grounded tire rubber from which the fabrics and belts have been removed. It has a granular texture and ranges in size from excellent powder to sand-sized particles. Crumb rubber has been successfully used as an alternative aggregate source in both asphalt concrete and PCC. This waste material has been used in several engineering structures like highway base courses and barriers. No local experience has been recorded in any utilization or management of this waste material; on the contrary, several cases of fatal and hazardous conditions occur on daily bases as a result of ignorance and inadequate handling of this waste materials daily locally and globally beyond standing issue to deal with (Shaytah,2007).

Excess water is released when subgrade soils thaw in the spring. Placing a 15 to 30cm thick tire shred layer under the road cab prevents the subgrade soils from freezing in the first place. In addition, the high permeability of the shreds allowed water to drain beneath the roads, preventing damage to the road surface (ASTM D6270-98). Tire shreds can be used to construct barriers on weak, compressible foundation soils. Tire shreds are viable in this application due to their lightweight fill materials are significantly a cheaper alternative (Tire Manufacturing Association

MATERIALS AND METHODS

Materials

This discusses the materials used for this research work and the detail of various tests carried out to investigate the properties of mortar made with crumb rubber as a partial replacement of fine aggregate. The mix ratio was 1:2.75, and the water-cement ratio was 0.5. Eighty-four cubes were cast in all, 12 cubes using only sand as fine aggregate, and seventy-two cubes containing crumb rubber in different proportions partially replaced fine aggregate (sand). This purpose is to check the difference or similarities in the properties of the resulting mortar as a result of the aggregate used.

Method of Study

The materials used in this research are as follows:

a. Crumb Rubber

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

b. Sand

The sand was sourced from the 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).

c. Cement

The cement used in this research is the Dangote Cement brand, a local OPC manufactured by the Dangote Company Limited in Nigeria. A supply of the cement is purchased from a local dealer in Samaru, Zaria.

d. Water

Portable water was used, free from any acid or inorganic compounds. Mixing and curing were used with it. The water used for the study was ABU portable water, which conformed to B.S. 3148(1980). Water plays a vital role in mortar mix production. It helps in the hydration of cement and starts the fusion action between the cement and the fine aggregate.

Determination of the Physical Properties of Fine Aggregate

Sieve analyses, Specific gravity, Moisture content, and Bulk density were carried out on fine aggregate to determine their properties. The sieve was thoroughly cleaned and weighed individually on an electronic weighing balance; the set of the sieve was arranged according to their size in descending order from maximum opening with a pan at the bottom. The sample to be used were weighed and then poured into the topmost sieve of the set of sieves. The set of sieves with the sample was shaken for a while, after which the sieves were removed from the stack and weighed. The weight of the sample retained on them after the shaking was determined by subtracting the weight of the sieve plus the sample retained on them. The sieve analysis test was carried out by (ASTMC67, 2014). This is clearly shown in the table in chapter four.

Specific Gravity Test

Specific gravity is the ratio of the mass of a unit volume of a reference substance for the same given volume; according to ASTMC 127-93, specific gravity is the ratio of mass (or weight In the air) of a unit volume of material to the mass of the volume of water at the same temperatures. Two density bottles were thoroughly cleaned and weighed, filled with air-dried samples and weighed. Water was added to each density bottle covering the soil and shaken to eliminate air voids.

Specific-gravity=$D/[C-(A-B)]$……..(1)Where A =weight of bottle containing sample and water.

B = weight of bottle containing water only

C = weight of saturated surface dry sample weight of the oven-dry sample

Natural Moisture Content

Moisture content is the water over the saturated and surface dry condition of the aggregate, i.e. when the pores of aggregate are filled.

The moisture content cans were weighed, and then the weight of the can plus the sample was also taken. Next, the cans with the sample in them were placed in the oven for 24 hours, after which they were removed from the oven and allowed to cool before taking the weight. Finally, the moisture content of the aggregate was calculated from the expression.

$$M.C = \frac{weight of water}{Weight of oven dry sample} \times 100 \quad (2)$$

ASTM2216 carried out the procedure.

Bulk Density Test

Bulk density is the actual mass of the sample that would fill a container of unit volume. Bulk density is used to convert quantities by mass to quantities by volume. The container was filled to about one-third full with the aggregate and tamped with 25 strokes of the rounded end of the tamping rod. A further quantity of aggregate was added, and a further tamping of 25 strokes was given. The measure was finally filled to overflowing, tramped 25 times, and the excess aggregates trucked off using the tramping rod as a straight edge. The net of the aggregate in the container was determined, and the Bulk density was calculated in (kg/m^3).

Bulk Density=Mass/Volume

The test was carried out by the procedures in BS812: part2:1975.

Mix Design and Sample Preparation

The mortar specimens were prepared and experimented with in this study. The specimen was named A, having seven (7) different mixes with cement to the sand ratio of 1: 2.75 and a fixed water cement ratio of 0.5 throughout the mix design. As a result, the only variation in sand and crumb rubber would influence the sample properties. In this study, sand was replaced by a volume of crumb rubber at a different percentage. The different percentages were 5%, 10%, 15%, 20%, 25% and 30%. Since crumb rubber has a very low relative density compared to sand, the volume replacement method was considered. In this method, the weight of sand to replace by crumb rubber was divided by its specific gravity, the volume of sand was obtained, and this volume is to be replaced by the volume of crumb rubber converted to the unit weight. The specific gravities of materials are as follows—cement – 3.15, and – 2.64, crumb rubber -1.15, water – 1.00.

Furthermore, each mixed design was designated with a unique name for easy referencing within the text. For instance, the A15 sample designation is ample in the specimen with 15% crumb rubber. The table below gives the mix proportion of different materials in cement mortar.

Table 1: Mix proportions of mortar cube

S/N0	Sample Designation	Cement(g)	Water(Ml)	Sand(g)	Crumb rubber (g)	Crumb rubber Content
1	A0	1000	500	2750.0	0	0%
2	A5	1000	500	2612.5	59.9	5%
3	A10	1000	500	2475.0	119.8	10%
4	A15	1000	500	2337.5	179.7	15%
7	A20	1000	500	2200.0	239.6	20%
6	A25	1000	500	2062.5	299.5	25%
7	A30	1000	500	1925.0	359.4	30%

METHOD

Cement, sand, crumb rubber and water were thoroughly mixed to form the paste. The chemical process known as hydration releases heat and changes the paste into hard, strong engineering material. This research investigates to prove that cement, sand, crumb rubber and water have equal and may be improved advantages as the usual mix of cement, sand and water to produce mortar.

Mixing of Mortar

Mixing was done manually. The fine aggregate was first spread in a uniform layer. Cement was then spread over the aggregate, and the dry materials were mixed by turning it over from one end of the heap to another and cutting with a trowel until the same appeared uniform. The heaps of the dry material were then spread in a uniform layer; the required water quantity was added and remixed thoroughly to achieve the final uniformity.

Casting of Samples

Molds of size 50mm x 50mm x 50mm were used. The molds were oiled with petroleum jelly to ease the de-molding of the samples. Eighty-four (84) cubes were cast for compressive and water absorption tests. The samples were de-molded after 24 hours.

Curing of Samples

Curing is the name given to procedures used to promote cement hydration. To obtain good mortar, placing an appropriate mix must be followed by curing in a suitable environment during the early stage. The method adopted for this project is to place mortar cubes in a hydration tank full of water to keep the mortar cubes in saturated condition throughout the testing period.

The mortar cube was de-molded after 24 hours of placing and transferred to the water tank for 3, 7, and 14 28days.

Fresh Mortar Properties

The following tests were carried out on fresh mortar to determine their properties:

I. Normal Consistency
II. Setting Time
III. Soundness Test

Normal Consistency

The standard consistency of cement paste using a 10mm diameter plunger fitted into a needle holder was determined. 400 grams of cement was mixed carefully with 30% of water. The mold lying on the steel plate was filled using the gauging trowel, the top paste was smoothed, and the mold was placed under the plunger in the Vicat apparatus. The plunger is then brought into contact with the top surface of the paste and released. The reading of penetration was taken. The property of the water-cement ratio changes if the consistency exceeds the range (5 to 7mm) until you get the required consistency (BS EN196-3, 1995).

Initial Setting Time:

A sample of cement paste of standard consistency was prepared, and the time of mixing the water with cement was noted. The initial set was determined using the filled mold and needle with a cross-sectional area of $1mm^2$. The needle of the Vicat apparatus was lowered gently onto the surface of the paste. It is then released quickly and allowed to sink to the bottom of the mold. This is repeated after each 10min in different positions of the mold until when the paste is sufficiently stiffened for the needle to penetrate not deeper than 5mm above the bottom of the mold—initial setting time elapsed since the mixing water was added to cement until this last reading.

Final Setting Time:

The needle was replaced by a 1mm square needle fitted with an annular metal attachment and allowed to come gently into contact with the surface of the cement paste each 15min. The final set is said to have taken place when the needle makes an impression on the surface, but the annular cutting edge fails to do so (BSEN196-3, 1995).

Soundness Test

After preparing a cement paste of the standard consistency, the Lechatelier mold was on the glass plate and filled with paste. It kept the mold split gently closed by tying it with a piece of cotton while this operation was being performed. Moreover, the top of the mold was covered with another piece of glass and immersed immediately in clean water (BS EN196-3, 1995). After 24hrs, the mold was required, and the distance between the pointers was taken. Then, the mold was re-immersed and brought to boil for 30min and afterward for one hour. Again, the distance between the pointers is taken. The differences between the two measurements represent the expansion of the cement.

Hardened Properties of Mortar

Compressive Strength Test

The compressive strength of mortar specimens was determined at 7, 14, 21 and 28days. CSA A3004-C2 has been utilized in determining compressive strength. At first, the sample specimens are removed from the curing room and wiped to a dry surface condition. Three samples were tested in each mix, and the average of these three values is presented in this study.

Water Absorption

Crumb rubber is low in specific gravity, and its water absorption capacity differs from natural sand aggregates. As such, the water absorption capacity of hardened mortar samples was examined. In this case, the previous test was done after 28 days of moist curing. The process included visible water removal using a damp cloth immediately after removing the samples from the curing chamber. Saturated surface dry (SSD) weight was measured at this point. Next, a preheated oven with a temperature of 65 °C was used to dry all the mortar specimens (ASTM C67, 2014). After continuous drying for 48 hours, the samples were removed, cooled at room temperature and weighed for oven-dry mass. Thus, water absorption was obtained by comparing the weight differences between wet and dry samples.

RESULTS AND DISCUSSIONS

SIEVE ANALYSIS

The result of the sieve analysis test conducted by (ASTM C67, 2014) on fine aggregate (sand) and crumb rubber are presented in figure 1 and figure 2. Figure 1 and 2 shows the graph of %cumulative passing versus sieve size for sand and crumb rubber, respectively. It has shown that both the size of crumb rubber and fine aggregate (sand) particles are well graded, which complies with the code.

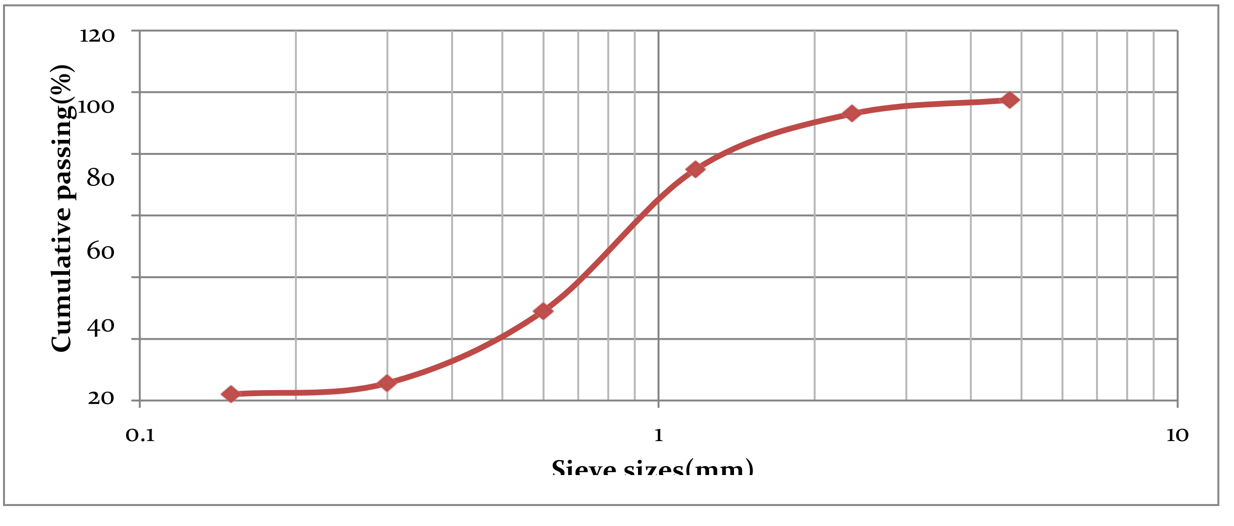

Figure1: Sieve analysis for fine aggregate

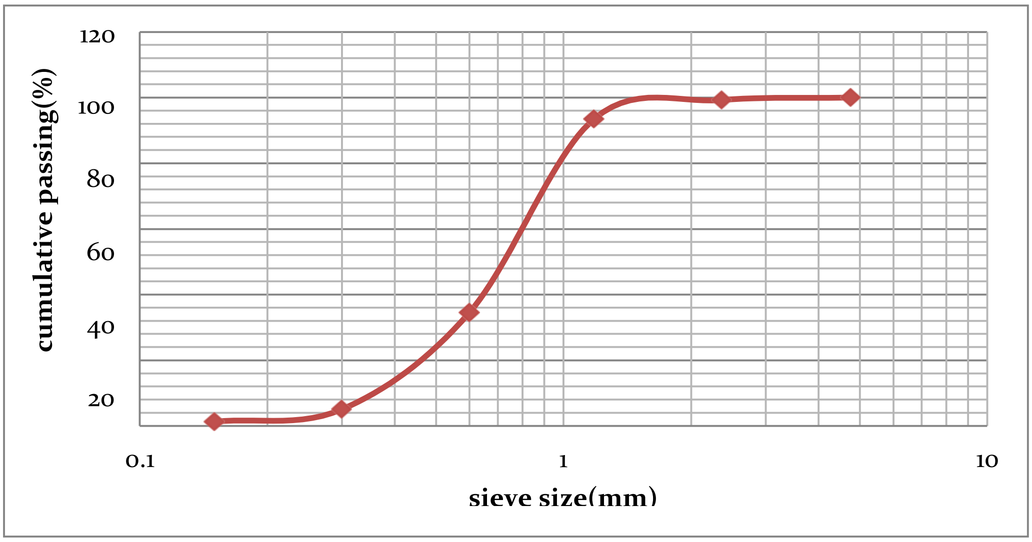

Figure 2: Sieve analysis for crumb rubber

SPECIFIC GRAVITY

TheresultofspecificgravityconductedaccordingtoASTMC127-93 on fine aggregate (sand) and crumb rubber is presented in tables 3 and 4 for sand and crumb rubber, respectively. The test indicates that the crumb rubber has a lower specific gravity than. The specific gravity value obtained for the fine aggregate (sand) and crumb rubber is 2.73 and 1.05, respectively. The lower value (1.05) obtained for crumb rubber is an indication that it is a lightweight material.

Table 3: Specific gravity of fine aggregate (sand)

S/N	Specific gravity	Mean specific gravity
Trial1	2.70	
Trial2	2.70	2.73
Trial3	2.77	

Source: (Lab. Work, 2022)

Table 4: Specific gravity of crumb rubber

S/N	Specific gravity	Mean specific gravity
Trial1	0.98	
Trial2	1.14	1.05
Trial3	1.05	

Source: (Lab. Work, 2022)

BULK DENSITIES

The result of Bulk density conducted according to BS 812: Part 2: 1975 on fine aggregate (sand) and crumb rubber are presented in tables 5 and 6 for sand and crumb rubber, respectively. The test indicates that fine aggregate (sand) has a higher Bulk density than crumb rubber. The values obtained for sand and crumb rubber were 1409kg/m^3 and 409.9kg/, respectively.

Table 5: Bulk density of fine aggregate (sand)

S/N	Mass(kg)	Volume(m^3)	Bulk density (Kg/m^3)	Mean Bulk density (Kg/m^3)
Trial1	3.89	0.00270	1440.74	
Trial2	3.90	0.00280	1392.86	1409.03
Trial3	3.86	0.00277	1393.50	

Source: (Lab. Work, 2022)

Table 6: Bulk density of crumb rubber

S/N	Mass(kg)	Volume(m^3)	Bulk density (Kg/m^3)	Mean Bulk density (Kg/m^3)
Trial1	1.09	0.0027	403.7	409.9
Trial2	1.14	0.00275	414.5	
Trial3	1.11	0.0027	411.5	

Source: (Lab. Work, 2022)

MOISTURE CONTENT

The result of moisture content conducted according to ASTM 22156 on fine aggregate (sand) and crumb rubber is presented in Tables 7 and 8 for sand and crumb rubber, respectively. Based on table 7 and table 8, it was indicated that the fine aggregate (sand) has higher moisture than the crumb rubber, with a moisture content of 6.77% and 2.1%, respectively.

Table 7: Moisture content of fine aggregate

S/N	Weight of water (g)	Weight of dry sample(g)	Moisture content (%)	Mean moisture content(%)
Trial1	18	271	6.64	6.77
Trial2	16	219	6.85	
Trial3	15	235	6.81	

Source: (Lab. Work, 2022)

Table 8: Moisture content of crumb rubber

S/N	Weight of water (g)	Weight of dry Sample (g)	Moisture content (%)	Mean moisture Content (%)
Trial1	3	102.0	2.94	2.1
Trial2	1.5	100.5	1.49	
Trial3	2	107.0	1.87	

Source: (Lab. Work, 2022)

TESTS ON PHYSICAL PROPERTIES OF CEMENT

The physical properties of cement tested are consistency test, setting times and soundness of cement paste. The tests are conducted by BS EN 196-3 (1995). The results are shown in Table 9. The physical properties of the cement have satisfied BS EN196-3 (1975) code which specified a consistency of 5-7mm (plunger penetration) from the bottom of the gauge, initial setting time of 45minutes (minimum), and final setting time of 10 hours (maximum) and soundness value of 10mm (maximum).

Table 9: Test on physical properties of cement results

Tests	Result obtained
Consistency	6.8mmpenetration
Setting time	
Initial	130minutes
Final	170minutes
Soundness	
Distance between indicator points	
- Before boiling, L1	11.50mm
- After boiling, L2	15.00mm
- The difference, L2– L1	3.50mm

Source: (Lab. Work, 2022)

SLUMP TEST

The slump test results conducted on 2.75 cement/sand mortar with different percentages of crumb rubber are presented in figure 3 and table 5. Figure 3 shows the graph of slump versus % the percentage of replacement of crumb rubber. Based on figure 3, it was observed at several ratios of crumb rubber, as a result of the volumetric replacement of fine aggregates (sand) by crumb rubber, the slump value decreases as the percentage of the replacement Increases. At 0% replacement, the slump is 4.5mm, while at 5% replacement, the slump decreases to 4mm, which is 11.11%. At 10%, replacement also decreases to 3mm, which is 33.33%. At 15%, 20%, 25% and 30% replacement, the slump value decreases to 2.5mm,1.5mm, 1mm and 0.5mm respectively, that is decrease of 44.44%, 66.67%, 77.78% and88.89%respectively.

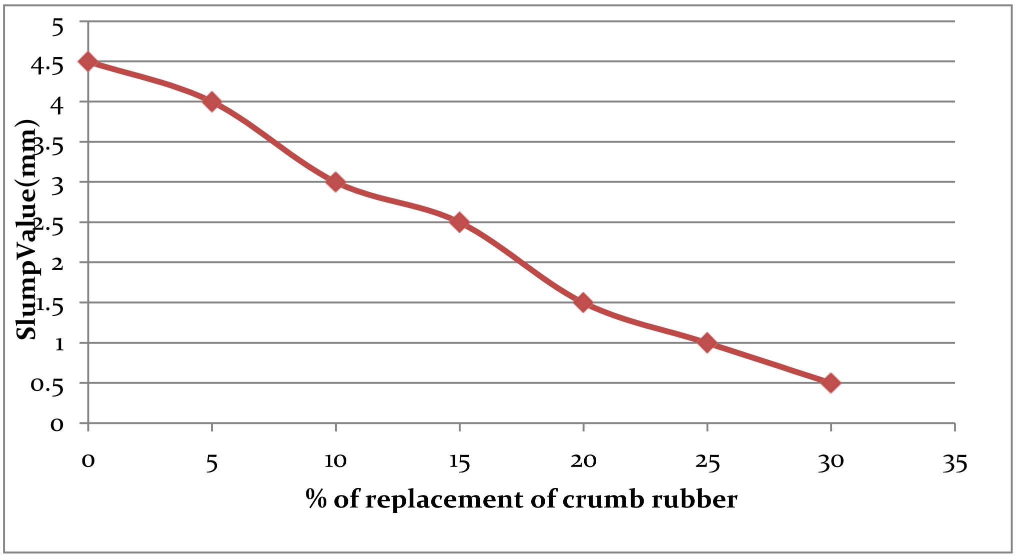

Figure 3: Graph shows slump versus % of replacement of crumb rubber.

COMPRESSIVE STRENGTH OF HARDENED MORTAR

The compressive strength of 1:2.75 cement/cement mortars for various percentage replacement of sand by crumb rubber is represented in table 11 and figure 4. Figure 4 shows the graph of the mean compressive strength of mortar versus age (days) for various percentages of replacement by crumb rubber.

Table 11 and figure 4 show the compressive strength test results for 3 days, 7 days, 14 days and 28days. It also indicates that the compressive strength increases with an increase in percentage replacement of crumb rubber up to 5%, then decreases up to 30% replacement of crumb rubber.

As a result of a volumetric of sand by crumb rubber, compressive strength at 3 days increases up to 5%. It decreases as the percentage of replacement increases, as shown in figure 4. At zero replacement, the compressive strength is 7.07N/mm^2, while at 5% replacement, the compressive strength increases to 8.67N/mm^2, an increase of 22.63%. At 10% replacement, compressive strength is 6.93N/mm^2, which is a decrease of 1.98% from the control. For the replacement of 15, 20, 25 and 30% replacement, the compressive strength is 5.75N/mm^2, 4.53N/mm^2, 4.27N/mm^2 and 3.86N/mm^2 respectively. The compressive strength drops to 18.67%, 35.93%, 39.6% and 45.4% respectively from the control value.

The compressive strength developed at age of 7days is 7.33N/mm^{2,} 8.80N/mm^2, 7.20N/mm^2, 5.86N/mm^2, 4.66N/mm^2, 4.40N/mm^2 and 3.93N/mm^2 for replacement value of 0%, 5%, 10%, 15%, 20%, 25% and 30% respectively. The % increase or drops reflecting those percentage is 20.05% increase, 1.17%, 20.05%, 36.43%,39.97% and 46.34% from the control value.

The compressive strength developed at age of 14days is7.73N/mm^{2,} 8.36N/mm^2, 7.33N/mm^2, 6.0N/mm^2, 4.8N/mm^2, 4.53N/mm^2 and 4.04N/mm^2 for replacement value of 0%, 5%, 10%, 15%, 20%, 25% and 30% respectively. The % increase or drops reflecting those percentage is 14.62% increase, 5.17%, 22.38%, 37.90%, 41.4% and 47.74% from the control values.

Furthermore, the compressive strength developed at age of 28 days is 8.33N/mm^2, 9.47N/mm^2, 8.93N/mm^2, 6.27N/mm^2, 5.20N/mm^2, 4.87N/mm^2 and 4.67N/mm^2 for replacement value of 0%, 5%, 10%, 15%, 20%, 25%

and 30% respectively. The % increases or drops reflecting those percentages are 13.69% increase, 7.2%, 24.73%, 37.58%, 41.54% and 43.94% from the control values. The decrease in compressive strength of mortar due to increased crumb rubber replacement (10%, 15%, 20%, 25% and 30%) is due to bonding between aggregate particles and the weakness of crumb rubber particles in comparison to sand. From this observation, it can be concluded that if the amount of replacement of crumb rubber exceeds 5%, it will reduce the compressive strength of mortar.

Table 11: Mean compressive strength

Age (days)	% replacement of Crumb rubber	Mean compressive strength	% difference in strength Concerning the control
3	0	7.07	-
3	5	8.67	22.63
3	10	6.93	1.98
3	15	5.73	18.95
3	20	4.53	35.93
3	25	4.27	39.60
3	30	3.86	45.40
7	0	7.33	-
7	5	8.80	20.05
7	10	7.20	1.77
7	15	5.86	20.05
7	20	4.66	36.43
7	25	4.40	39.97
7	30	3.93	46.34
14	0	7.73	-
14	5	8.86	14.62
14	10	7.33	5.17
14	15	6.00	22.38
14	20	4.80	37.90

14	25	4.53	41.40
14	30	4.04	47.74
28	0	8.33	-
28	5	9.47	13.69
28	10	8.93	7.20
28	15	6.27	24.73
28	20	5.20	37.58
28	25	4.87	41.54
28	30	4.67	43.94

Source: (Lab. Work, 2022)

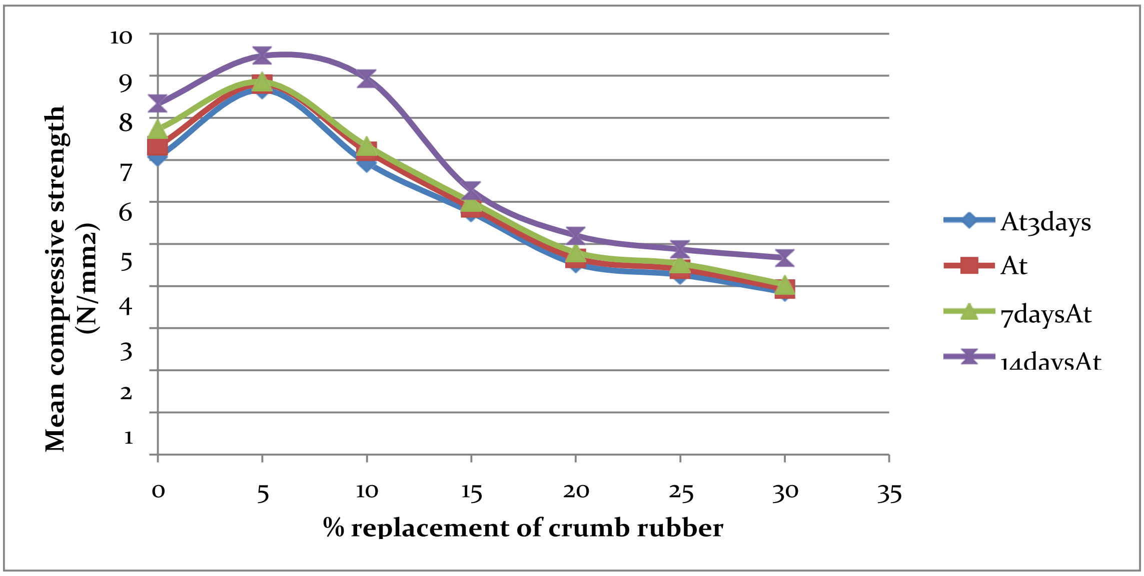

Figure 4: Mean compressive strength of 1:2. 75 cement/sand mortars for various % replacement of crumb rubber.

DENSITY OF HARDENED MORTAR

The summary of the results of density is presented in table 12 and figure 5. Figure 5 indicates the graph of mean density against % replacement of crumb rubber. Table 12 shows the results of density developed at the age of 28 days; figure 5 shows the basic relationship of density versus percentage replacement of crumb rubber. The density decreases as the % replacement of crumb rubber increases. The densities are 2285.33kg/m^3, 2266.67kg/m^3, 2262kg/m^3, 2165.33kg/m^3, 2157.33kg/m^3, 2146.67kg/m^3 and 2106.67kg/m^3 for replacement of 05, 10, 15, 20, 25 and 30% respectively. Those replacement shows decrease of density in which the density decrease to 0.82%,1.02%, 5.25%, 5.6%, 6.12%and 7.82%.

Table 12: Density of mortar samples

	Mass of Dry cubes (Kg)			Volume (m^3)	Average Density
ID	M1	M2	M3	V	D
A_0	0.291	0.291	0.275	0.000125	2285.33
A_5	0.279	0.291	0.280	0.000125	2266.67
A_{10}	0.293	0.280	0.294	0.000125	2312.00
A_{15}	0.271	0.270	0.271	0.000125	2165.33
A_{20}	0.255	0.264	0.290	0.000125	2157.33
A_{25}	0.271	0.263	0.271	0.000125	2146.67
A_{30}	0.260	0.265	0.265	0.000125	2106.67

Source: (Lab. Work, 2022)

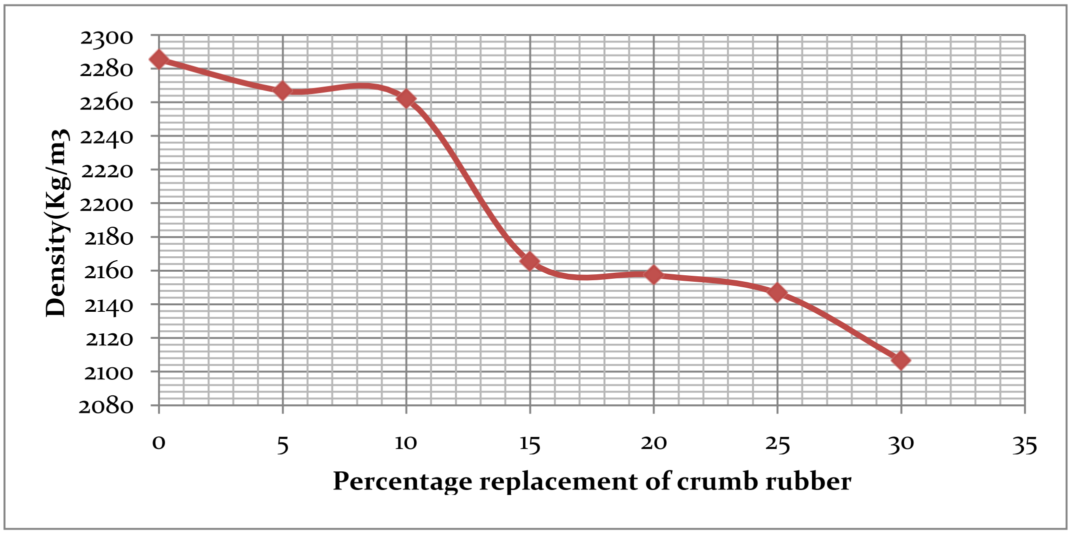

Figure 5: Density versus percentage replacement by crumb rubber.

WATER ABSORPTION TEST RESULTS

The results of the water absorption test are presented in table 13 and figure 6. Figure 6 indicates the graph of mean water absorption against % replacement of crumb rubber. Table 13 shows the results of water absorption developed at the age of 28days; figure 6 shows the basic relationship between water absorption versus percentage replacement of crumb rubber. Notice how water absorption behaves as replacement increase at 5%, 10%, 15%, 20%, 25%and 30%.

Water absorption decreases at 5% replacement and pounces back at 10%, 15%, and 20% and attains approximately its control value at 25% and increases at 30%. Therefore % replacement of up to 5% can be used as waterproofer to the mortar.

Table 13: Water absorption (%)

S/N	Water/cement ratio	%replacement By C.R.	Mean Water Absorption (%)
1	0.5	0.0	8.66
2	0.5	5.0	5.78
3	0.5	10.0	6.93
4	0.5	15.0	8.37
5	0.5	20.0	7.18
6	0.5	25.0	9.34

7	0.5	30.0	10.12

Source: (Lab. Work, 2022)

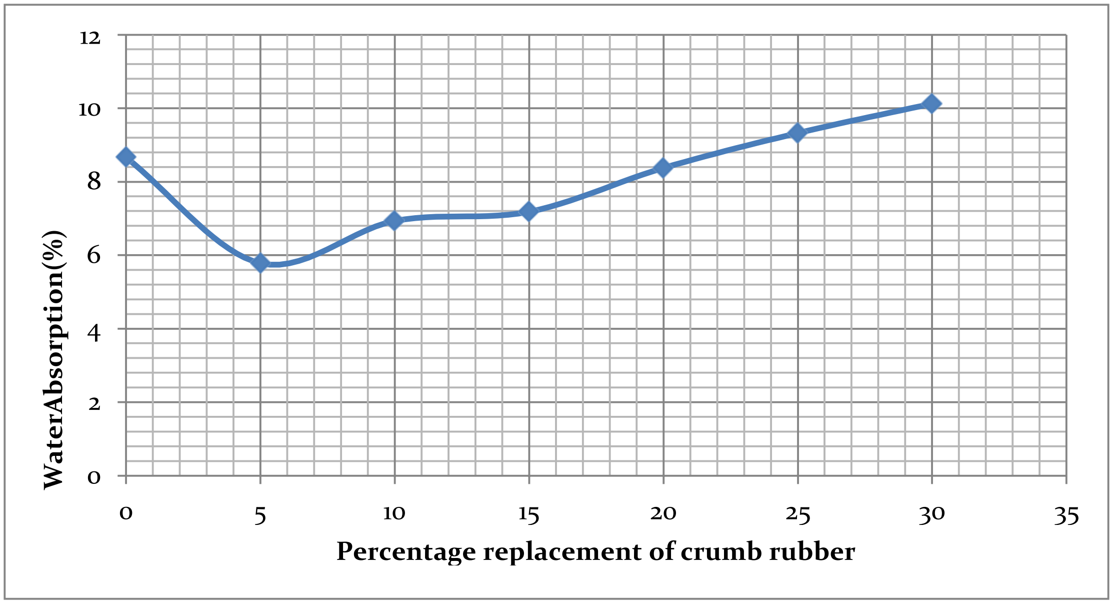

Figure 6: Graph of mean water absorption against% replacement of crumb rubber

CONCLUSIONS

Based on the results and analysis of this research, the following can be concluded.

- The slump test result shows a slight decrease in slump value as crumb rubber increases, indicating a true slump.
- Compressive strength increases at 5% of crumb rubber replacement and decreases as the crumb rubber increases at (10%, 15%, 20%, 25%, and30%) in mortar samples.
- Water absorption decreases at 5% and pounces back at 10%, 15%, and 20% and attains approximately its control value at 25% and increases at 30% and density decreases as the crumb rubber replacement in mortar production.
- Finally, 5% replacement of crumb rubber represents the optimum percentage required for best performance.

RECOMMENDATIONS

- Since adding crumb rubber increases compressive strength at 5% replacement, using the crumb rubber for mortar at that percentage replacement is recommended.
- Since adding crumb rubber decreases mortar density, it is recommended to use it for non-structural elements to reduce dead load.
- Studying the effect of larger sizes of shredded as partial replacement of coarse aggregate in concrete production is recommended.
- It is recommended to use replacement in an increment of 2% for better identification of the behavioral changes in the physical characteristics in future research.
- Using crumb rubber in producing concrete blocks, ribbed concrete blocks, and paving is strongly recommended.
- It is recommended to further test on physical characteristics of mortar through shrinkage limit, permeability etc.

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