

# THE ECONOMIC BENEFIT OF USING WASTE CRUSHED GLASS TO REPLACE SEA SAND AND ROAD SIDE SAND IN CONCRETE

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## ABSTRACT

*The reuse of waste glass in concrete production is among the most important options for the eradication of waste. Waste from building and construction sites contributes up to 75% of waste generated which is the highest waste generating sector in the world. The possibility of using discarded glass crushed into fine aggregate sizes as a partial replacement for sea sand and road side sand in concrete was investigated in this study. The crushed glass was varied from 0, 5, 10, 15, and 20% by weight to replace both sea sand and road side sand in a concrete mix of grade 40 using a water-cement ratio of 0.5. Concrete mixes were made using a mix proportion of 1:1:1 (cement: fine aggregate: coarse aggregate). Concrete samples were cured for 28 and 90 days. Tests were conducted on a total of 70 concrete cube specimens measuring 100 x 100 x 100mm. The Compression test shows that 15% replacement of sea sand with crushed glass mixed concrete at 90 days has a value of 50.71 MPa which had the highest compressive strength, a value which is more than the value of the control with 0% percentage replacement of fine aggregates. The partial replacement of sea sand and road side sand with crushed waste glass enhanced the compressive strength to a tolerable value of 20% replacement for both sea sand and road side sand, which may be utilized for structural purpose at building sites where there is no river sand. It is recommended that concrete produced by substituting fine aggregates with crushed glass for up to 20% can help reduce the emission of carbon dioxide by producing environmentally friendly concrete.*

**Keywords:** Waste glass, Fine Aggregates, Compressive strength, Structural purpose

## 1 INTRODUCTION

Daily lives as a result of manufactured goods including vacuum tubes, bottles, and sheet glass he wastes utilization of recycled glass helps in the energy saving. Glass is used often in our [1]. Promising findings have been obtained in recent studies that has examined the feasibility of utilizing waste glass as a partial substitute to fine aggregate. This study's key finding that glass color had no impact on concrete qualities [2]. Reusing these glass wastes is the quickest way to lessen their impact on the environment. Glass waste recycling is a great way to conserve resources, lessen the amount of space taken up by landfills, and save money and energy [3]. Most people use glass every day; it is essentially a translucent frozen liquid made of silica, soda ash, and calcium carbonate (CaCO<sub>3</sub>) that liquefies at very high temperatures. It is allowed to cool quickly to prevent the liquid from crystallizing [4, 5]. Sand and gravel make up the majority of all mined materials worldwide. Sand and gravel accounted for 68% to 85% of the

47 to 59 billion tonnes of materials discovered annually across the world [6]. In Nigeria, it's estimated that glass makes up 8.7% of the country's waste stream that is solid [7]. The building construction industry frequently uses recycled waste glass in concrete as partial replacements for at least one or more of its constituents. Researchers looked at utilizing waste glass as a partial replacement for fine or coarse aggregate, or for both fine and coarse aggregates together. Others employed glass powder as a partial replacement for cement due to its pozzolanic nature [8]. Waste glass should not be dumped since it is nonbiodegradable and less ecologically friendly than other waste [9]. In place of natural sand, finely crushed recycled glass was utilized in concrete. The findings showed that adding more glass aggregate substitute to concrete improved its compressive strength noticeably [10]. The impact of using 100% glass instead of natural fine particles was investigated. Three mixes of fine glass aggregate and four mixes of natural sand were among the seven mixtures that were created and tested. The two types of mixes with the same w/c and cement paste content had their fresh and mechanical characteristics tested for 28 days of compressive strength [11]. The impact of using glass powder in concrete was examined, and the findings revealed that glass powder boosts concrete's workability and compressive strength but decreases concrete's density when compared to normal concrete [12]. According to this study, concrete with up to 30 % glass aggregate has better compressive strength than concrete without glass aggregate, with compressive strength declining at higher mix proportions [13]. In this study, fine glass powder was utilized in place of cement in the construction of concrete. At 10, 20, 30 and 40% of cement content, glass powder was mostly substituted, and its compressive strength, tensile strength, and flexural strength were evaluated up to 60 days after curing. The outcomes were compared with those of conventional cement. The findings show that glass powder can be used as a replacement material for salt silica up to molecular sizes less than 75 $\mu$ m. Also, it was shown that the compressive strength increased with an increase in glass powder content up to 40%; however, a further increase in glass powder causes the compressive strength to drop [14]. Increases in the pozzolanic reaction of glass powder result in more C-S-H gel and better mechanical and long-lasting glass powder concrete [15]. An Increase in the pozzolanic reaction of glass powder results in more C-S-H gel and better mechanical and long-lasting glass powder concrete [16]. This study addressed a research gap by employing discarded crushed glass as a partial substitute for both road-side sand and sea sand in concrete, where little or no work has been done incorporating waste-crushed glass in concrete as a partial replacement of road-side sand in concrete.

## **2 MATERIALS AND METHODS**

The materials used in this project were Lafarge Portland limestone cement grade 42.5.N which met the specifications of [17]. Sand was within the range of 0- 4.5 mm in size, crushed granite was 12 mm in size, which was angular in form and well graded. Lafarge Portland limestone cement was obtained from a construction site in Abeokuta. The crushed glasses were sourced locally and were processed using a hammer mill into finer granules. The pulverized glass was sieved using a sieve size 4.75mm to obtain the fine aggregate of the glass shown in Plate 1. Road side sand shown in Plate 2 was sourced from the Alabata - Federal University of Agriculture Abeokuta Road, the coarse aggregates (CA) was sourced from Alabata Abeokuta, Nigeria, while sea sand shown in Plate 3 was obtained from Elegushi beach, Lekki in Lagos. They were produced and used in accordance with [18]. Water was obtained from a borehole was used for mixing and production in the Civil Engineering Laboratory of the Federal University of Agriculture Abeokuta, Nigeria, which was in accordance with [19]. The fine aggregates used in the study were Road-side sand and sea sand. The following road-side sand to wasted crushed glass ratios was selected and the concrete produced and cured for a period of 28 and 90 days.

- 95% Road-side sand mixed with 5 % of wasted crushed glass.
- 90% Road-side sand mixed with 10 % of wasted crushed glass.
- 85% Road-side sand mixed with 15 % of wasted crushed glass.
- 80% Road-side sand mixed with 20 % of wasted crushed glass.

The following sea sand to wasted crushed glass ratios were selected and the concrete produced and cured for a period of 28 and 90 days.

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Plate 1. Crushed waste



Plate 2. Road side sand



Plate 3. Sea sand

## 2.1 Preparations of test samples

For each replacement, the weight batching technique was applied, and five replicates were obtained. For the seven percentage replacements, mass substitutions of crushed glass with sea sand and road side sand were 0, 5, 10, 15 and 20% respectively. For all batches, the water content was kept constant at 0.5. Table 1 shows the mix ratio of 1:1:1.

Table 1. Batch mix proportions for waste crushed glass concrete replacement

% Replacement	Cement (Kg)	Sea sand & Road side sand (Kg)	Granite (Kg)	Crushed Glass (Kg)
0.00	18.18	18.18	18.18	0.00
5	18.18	17.28	18.18	0.91
10	18.18	16.36	18.18	1.82
15	18.18	15.45	18.18	2.73
20	18.18	14.54	18.18	3.64

## 2.2 Casting of concrete

Crushed glass was utilized in concrete to partially replace fine aggregates (sea sand and road side sand) at 0, 5, 10, 15 and 20%. Samples were cast using concrete target strength of 40 N/mm<sup>2</sup> and a w/c ratio of 0.5. 100 x 100 x 100mm concrete cubes were cast by hand mix in a mould and de- moulded after 24 hours. For identification purposes, each specimen was labelled suitably. For each % substitution of waste glass with both sea sand and road side sand, the samples were cured in potable water by complete immersion at room temperature and tested for compressive strengths at ages of 28 and 90 days. Plate 4 show mixing of aggregates, while plate 5 show curing of cubes.



Plate 4. Mixing of aggregates



Plate 5. Curing of cubes

### **2.3 Specific gravity**

The specific gravity of the cement and crushed waste glass were carried out according to the standard of [20].

### **2.4 Compressive Test**

Five duplicate specimens were tested for strength. Using a 600 kN capacity Zhejiang Tugong Universal testing machine, the compressive strength of concrete cubes was evaluated in accordance with [21]. Concrete samples were prepared and tested at Engr. Habu Ahmed Gumel Civil Engineering building FUNAAB (Plate 6).



Plate 6. Compressive Test using Zhejiang Tugong Universal Testing Machine

### **2.5 Chemical Composition**

The samples were pulverized and sieved before being analyzed. Skyray EDX3600B X-ray spectrometer was used (Plate 7) to determine the elemental composition of crushed glass and cement. The X-ray spectrometer was used with a variety of crystals (synthetic, Ge, or LiF) and detectors (flow, scintillator, or combination flow/sealed detector) depending on the element with an acceleration voltage range of 32–60 kV and a current range of 10 to 125 mA.



Plate 7. XRF complete system using a Skyray EDX3600B X-ray Spectrometer

### 3 RESULTS AND DISCUSSION

#### 3.1 Specific Gravity

Specific gravity was directly related to the relative density of the solid material which made up the constituent particles, not including the pore space within the particles that was accessible to water. The road side sand was lighter than the sea sand, while the waste glass was lighter than the sea sand as seen in Table 2. As a result, when waste glass was partially replaced with road side sand (fine aggregate), the concrete was lighter than when waste glass was partially replaced with sea sand. This corroborates with the result showed in Table 2, from the compressive strength result showing a higher strength value experienced in concrete samples made when waste glass was partially replaced with sea sand compared to the lower compressive strength value when waste glass was partially replaced with road side sand. This result is in agreement with [22]. The values of cement and fine aggregates were more than crushed glass which meant that crushed glass produced lighter concrete in terms of weight.

Table 2. Determined specific gravity

Type of sample	Specific gravity
Cement	3.09
Sea sand	2.39
Road-side sand	2.27
<u>Waste Glass</u>	<u>2.19</u>

#### 3.2 Chemical Composition

Table 3 lists the primary chemical constituents of crushed glass as determined by XRF. Silicon oxide makes up 64 percent of the crushed glass. The high reactive silica concentration and lime fixation capacity, which match its chemical composition as indicated by X-ray fluorescence (XRF) data, are noteworthy. Silicon oxide (SiO<sub>2</sub>) was the most abundant component, followed by aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) and iron oxide (Fe<sub>2</sub>O<sub>3</sub>). This result of the chemical properties of crushed glass was in agreement with [23]. The mass fractions (SiO<sub>2</sub>+ Al<sub>2</sub>O<sub>3</sub>+ Fe<sub>2</sub>O<sub>3</sub>) was greater than >70 for natural pozzolana which met [24]. In addition, the SO<sub>3</sub> and loss on ignition (LOI) met the requirements of [24].

Table 3. XRF results of crushed glass samples

Element	Crushed Glass	Cement
SiO <sub>2</sub>	69.46	17.769
Al <sub>2</sub> O <sub>3</sub>	1.09	4.308
Fe <sub>2</sub> O <sub>3</sub>	0.71	2.757
CaO	8.22	59.888
MgO	3.65	1.378
SO <sub>3</sub>	0.06	2.295
K <sub>2</sub> O	0.19	0.125
Na <sub>2</sub> O	12.84	0.000
P <sub>2</sub> O <sub>5</sub>	0.06	0.136
LOI	0.00	9.800
M <sub>2</sub> O <sub>5</sub>	0.13	0.000
TiO <sub>2</sub>	0.18	0.000

#### 3.3 Compressive Strength Test

Table 4 showed that the road-side sand performed moderately in comparison with sea sand. The result showed that the compressive strengths for 28 and 90 days for sea sand was higher than that of road-

side sand. The result was in line with [25] who compared the mechanical and physical properties of concrete cubes by substituting varying degrees of fine and coarse glass in the concrete mix. It was observed that the results were greater than the typical concrete sample reducing the alkali- silica reaction in concrete.

Table 4. Results of Compressive Strength of partially replacing crushed glass with road-side and sea sand

% Replacement of Crushed Glass added	28 days Road- side sand (MPa)	28 days Sea- sand (MPa)	90 days Road- side sand (MPa)	90 days Sea sand (MPa)
0%	35.04	41.72	37.67	44.01
5%	40.39	42.62	41.03	45.23
10%	37.5	45.78	38.63	46.16
15%	41.58	48.29	44.69	50.71
20%	32.32	32.35	32.74	34.26

The optimum compressive strength occurred at 90 days with a value of 50.71 MPa which was at 15 percentage replacement of sea sand with crushed waste glass. The minimum compressive strength was 32.32 MPa at 28 days for 20 percentage replacement of road-side sand with crushed glass. Overall, there was a general increment from zero percentage replacement to 15 percentage replacement of crushed waste glass with both sea sand and road-side sand. Overall, at both 28 and 90 days, the partial replacement of sea sand with crushed glass performed better than the control (0% replacement of sea sand with crushed glass) in all percentage replacements from 0 to 15% except for 20% which was lower than the control value. This result was in line with [26] who studied the use of crushed glass as a substitute for fine aggregates in concrete production, the compressive strength from the experimental data revealed that the compressive strength increased up to 20% substitution dosage, then dropped at 30 and 40% substitution.

#### 4 CONCLUSIONS

The present study has efficiently and effectively demonstrated the application of waste glass into useful constructional materials as well as reducing its menace in our surrounding. Waste crushed glass up to 20% replacement did not meet up with the desired strength of 40 MPa but it can effectively be used as fine aggregate replacement (sea sand and road-side sand). The optimum compressive strength was 15% at 90 days curing period with a value of 50.71 MPa. The use of roadside and sea sand can be used to replace river sand because river sand is becoming an increasingly scarce fine aggregate material. The use of waste glass in concrete is economical and reduces the wastage of waste glass creating a cleaner and environmentally friendly concrete.

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