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Investigation On The Strength And Density Of Concrete Made By Partial Replacement Of Waste Glass As Coars Aggregate

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ABSTRACT

Concrete is a highly compacted construction composite material made by mixing suitable quantities of coarse and fine aggregates, cement and water. Its strength is much greater than ordinary bricks used in construction due to its nature of cast. Concrete is used in beams as pillars to hold structure firm to the ground, and in up-floors for storey buildings. Glass is an indispensable solid waste in our environment. Its durability, none-biodegradability and noncorrosive characteristics places it permanently in our surroundings as waste and hence the need to find suitable ways of converting it into proper usage to clean our habitat. In the present paper, we investigate the suitability of waste glass as stabilization in concrete as coarse aggregate. We deduce from the experiment that concrete with 0 % replacement has the maximum average strength of 29.27 N/mm^2 and highest density of 2591 kg/m^3, followed by 50% partial replacement with strength of 28.59 N/mm^2 and density 2558 kg/m^3. Relationship between density and load response indicate that density of concrete is directly proportional to the load it can take before failure and this is also proportional to the compressive strength. The least weight is recorded in the 100% glass replacement making concrete made of glass suitable for application in up-floor on storey buildings to reduce pressure on beams.

***Keywords*:**Coarse aggregate, concrete, waste glass, compressive strength, density

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I. INTRODUCTION

Over the past decades, human civilization has continued to evolve in the area of building and construction for shelter. Every animal needs shelter from adverse weather conditions such as rainfall, the scorching sun, and extreme wind.

Human being been the highest class of animals with rational reasoning and senses are placed on a better advantage over other creatures. Humans are creative and innovative and as a matter of fact seek better ways of making their own homes for shelter. Advances in research due to civilization have over the years introduced steady modifications in the architectural development of buildings. The early man lived in caves, covered his head with hedge**.** This was followed by molding the earth crust or soil into houses for shield and cover.

The quest for comfort and style crept in, taking construction to higher levels. Scientific discoveries led to great industrialization. Companies, industries and factories came to stage as man continued to explore his environment. Development has therefore resulted to several advances in the construction sector, making researchers look for different ways of making structures.

The human population is continually growing in number. There is therefore great demand for constructing more structures to facilitate the needs of our communities [1]. Our quarry has suffered over usage and is running out of its supply. Operations in the quarry site increases yearly with human population and hence demand. In places where gravel cannot be found, mountains are been blasted and treated into suitable sizes of stones for concrete making. The uncontrolled destruction of mountains constitutes a major contribution to landslide and flashfloods.

The excavation of gravel is degrading our environment. These menaces coupled with the depletion of the quarry has lured researchers into finding alternative materials as replacement in concrete. Looking around our habitat, there are some industrial byproducts that can be used in the construction industry. Such waste materials from our homes and factories lither our surrounding, and burden the environment by occupying the little space around us. According to [2], there is therefore a significant world-wide interest to solve the environmental problems caused by industrial waste and other materials by including such materials in the manufacture of concrete.

Waste matter such as glass can well be researched to check its suitability in the construction industry. Glass in general is a highly transparent material formed by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at elevated temperature followed by cooling during which solidification occurs without crystallization [3,4].

Glass enters our environment through different ways. Glass comes from the manufacturing industry in the form of bottles containing diverse substances such as beverages, powders and chemicals. It also comes in the form of glass sheet used for various purposes, vacuum tubes and glassware. Since its discovery, glass has become indispensable to our daily lives. We contact or use glass every day that passes by. The discouragement of metals due to their rusting problems thereby reacting with their contents and contaminating them have increased the use of glass and plastics for storage, carriage and passages.

Glass containers are often littered in our habitat and are found in large quantities. In recent times, glass is recycled in the industry into new products for different uses. This waste material is also been thought of as being useful to the building and construction industry. Many scientists have looked into its viability for construction, and the research is still ongoing. According to [5] the application of glass in architectural concrete still needs improvement and hence further study is need to see how to beat down the cost of concrete casting.

The major objective of the research is to study the stabilization of glass in concrete. While the specific objectives are: to comparatively study the load response of concrete made with 100% glass and gravel; to investigate the effect of different percentages of glass-gravel mix in the strength of concrete; and to study the effect of partial replacement of waste glass on the weight of concrete for up-floor in storey buildings.

1.1 Advantages of Waste Glass as Coarse Aggregate

According to [6], recycled glass has the following advantages in concrete.

(i) It provides aesthetic look
(ii) It provides high abrasion resistance
(iii) It provides greater water tightness
(iv) Its removes waste glass from the environment which otherwise is difficult to dispose of.
(v) It provides good soundness as glass is a hard material.

II. MATERIALS

2.1 Sand

The sharp sand was collected from River Benue, Makurdi, Nigeria. It was made clean and free from dirt and organic matter of any predictable description. The sand particles have average size of 4.5 mm with specific gravity of 2.42.

2.2 Cement

The binding agent, cement, was obtained from Dangote Cement Company, Gboko, Benue State, Nigeria whose properties conform to high standard. The Portland limestone cement is of 42.5N grade with specific gravity of 3.15.

2.3 Water

Portable water suitable for human consumption was used as solvent for the insoluble matter in the mix. The water had all the standard physical characteristic of good water.

2.4 Coarse Aggregate

Coarse aggregate are the angular materials obtained from rocks and crushed stones. They may also be derived from synthetic materials like slag, shale, fly ash and clay use in light-weight concrete [7]. Research has shown that aggregate plays a substantial role in determining workability, strength, dimensional stability and durability of concrete. Aggregate can also have a significant effect on the cost of concrete [8].

The coarse aggregate comprises of both crushed waste glass and granite of sized 10 – 13 mm size. The waste glass bottles were obtained from Nigeria Breweries, Makurdi, Benue State, Nigeria. Bottles were washed and all labels removed. It was later crushed into desired size suitable for coarse aggregate. The specific gravity of the waste glass was determined to be 2.58.

The following materials were used to prepare the concretes: Cement, fine aggregate, gravel, broken bottles, water, tamping rod (16 mm in diameter and 610 mm long), sieve (25 mm), mould (150 x 150 x 150) mm, curing tank, slum cone, and vibrating machine. Testing of the cubes was done using compressive testing machine (model ELE Compact-1500). The sharp sand was collected from River Benue, Makurdi while the cement was supplied by Dangote Cement Company.

III. EXPERIMENT

3.1 Total Replacement of Coarse Aggregate

Mix ratio of concrete defines the ratio of cement, sand and coarse aggregate in that order. The cement was first mixed with fine aggregate (sharp sand) in the ratio 1:2 on a water tight none-absorbent platform until the mixture was thoroughly blended and of a uniform colour. Meanwhile the aggregates were cleansed and made free from impurities which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix and it reduces the durability of concrete [9].

The coarse aggregate (100% gravel) was then added to the already prepared cement-sand mix in a ratio 1:2:4. The mixing continued until the coarse aggregate was uniformly distributed throughout the batch while adding water to the system until the cement appears to be homogeneous and of the desired consistency. The prepared mix was poured into the moulds to cast the concrete cubes. Six cubes were casted for each batch and labeled accordingly, noting also the expected curing period.

The above procedure was repeated for a complete 100% broken glass replacement as coarse aggregate in the concrete production.

3.2 Partial Replacement of Coarse Aggregate

On a partial replacement of broken bottles as coarse aggregate in concrete, the cement and fine aggregate was first mixed as explained earlier after which 75 % broken bottle and 25 % gravel were added to the cement-sand mix. The mixture was done until the coarse aggregate (gravel-glass) was distributed throughout the batch. Water was then added to slurry.

The above procedure was repeated for 25 % broken bottles replacement and 75 % gravel for another batch of concrete. The last batch of concrete was prepared in the amount of (50 – 50) % glass-bottles replacement. Samples were labeled A and B respectively.

3.3Casting

The moulds were properly cleansed and oil applied to the inner part of the moulds for easy removal. The slurry was filled in the moulds in 3 layers approximately 5 cm thick. The electric vibrating machine was used during the compacting process for uniform pressure distribution. Care was taken during compaction to avoid segregation. The top surface was leveled and smoothed with a travel. Altogether, 30 cubes of 150 x 150 x 150 mm size were casted along 0.58 water-cement ratio (w/c) with a total volume of 0.02025 m^3.

3.4 Curing

After eight to ten hours of casting, the cube moulds were wrapped with wetted hessian cloth to minimize moisture lost. The mould's top portion was covered with a polythene sheet so that water doesn't fall on the concrete surface. The cube moulds and content were uncovered after 24 hours of casting and ready for detachment. The nut-bolts of the moulds were loosened and the specimen carefully removed to avoid distortion, because at this stage concrete is still weak and can be broken.

The specimens were put into a tank of clean water for curing immediately after removal. The cubes were fully submerged in the water. The water for curing was tested and maintained at room temperature of 27^0C throughout the curing period. The concrete specimens were removed from the curing tank and taken to the Civil Engineering laboratory of University of Agriculture Makurdi for compressive strength test after the 7th, 14th, 21^{st} and 28^{th} day of curing respectively. Two cubes were aged in the same period of time and tested to obtain averages of weight, density, load response and strength ensure accuracy. The Cubes were individually tested in the laboratory using compressive strength testing machine of model ELE compact-1500 and the results recorded.

3.5 **Calculations**

The density of materials was found using the formula

$$\text{Density} = \frac{\text{Ratio of materials}}{\text{Total ratio}} \times \text{total volume} \times \text{specific gravity of the material} \quad (1)$$

The quantity of coarse aggregate for partial replacements was calculated using the mathematical relation.

$$\text{Amount of coarse aggregate} = \frac{\text{percentage of replacement}}{100} \times \text{density of coarse aggregate} \quad (2)$$

Figure 1: Broken bottles

Figure 2: Curing of specimens

Figure 3: Cube strength test

IV. RESULTS

Table 1: Slum Test for Different Ratios of Concrete Mix

Table 1: Slum Test for Different Ratios of Concrete Mix

Partial replacement (%)	Water/cement ratio	Slum (cm)
0	0.58	5.0
25	0.52	4.4
50	0.58	5.0
75	0.47	4.8
100	0.55	4.5

Table 2: Compressive Strength for 0 % Glass Replacement

Age (days)	Strength (N/mm^2)	Weight (g)	Density (kg/m^3)	Load (kN)
7	26.49	8426	2497	596
14	27.16	6518	2524	610
28	34.16	9288	2752	768

Table 3: Compressive Strength for 100 % Glass Replacement

Age (days)	Strength (N/mm^2)	Weight (g)	Density (kg/m^3)	Load (kN)
7	17.78	8034	2375	395
14	15.11	7954	2357	340
28	12.89	6437	1907	290

Table 6: Compressive Strength for 25 % Glass Replacement

Age (days)	Strength (N/mm^2)	Weight (g)	Density (kg/m^3)	Load (kN)
7	23.22	8406	2490	528
14	24.45	8486	2514	550
28	31.11	9012	2670	700

Table 7: Averages of Compressive Strength, Load and Density of Concrete

Partial replacement (%)	Strength (N/mm^2)	Load (kN)	Density (kg/m^3)
0	29.27	658.0	2591
25	26.26	387.7	1969
50	28.59	592.7	2558
75	17.39	592.0	2532
100	15.26	341.7	2218

Table 4: Compressive Strength for 75 % Glass Replacement

Age (days)	Strength (N/mm^2)	Weight (g)	Density (kg/m^3)	Load (kN)
7	16.56	8022	2377	373
14	19.16	8216	2434	420
28	16.45	8278	1096	370

Table 5: Compressive Strength for 50 % Glass Replacement

Age (days)	Strength (N/mm^2)	Weight (g)	Density (kg/m^3)	Load (kN)
7	22.22	8160	2418	496
14	32.00	8486	2514	570
28	31.56	8987	2663	710

Figure 4: Bar chart of compressive strength against age

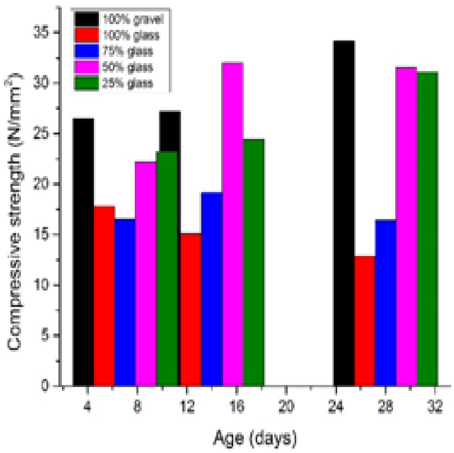
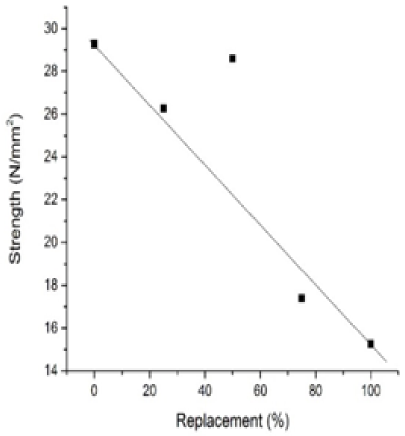


Figure 5: Graph of strength against partial replacement



V. DISCUSSION

5.1 Slum

Slum test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete and therefore, the ease with which it can flow. It can also be used as an indicator of an improperly mixed batch. The slum test is used to ensure uniformity for different loads of concretes under field conditions [10].

The slum test in Table 1 reveals that both 0% and 50% replacement of glass have the highest but equal slum value of 5.0 cm with the highest water/cement ration of 0.58. This is followed by 75% glass replacement with 4.8 cm slum. While 100% and 25% partial replacement takes the least average slum value of 4.5 cm. The slum is in approximate range with that achieved by [8].

5.2 Compressive Strength

As can be seen from Fig. 4 and Tables 2 – 6, the compressive strength of concrete made by 0 % glass replacement increased with age from 26.49 N/mm^2 on the 7th day to 34.16 N/mm^2 on the 28th day. The concrete takes the highest load of 658 kN and has the highest density of 2591 kg/m^3. While concrete with 100% glass replacement experienced decrease in strength from 17.78 – 12.89 N/mm^2 with increasing age taking the least load 341.7 kN. The decrease in strength with time could be attributed to the type of coarse aggregate which in our case is glass since it is not rough and angular like gravel. The broken bottles have policed and smooth surfaces which can reduce cohesion except at the edges.

Another significant increasing strength with aging is observed in the 25% glass replacement with respond pressure value range 23.22 – 31.11 N/mm^2 been the second with load and density values of 592.7 kN and 2558 kg/m^3. For the 50% glass replacement, the strength increased from 22.22 – 31.56 N/mm^2 with high load response value of 592 kN equal to the 25% glass replacement. A similar trend of decrease in strength with increasing glass replacement is reported by [3,4].

On the average, as can be seen in Fig. 5 and Table 7, the compressive strength decreases with increasing percentage replacement of glass as coarse aggregate (29.27 – 15.26) N/mm^2. This is also demonstrated in Figure 5 with a negative slope. The compressive strength is observed to decrease by 0.14 N/mm^2 per 1 % partial replacement by waste glass.

Generally, we observed that the more the quantity of gravel present, the greater the strength of concrete and density which implies that gravel gives better strength and toughness to concrete but has more weight. In the other hand, the more the amount of glass present, the less the strength and hence density of concrete. Meanwhile it is noticed that the maximum load a concrete can take is proportional to its density. We therefore assert that concrete made of glass can be suitable for non-beam platforms to reduce pressure on beams or pillars.

VI. CONCLUSION

Investigation on the use of waste glass as coarse aggregate in concrete was successfully carried out. The best slum value of 5.0 cm was observed at both 0 % and 50% glass replacement. We observed that gravel provides better strength to concrete due to its roughness and interfacial bonding with other matter in the mix. Concrete made of glass is light-weight and is considered good for beamless applications since its strength is also good for concrete making. We recommend glass for partial replacement as coarse aggregate in concrete as it possesses the following properties: light-weight, economical and reduced thickness.

REFERENCES

[1]. U.G. Tomas (Jr).: Use of recycled glass bottles as fine aggregate in concretes,International Journal of Advanced Science and Technology, 61, 2013, 17 – 28.

[2]. N.Koli, N.Aiwale, A.Inamdar,S. Abbhishek,Manufacturingofconcrete paving block by using waste glass materials, International Journal of Scientific Research Publication, 6 (6), 2016, 61 – 77.

[3]. S.Jagmeet and S.Rajindervir,a review on recycling of waste glass in construction industry. International Journal of Advances Research in Engineering and Applied Science, 5(7), 2016, 37 – 44.

[4]. S. Shalini, Partial replacement of coarse aggregate with waste glass in concrete,International Journal of Innovative Research in Science, Engineering and Technology, 6(4), 2017, 6723 – 6728.
[5]. S. P. Gautan, S. Vihkas, and V. C. Agawal, Use of glass waste as fine aggregate in concrete. Journal Academic and Industrial Research, 1(6), 2012, 320 – 322
[6]. S.Navinderdeep, and Manisha,Utilization of crushed glass waste as aggregate. International Journal of Recent Trends in Engineering Research, 2 (4), 2016, 506 – 511.
[7]. S.Vikas, S. P.Gautam, V. C.Agarwal, P.K.Mehta, Journal of Environment and Nanotechnology, 3(1), 2014, 67 – 71.
[8]. U. G. Tomas(Jr), The effect of waste glass bottles as an alternative coarse aggregate in concrete mixture. International Journal of ICT – Aided Architecture and Civil Engineering, 1 (2), 2014, 1 – 10.
[9]. I.R.Muhit, S.Haque, A. Md.Rabiul, Influence of crushes coarse aggregate on properties of concrete. American Journal of Civil Engineering and Architecture, 1(5), 2013, 103 – 106.
[10]. G.Zoran, D.Iva, T. C.Gordana, Properties of Self-Compacting Concrete with Different Types of Additives. Architecture and Civil Engineering, 5(2), 2008, 173 – 177.

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