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INVESTIGATING FOR POZZOLANIC ACTIVITY IN THE BLEND OF GROUND GLASS WASTE WITH CEMENT FOR SUSTAINABLE CONCRETE

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ABSTRACT

This research work investigates the tensile and flexural strengths of concrete containing ground glass as a partial replacement for cement. Sustainability is to be attained by the reduced volume and cost of disposing the glass wastes that would have been meant for landfills, reduce the cost of glass-cements blend because the glass are unwanted wastes that needs lesser heat to process as a pozzolan for use in concrete, and reduce greenhouse gas emissions due to the reduced use of cement needed per unit concrete due to the replacement.

The ground glass was obtained from waste louver blades, pulverized and sieved with a 100µm sieve size. The physical properties such as moisture content, bulk density and specific gravity of the ground glass (GG) were determined. Sixty (60) cylinders of 150mm diameter and 300mm high were cast, three (3) samples for each of the percentage replacement groups of 0%, 10%, 20%, 30% and 40% corresponding to the curing ages of 3, 7, 28 and 56 days for each test. Thirty-six (36) beams of

100x100x500mm were also cast for flexural strength test, three (3) samples for each of the percentage replacement groups of 0%, 20% and 40% corresponding to the curing ages of 3, 7, 28 and 56 days. The specific gravity of the GG was found to be 3.67 and the bulk density was 1275kg/m^3. The results of the findings show that as the partial replacement of cement with ground glass increases from 10% to 40%, the tensile strength of specimens for all curing periods of 3 to 56 days decreases. The flexural strength tests show a similar pattern of reducing flexural strength for all the curing ages as percentage replacement increases. However, it was observed that concrete with 10% replacement of cement with ground glass at 100μm fineness level had slight improved tensile strength of the concrete than the control (0% replacement with the GG) for the later curing period indicating the pozzolanic activity of ground glass.

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1. BACKGROUND OF THE STUDY

The ecologically sound disposal of municipal waste has been a matter of increasing concern in recent years with decreasing availability of landfill space [1]. To this effect, research have been carried out to investigate how these wastes could be recycled to other useful products. One of the identified ways these materials could be recycled is in concrete as a pozzolan, which means that they can be used to replace cements at varying degrees. According to [2], a pozzolanic material is a siliceous or siliceous and aluminous material which, in itself, possesses little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Several studies have identified that most industrial and agricultural wastes such as fly-ash, rice husk ash, saw dust ash and blast furnace slag are pozzolanic [3] and can replace cement at varying degrees in concrete production. The use of fly-ash, blast furnace slag and silica fumes are being standardized in [4] as viable cement replacements in concrete. They are even proven to impute better strength and durability characteristics than when only cement is used in concrete production.

Waste glass has over many years been a major toxic waste material posing serious problems for municipalities worldwide, since glass is not biodegradable and only a small fraction can be reused by primary market like the bottling and container industry [5].

Concrete is the world most manmade consumed material [6], the possibility of recycling glass into concrete production has the potential of eliminating the nuisance this nonbiodegradable waste pose to the environment. Also, the use of glass pozzolan as an alternative binder to cement in concrete will bring about the utilization of waste glass, hence, proffering solutions associated with the disposal in waste generation, the reduction in quantity and cost of cement applied in concrete and may improve the durability and properties of concrete. This cost reduction can ultimately translate to lower housing cost and reduce the housing deficit currently being experienced in most developing countries [7].

Also, cement is a major material in concrete that release green house gasses that harm the environment. According to [8], concrete production contributes 5% of the annual global carbon dioxide (CO_2) emissions of which the bulk is from the production of cement. The possibility of waste glass replacing cement will be a very viable environmental benefit venture. This will reduce the volume and cost of disposing the glass wastes that would have been meant for landfills, reduce the cost of glass-cements blend because the glass are unwanted wastes that needs lesser heat to process as a pozzolan for use in concrete, and reduce greenhouse gas emissions due to the reduced use of cement needed per unit concrete due to the replacement. In the efforts for greener construction material development, there have been efforts to replace cement with other agricultural and industrial wastes [9-12]

It is therefore important to examine the strength characteristics of concrete containing glass pozzolans as an alternative binder to cement with view to developing parameters and providing empirical basis for the effective structural utilization of glass (which could have otherwise been passed as waste) in housing construction. This will be achieved by investigating the effect of replacement level of cement with waste ground glass on the strength characteristics of concrete; investigate the effect of curing age on the strength characteristics of concrete in which the cement binder has been partially replaced with ground glass; and compare the rate of gain of strength of ground glass pozzolan/cement concrete with normal strength concrete (without pozzolan). Waste glass is often less expensive and replacing a portion of conventional cement with ground glass, the cost of the overall cementitious composition can be reduced thus reducing the consumption of Portland cement and consuming excess calcium hydroxide in the cementitious composition which could have reacted with chemicals in the environment to weaken solidified concrete. It would help overcome problems of waste glass in waste management and may lead to improvement in durability, prevention of deterioration and increment in the long-term strength of concrete, energy savings, promotion of ecological balance and conservation of natural resources [13].

2. MATERIALS AND RESEARCH METHODOLOGY

The ground glass in this study was obtained from waste lourve blades which were cleaned, crushed, ground and sieved using 100µm sieve. Laboratory tests such as sieve analysis, bulk density, relative density, specific gravity and water absorption tests were carried out on the samples of GG. A trial mix design was used to determine the proportion of the respective samples used for the production of 60 numbers of 150mm by 300mm cylinders and 36 numbers of 100mm by 100mm by 500mm beam (3 for each of the percentage replacement groups, corresponding to 3, 7, 28, 56, 90 days). The mixing of the samples were done manually after which the slump test were carried out. The specimens were de-moulded after twenth-four (24) hours of casting and were immersed in a curing tank. Compressive strength test, tensile strength test, flexural strength test was carried out for 3, 7, 28, 56, 90 days hydration period. These strength tests were performed to [14]. Table 1 and Table 2 shows the schedule of concrete samples for the cubes for compressive strength test, cylinders for tensile strength test and beams for the flexural strength test.

Table 1 Schedule of Concrete 150mm by 300mm Cylinders

% rep	0	10	20	30	40	Total
3	3	3	3	3	3	15
7	3	3	3	3	3	15
28	3	3	3	3	3	15
56	3	3	3	3	3	15
Total	12	12	12	12	12	60

Table 2 Schedule of Concrete 100mm by 100mm by 500mm Beams

% rep	0	20	40	Total
3	3	3	3	9
7	3	3	3	9
28	3	3	3	9
56	3	3	3	9
Total	12	12	12	36

3. RESULTS AND DISCUSSIONS

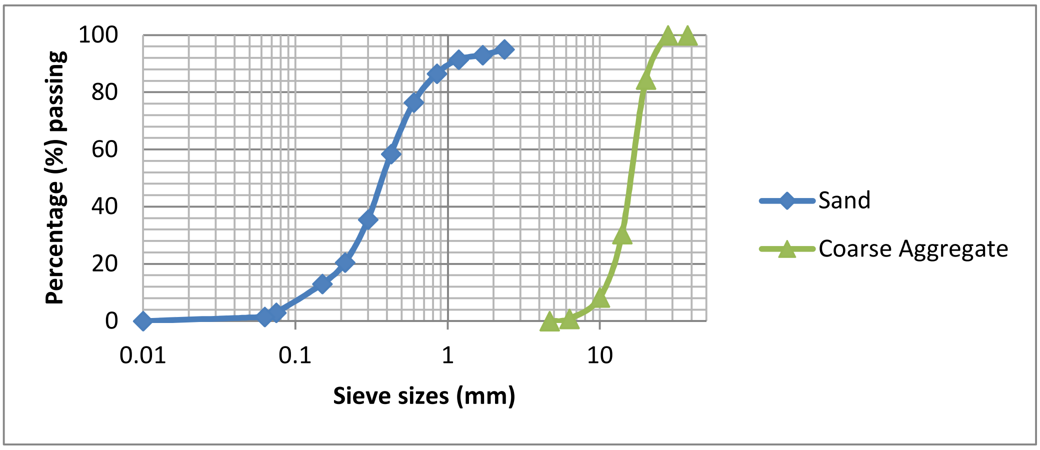

Figure 1 Sieve analysis of parent concrete materials.

Table 3 Properties of the parent concrete materials

Property		Ground Glass (GG)
Bulk Densities	Compacted	1.275
	Uncompacted	0.983
Relative Density		3.67
Water Absorption		-

Figure 1 and Table 3 shows the physical properties of the constituent material used in conducting the laboratory procedures.

From Figure 1, the fine aggregate, sand, is a well graded sample while the coarse aggregate is uniformly graded. This is expected since the coarse aggregate is expected to be of uniform size. The Ground Glass is closest to being a uniformly graded sample.

3.1. Tensile Strength Test Result

The results of the tensile strength developed with the hydration period of 3, 7, 28, and 56 days for all the percentage replacement are presented in Table 4.4 and Table 4.5.

Figure 2 and Figure 3 show that the tensile strength of concrete increases independently of the percentage replacement as the curing period increases.

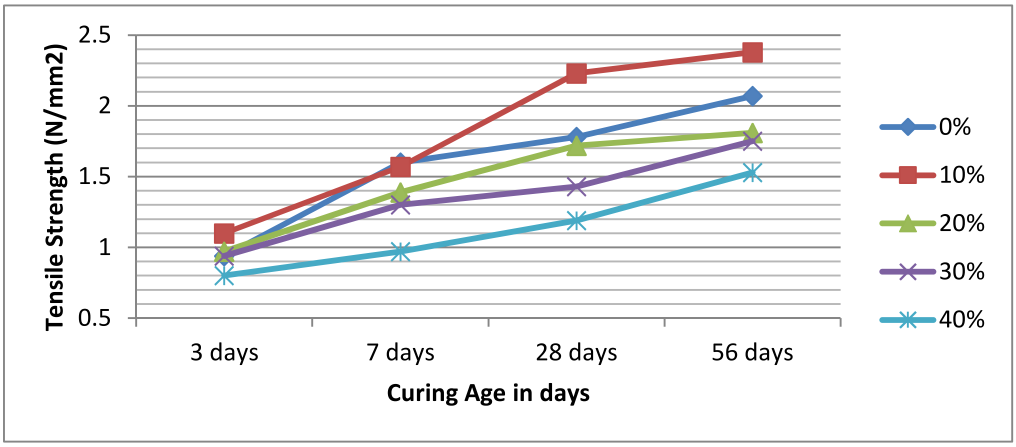

Figure 2 Variation of tensile strength with curing age at various levels of percentage replacement of cement with ground glass.

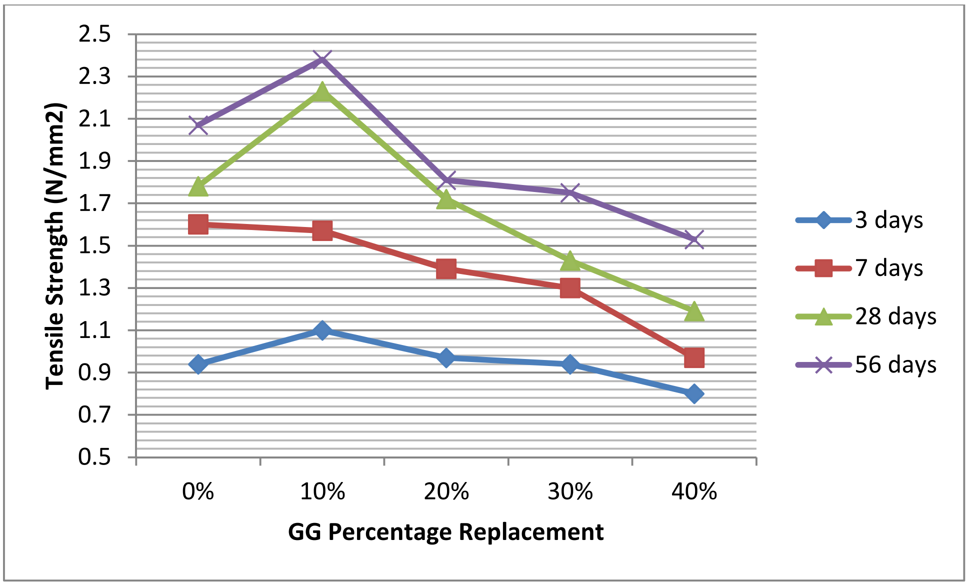

Figure 3 Tensile strength corresponding to curing age and percentage partial replacement of cement with ground glass.

3.1.1. Influence of Percentage Replacement of Cement with Ground Glass on Tensile Strength of Concrete Specimen

Figure 2 and Figure 3 show the variation of tensile strength with curing age at various levels of percentage replacement of cement with ground glass investigated. The graphs show that the tensile strength for all the curing age increases from 0% to 20% and thereafter, decreases at a non-consistent rate from 10% to 40% for 3days, 7days, and 56days curing age. 3days and 28days curing age increases at a decreasing rate for 0% to 20% and decreases at a decreasing rate for 10% to 30% replacement and at an increasing rate for 20% to 40% replacement. 7days curing age increases at an increasing rate for 0% to 20% and decreases at a decreasing rate for 10% to 30% replacement and at an increasing rate for 20% to 40% replacement. 56days curing age increases at a decreasing rate for 0% to 20% and decreases at a decreasing rate for all the 10% to 40% replacement.

The tensile strength increases by 17.02% for 0 to 10%, and decreases by 11.82% for 10 to 20%, 3.09% for 20 to 30%, and 14.89% for 30 to 40% for 3days curing age. It increases by 1.88% for 0 to 10%, and decreases by 11.46% for 10 to 20%, 6.47% for 20 to 30%, and 57.40% for 30 to 40% for 7days curing age. For 28 days curing age, it increases by 25.28% for 0 to 10%, and decreases by 22.90% for 10 to 20%, 16.86% for 20 to 30%, and 16.78% for 30 to 40%. For 56 days curing age, it increases by 14.98% for 0 to 10%, and decreases by 23.95% for 10 to 20%, 3.31% for 20 to 30%, and 12.57% for 30 to 40%.

It is observed that as the partial replacement of cement with ground glass increases from above 10% replacement, there is general decrease in the measured values of tensile strength for all the curing age.

Figure 3 further show that 10% replacement with ground glass improves the tensile strength of concrete. This could also be attributed to the degree of fineness of ground glass i.e. 100µm fineness level.

This therefore, affirms that the higher the percentage replacement from above 10% replacement, the lower the tensile strength of the ground glass concrete specimens (due to weaker aggregate/matrix bond formed).

Furthermore, the interaction of percentage replacement with curing age has a significant effect on the measured values of tensile strength.

3.1.2. Influence of Curing Age of Cement with Ground Glass on Tensile Strength of Concrete Specimen

Figures 2 and Figure 3 shows the variation of tensile strength with levels of percentage replacement of cement with ground glass at various curing age investigated.

The graphs show that the tensile strength for all the levels of percentage replacement increases as the curing age increases.

10% and 20% replacement increase at a decreasing rate for all the curing days. 40% replacement increases at an increasing rate for all the curing days. 0% and 30% replacement increase at a decreasing rate from 3 to 28 days and increases at an increasing rate from 28 to 56 days.

The tensile strength for 0% replacement increases by 70.21% for 3 to 7days, 11.25% for 7 to 28days and 16.29% for 28 to 56days. For 10% replacement, it increases by 42.73% for 3 to 7days, 42.04% for 7 to 28days and 6.73% for 28 to 56 days. For 20% replacement it increases by 43.30% for 3 to 7days, 23.74% for 7 to 28days and 5.23% for 28 to 56days. It increases from 38.30% for 3 to 7days, 10.00% for 7 to 28days and 22.38% for 28 to 56days for 30% replacement. It increases by 21.25% for 3 to 7days, 22.68% for 7 to 28days and 28.57% for 28 to 56days for 40% replacement.

It is observed that as the curing age increases, there is general increase in the measured values of tensile strength for partial replacement of cement with ground glass.

This therefore, affirms that the higher the curing age, the higher the tensile strength of the ground glass concrete specimens

Furthermore, the interaction of curing age with percentage replacement has a significant effect on the measured values of tensile strength.

3.2. Flexural Strength Test Result

The results of the flexural strength developed with the hydration period of 3, 7, 28 and 56 days for the percentage replacement of 0%, 20% and 40% are presented in Figure 4 and Figure 5. It show that the flexural strength of concrete also increases independently of the percentage replacement as the curing period just as in the tensile strength.

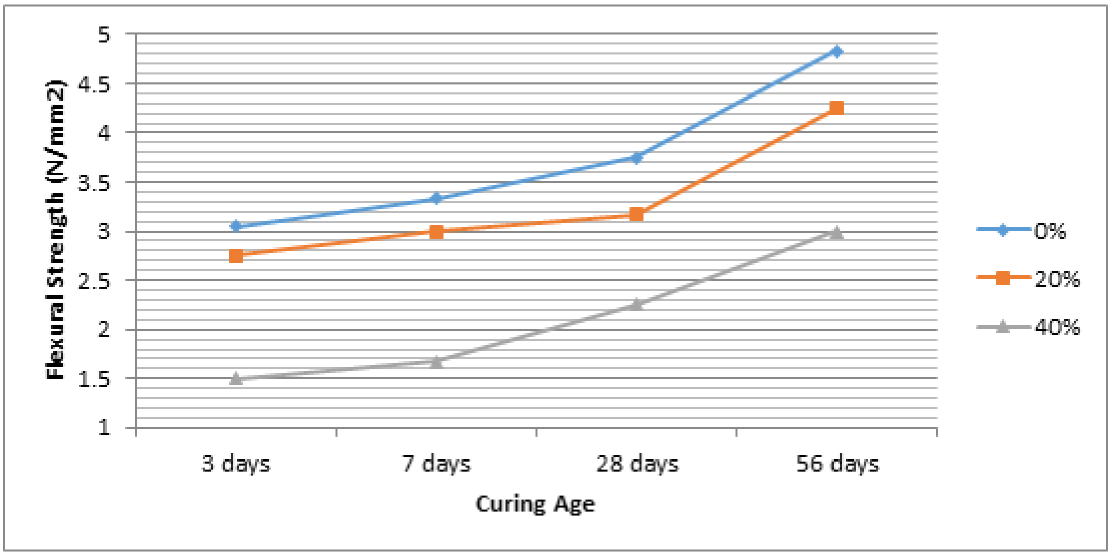

Figure 4 Variation of flexural strength with curing age at various levels of percentage replacement of cement with ground glass.

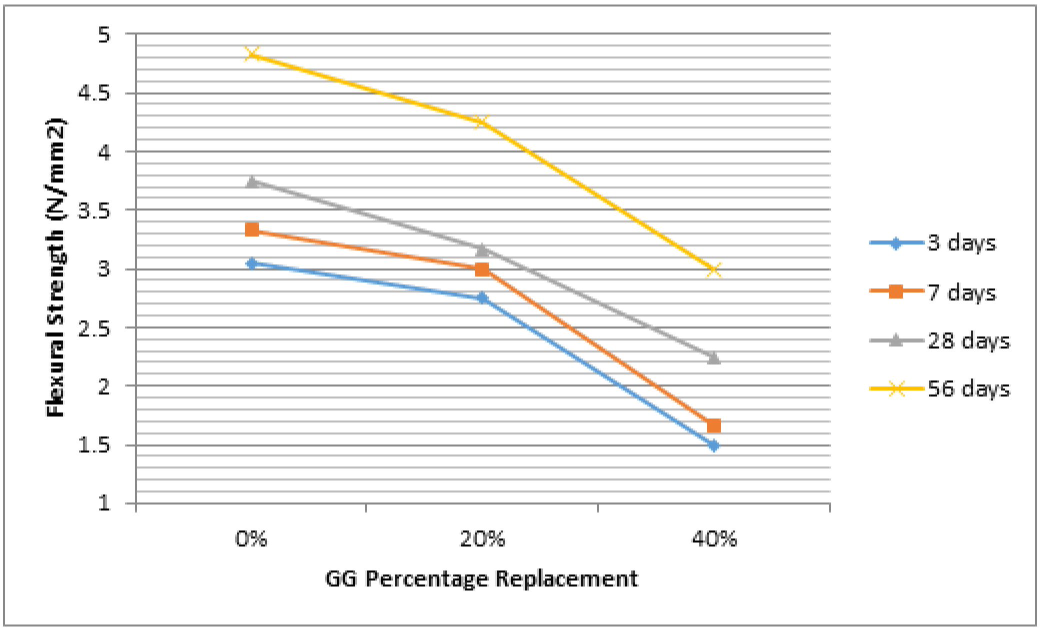

Figure 5 Flexural strength corresponding to curing age and percentage partial replacement of cement with ground glass.

3.2.1. Influence of Percentage Replacement of Cement with Ground Glass on Flexural Strength of Concrete Specimen

Figures 4 and 5 show the variation of flexural strength with curing age at 0%, 20% and 40% percentage replacement of cement with ground glass investigated.

The graphs show that the flexural strength for all the curing age decreases at an increasing rate for all the levels of percentage replacement.

The flexural strength increases by 9.84% for 0 to 20% and 45.45% for 20 to 40% for 3days curing age. It increases by 9.91% for 0 to 20% and 44.33% for 20 to 40% for 7days curing age. For 28 days curing age, it increases by 15.47% for 0 to 20% and 29.02% for 20 to 40%. For 56 days curing age, it increases by 12.01% for 0 to 20% and 29.41% for 20 to 40%.

It is observed that as the partial replacement of cement with ground glass increases, there is general decrease in the measured values of flexural strength for all the curing age.

This therefore, affirms that the higher the percentage replacement, the lower the strength of the ground glass concrete specimens (due to weaker aggregate/matrix bond formed).

Furthermore, the interaction of percentage replacement with curing age has a significant effect on the measured values of flexural strength.

3.2.2. Influence of Curing Age of Cement with Ground Glass on Flexural Strength of Concrete Specimen

Figures 4 and 5 show that the variation of flexural strength with 0%, 20% and 40% replacement of cement with ground glass at various curing age investigated.

The graphs show that the flexural strength for all the curing age increases at a non-consistent rate for all the levels of percentage replacement used.

It increases at an increasing rate for all the curing age for 0% replacement. For 20% replacement it increases at a decreasing rate from 3 to 28days and increases at an increasing rate from 7 to 56 days. For 40% replacement, it increases at an increasing rate from 3 to 28days and increases at a decreasing rate from 7 to 56 days.

The flexural strength for 0% replacement increases from 9.18% for 3 to 7days, 12.61% for 7 to 28days to 28.80% for 28 to 56days. For 20% replacement, it increases by 9.09% for 3 to 7days, 5.67% for 7 to 28days and 34.07% for 28 to 56 days. It increases from 11.33% for 3 to 7days, 34.73% for 7 to 28days to 33.33% for 28 to 56days.

It is observed that as the curing age increases, there is general increase in the measured values of flexural strength for the percentage replacement of 0%, 20% and 40%.

This therefore, affirms that the higher the curing age, the higher the flexural strength of the ground glass concrete specimens.

Furthermore, the interaction of percentage replacement with curing age has a significant effect on the measured values of flexural strength.

4. CONCLUSION AND RECOMMENDATION

From the preliminary studies of the technical feasibility of using ground glass as an alternative binder to cement in concrete production, the following conclusion can be drawn;

- The Specific gravity of ground glass (GG) is 3.67, which is close to 3.15 for cement as provided by [15].
- The bulk density of ground glass (GG) is 1275kg/m^3 as compared to that of cement which is 1440kg/m^3 as provided by [15].
- The workability parameter (slump test) fall within the range of 50 to 75mm as the percentage replacement increases from 0% to 40% using 0.65 water/cement ratio as derived in the trial mix design.
- The graphical methods of analysis show that as the percentage replacement of ground glass increases from 10% replacement, there is general decrease in the measured values of the tensile and flexural strengths.
- The graphical methods of analysis show that as the curing period increases, there is general increase in the measured values of the tensile and flexural strength.
- The statistical analysis carried out on the tensile and flexural strengths shows a significant increase value as the curing age increases from 3days to 56days across the different percentage partial replacement. On the other hand, there is significant decrease in compressive strength as the percentage partial replacement increase from 0% to 40%.
- The results of the research work show that concrete containing 10% ground glass at 100µm fineness level develops a higher tensile strength for the curing ages of 3, 7, 28and 56days than the normal control concrete. Hence, indicating the pozzolanic activity of ground glass in concrete.

From these conclusions the followings are recommended:

- 10% replacement of cement with ground glass at 100µm fineness level is economical and effective for the improvement of concrete. Higher percentage replacement of cement with ground glass at lower level of fineness may however improve the strength characteristics of concrete. Therefore, there is need for further studies in this area.
- Previous researches on the use of glass in concrete show that an adverse effect may occur as a result of alkali-silica reaction (ASR). Further research should be carried out on the reduction of the impact of ASR with the use of low alkali cement, set retarder, and air entrainment system. Research should also be carried out on the behavior of concrete containing ground glass at elevated temperature.
- The effect of sulphate attack and permeability of concrete containing ground glass at varying percentage of partial replacement of cement should be investigated.

- The use of waste glass in concrete has proved to be effective. Hence, research should be carried out on the utilization of waste glass as aggregates in concrete and blockwork to further proffer solutions associated with waste glass in waste generation.

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