Predictive Models for Compressive Strength of Concrete Produced with Waste Glass as Replacement for Aggregates

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Abstract

The assessment in this research is centered on evaluating the performance of grade 20(1:2:4:0.5) concrete by substituting normal aggregates with waste glass graded into fine and coarse specimens and the replacement carried out in the ratio of 20%, 40%, 60% and 80% for river sand and gravel aggregates replacements.Also predictive models were deduced from data obtained from the experimental study for estimation of the strength of glass concrete. The experimental and predictive models established for all the cases investigated shows a good correlation as targeted strength were reasonably achieved. Generally the results shows the control mix gave the best strength with the exception of 20% fine/coarse glass replacement suggesting an optimum replacement of 20% for both cases.

I. INTRODUCTION

The generation of glass waste have been rising over time due to increase in industrializationin our society and unfortunately the majority of these waste are not put into use by recycling but rather disposed to the environment causing environmental pollution [1,2]. Glass is a recyclable material, and hence its reuse in civil engineering as aggregate is beneficial for reasons that, it decreases the ecological impact, economic expenditure of quarrying operations, transport, and processing. As urbanization continue to take place, the availability of natural gravel and sand for concrete production is facing serious challenge [3, 4].

In 1994 it was estimated that glass waste, which are by-products of production of glass, and unwanted glass materials that are left or discarded after use were estimated to be about 9.2 million metric tons and also statistics shows that glass waste comprise of about 4.5% of the total waste stream [5-9]. Currently, there are limited replacement material for natural aggregate, hence it is now necessary to investigate the potential of the re-use of glass waste in low cost concrete production, which other-wise would have been disposed.

The main target of this article is to evaluate the beneficial use of waste glassgraded into fine glass and coarse glass as partial replacementfor fine and coarse aggregates in the production of a target strength of grade 20 concrete using regression models to appraise the performance of different specimens.

II. MATERIALS AND METHOD

The cement used was Dangote Limestone Port Land cement. Also, coarse aggregate used was natural gravels of maximum size 25mm, while fine aggregate was natural sand of maximum size of 4.75mm with specific gravity of about 2.62. Waste glasses werecollected from the University of Port Harcourt campus, project sitesand were used as partial replacement for fine and coarse aggregates.

A. Preparation of the Concrete Mixtures

Four types of concrete mixtures were prepared for this study. The control mix ratio was 1:2:4 (cement: fine aggregate: coarse aggregate) with water-cement ratio (W/C) of 0.5. The concrete mix is summarized in the table below with 20%, 40% and 60% of glass aggregate replacement. Four cubes were prepared for each specimen, and were cured for7 and 28 days respectively.

Table 1: Aggregate Mix Proportion.

Cubes specimen	% of glass aggregate	Number of cube
CA80CG20	20% coarse glass + 80% gravel	4
CA60CA40	40% coarse glass + 60% gravel	4
CA40CA60	60% coarse glass + 40% gravel	4
FA80FA20	20% fine glass + 80% sand	4
FA60FA40	40% fine glass + 60% sand	4
FA40FA60	60% fine glass + 40% sand	4

The adopted nominal mix (1.2:4:0.5) design gave the weight in kilograms of the different materials necessary to produce 0.0045m^3 of compacted concrete. The batch weights for the trial mix were obtained directly by multiplying the proportion of each of the constituents by the volume of the mix required; for example, in the production of the nominal mix, 28 cubes of 0.003375m^3 each, taking density of concrete to be 2400 kg/m and assuming adjustment factor of 1.1

The specimens were cast in iron cube moulds of 150 x150 x150mm size. The moulds surface were first cleaned and oiled on their inside surfaces to prevent bond development flanked by the mould and the concrete. The moulds were packed with concrete in three layers each layer being compacted manually to remove entrapped air. The moulds were filled to brimful and surplus concretes removed by sawing action of steel rule. Lastly, surface finishing was done by means of a trowel. The test specimen was then left in the mould for 24 hours. After this, the specimen, were demoded with care, before placing them into a curing tank at room temperature.

B. Sieve Analysis

Sieve analysis helps to evaluatethe particle size distribution of the coarseand fine aggregates. This was done using the standard ASTM U.S sieves by passing the dried aggregates through a series of the standard test sieves. The diameter of the test sieves and mesh apertures are given in BS410:1976.

The weight of aggregates retained in each sieve, were in turn recorded. Theweights and percentages of aggregate passing each test sieveanalysis were computed.Adequate grading of the coarse aggregates is significant as it improves the workability and strength of concrete. The development of strength equivalent to a given water cement ratio requires complete compaction and this can only be feasible with correct workable mix.The sieve analysis was done according to ASTM standard.

The analysis revealed that sizes of the coarse glass aggregates were contained by 2.36mm to 13.2mm with a reasonably (good) gradation pattern and maximum nominal particle size diameter of 25mm.

However, the study revealed that greater part of the fine glass aggregates were within particle size diameter series between 0.6mm to 2.36mm with a fairly decent gradation arrangement and having maximum nominal particle size diameter of 4.75mm.

C. Waste Glass

In this study, glass wastes from windows were used. The raw materials of the waste glass were cleaned and passed through grinding machine which was then crushed into different particles sizes. The same standard method was applied to conduct sieve analysis for the representative samples of the glass waste aggregate according to the ASTM specification.

III. RESULTS OF SLUMP AND COMPRESSIVE STRENGTH TEST

These specimens were tested using compression testing machine after 7 and 28 days curing of the various cubes. The cubes were placed with the faces in contact with the platens of the testing machine that was applied at a constant rate of 3.0kN/s till the cube fails. The load at the point of failure divided by the area of the cube gives the compressive strength of the cube.

The typical slump results for the different specimens is recorded in Table 2 which shows reduced slump as glass content is increased The average mass densities, and the corresponding compressive strength for hardened concrete at 7 and 28days is given in Table 3. Generally the control mix gave the best strength with the exception of mix CA80CG20 (20% coarse glass replacement). The best strength as regards fine glass replacement was FA80FG20 (20% fine glass replacement) suggesting again an optimum replace of 20% for both coarse and fine aggregate replacement.

Table 2: Slump data

Specimen ID	%of glass	Slum(mm)
CA100FA100	Control mix	12.5
CA80CG20	20% coarse glass	8.5
CA80CG40	40% coarse glass	7.0
CA80CG60	60% coarse glass	2.5
FA80FG20	20% fine glass	11.5
FA80FG40	40% fine glass	10.5
FA80FG60	60% fine glass	4

Table 3: Mass Densitiesand Compressive Strength Values.

Specimen ID	Density(kg/mm3)	7days strength(N/mm$^{2)}$	28days strength(N/mm$^{2)}$
CA100FA100	2387.9	26.21	33.45
CA80CG20	2367.11	26.71	34.46
CA80CG40	2313.18	22.38	31.93
CA80CG60	2270.22	21.60	26.74
FA80FG20	2330.1	24.62	32.49
FA60FG40	2330.1	23.84	30.90
FA40FG60	2304.89	23.34	30.71

A graphical representation of the densities and corresponding compressive strength for the four specimens is shown in Figure 1 and 2 to give a pictorial view of the discussion

IV. DEVELOPMENT OF THE PREDICTIVE MODELS

It can be observed from the table above that there were strong negative linear correlation and high coefficient of determination for the 28-days strengths for both fine and coarse glass specimens. The coefficient of determination for both coarse and fine glass specimens were 0.9314 and 0.7268 respectively. This indicates that the model can deduce 93% and 73% of the 28-daysstrength for both coarse and fine glass specimens respectively. The negative value of 'R' indicates that an increase in glass percentages was accompanied by a decrease in the responses; hence, the corresponding regression line has a negative slope.

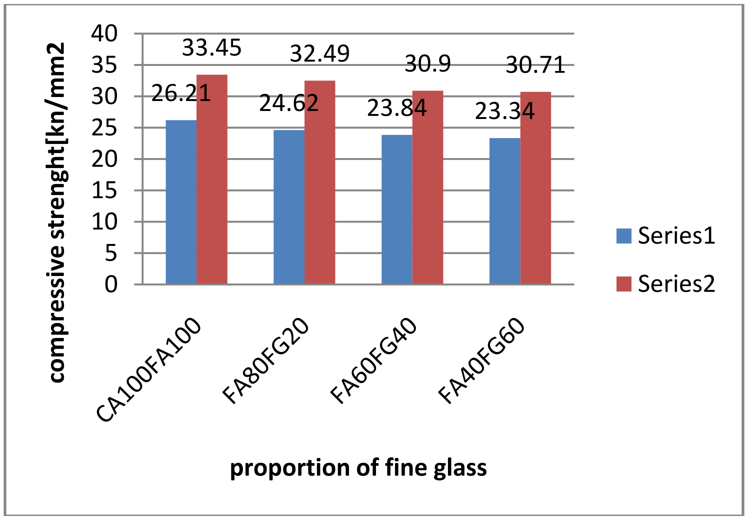

Figure 1: Density and Corresponding Strength for Fine Glass Concrete

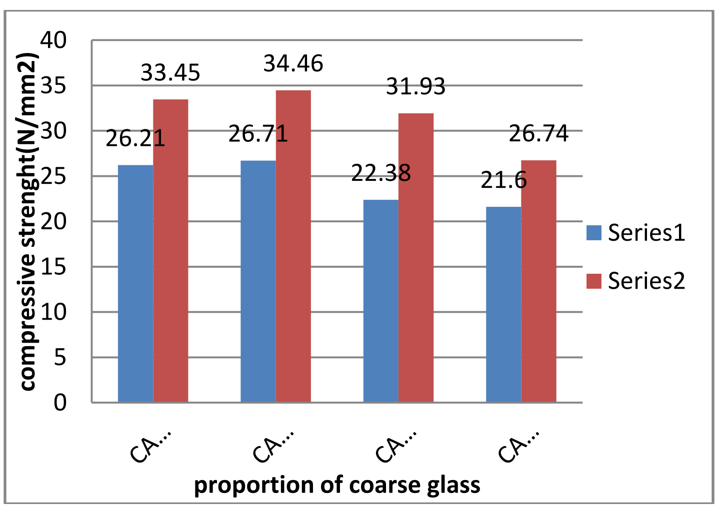

Figure 2:Density and Corresponding Strength for Coarse Glass Concrete

The graphic representation of the model as can be seen in figure 3 and 4 shows that most of the data inputs were out of the line, hence a polynomial function was investigated.

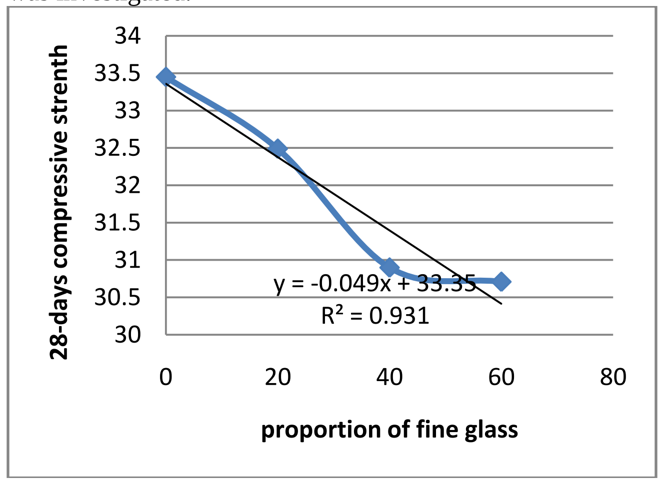

Figure 3: Linear Model of Mixes with Fine Glass at 28 Days

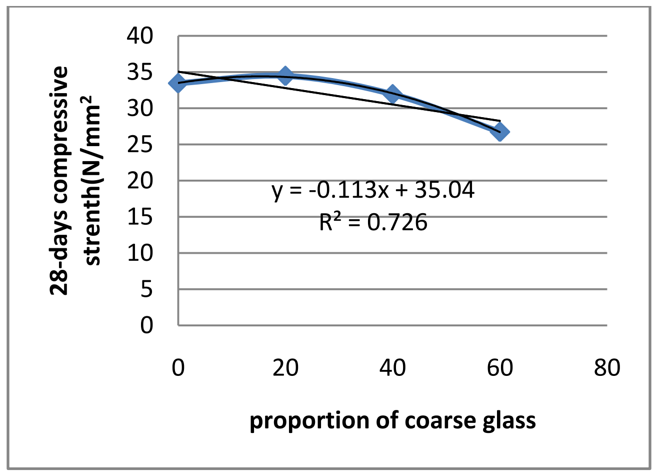

Figure 4: Linear Model of Mixes with Coarse Glass at 28 Days

Computation of the responses (y-values) was done by substituting the x-values, which are the proportions of fine/coarse glass in the mixture. The output results indicated that the y-values obtained were fairly equal to the corresponding mean strength. Hence this validated the predictive models which can be adopted for the estimation of the strength of glass concrete.

V. CONCLUSIONS

The objective of this project was to examine the re-use of glass waste as a partial replacement for aggregates in concrete. The properties of waste glass infine and coarse aggregate form were characterized and evaluated. The workability, density and compressive strength of the various mixtures with different proportion of waste glass, were compared with that of the control mix. The following specific conclusions can be drawn from the study.

i. The experimental results indicated that, there was a relatively gradual drop in the concrete workability as the percentage of glass aggregates increased.
ii. It can be concluded that concrete density decreases as the percentage of glass aggregate increased which be deduced from the lower specific gravity of the glass aggregate compared to the normal aggregates.
iii. Generally the control mix gave the best strength with the exception of 20% fine/coarse glass replacement suggesting an optimum replacement of 20% for both cases.

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