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Optimization of the various strengths of concrete made from two different types of coarse aggregates using Scheffe's model

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Abstract

This research work on the Optimization of the Various Strengths of Concrete Made from Two Different Types of Coarse Aggregates using scheffe's model. The coarse aggregates (crushed and uncrushed) was obtained from Nkalagu, Ebonyi State. Cement was bought from Kenyatta market, sharp river sand was collected from Nyama River here in Enugu State and water used was gotten from Enugu state water corporation. The practical tests were conducted at Enugu State University of Science and Technology (ESUT) Laboratory, Enugu. Tests that were carried out were series of tests, specific gravity, casting and crushing of the cubes and compressive strength tests were carried out. Natural sand with fineness modulus of 2.27 was used as fine aggregate. Ordinary Portland cement was used as binding material. Mix proportions 1:1:2 with crushed and uncrushed aggregate types were used in the research. The water/cement ratio adopted for the study was 0.59 throughout the experiment. The target mean strength at 28days was 25N/mm^2. Twelve concrete cubes (150mm x 150mm x 150mm) were cast for each coarse aggregate type of which three were crushed at each maturing age namely 8, 14, 21, and 28 days from each mix, 12 cubes were cast for each of the two types of coarse aggregate, making a total number of 24 cubes. The concrete cubes are to be casted in laboratory and tested in hydraulic compression testing machine.

Keywords: Optimization of concrete strengths; Types of coarse aggregates; Scheffe's model

1.1 Introduction

Concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement, and aggregates (fine and coarse). Strength is the most desired quality of a good concrete. It should be strong enough, at hardened state, to resist the various stresses to which it would be subjected. Compressive strength of concrete, therefore, is the value of test strength below which not more than a prescribed percentage of the test results should fall (Kong and Evans, 1987).

The high variation in strength between concrete and mortar of the same cement/aggregate proportion, suggests the quintessence of coarse aggregates in the development of strength in concretes. The coarse aggregates are obtained naturally or artificially and occupies up to 60% by weight or volume of the concrete, depending on the mix proportion adopted which, in turn, depends on the expected compressive strength. Aggregate is commonly considered inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Although aggregate is considered inert filler, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability. Aggregate is classified into two different types, coarse and fine. Coarse aggregate is Usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve). The compressive aggregate strength is an important factor in the selection of aggregate. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and

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therefore not a factor in the strength of normal strength concrete. Lightweight aggregate concrete may be more influenced by the compressive strength of the aggregates UNILORIN (2011).

1.2 Statement of Problem

The quality of the coarse aggregates is essential when considering the quality of the concrete itself. The properties of coarse aggregates do grossly affect the durability and structural performance of concrete. Such properties as size, shape, and surface conditions of aggregates are considered alongside the mineral composition of the rock material from which the aggregate formed a part.

It is a common practice in Nigeria to use locally found aggregates (crushed and uncrushed coarse aggregates) for construction purposes. The integrity of these aggregates should be investigated to ascertain their performance in structural members. Recent constructions in Nigeria, especially in Awka and its environs make indiscriminate use of aggregates notwithstanding their sources and not considering their physical condition at the time of use. For instance, gravels may be obtained from the same source but one should not expect the same strength performance from them if some were used without washing and others used after washing. The relative effect of these variations in the nature of coarse aggregates on the compressive strength achieved by the concretes has been investigated and presented in this study.

1.1. Limitations of Study

This project is limited to studies on coarse aggregates. Due to time and resources was not able to go outside the scope of this project.

2. Literature Review

The strength of concrete is its major characteristic. Neville, 1981 stated that aggregates are inert materials that are dispersed through-out the cement paste whose strength depends majorly on its shape, surface texture, and cleanliness. In his research findings, he published that entirely smooth coarse aggregates lowered the strength of concrete by 10% than when the aggregates were roughened. Young and Sam, 2008 also stated that smooth rounded aggregates was more workable but yielded a lesser compressive strength in the matrix than irregular aggregates with rough surface texture. They were also of the opinion that a fine coating of impurities such as silt on the aggregate surface could hinder the development of a good bond and thus affects the strength of concrete produced with the aggregates.

The test carried out by Soroka, (1993) revealed the variations between the compressive strengths of concrete made with crushed stone and uncrushed stone. He achieved a better compressive strength with the crushed stone than the uncrushed stone. This strength performance was as a result several factors like water/cement ratio, grading, surface texture, shape, strength, and stiffness of aggregates, used. Bloem and Gaynor, (1963), also studied the effect of shape, surface texture, fine coatings, and maximum size of aggregates on the water requirement and strength of concrete. The study reported that at equal water/cement ratio, irregular shaped smaller sized aggregates without coatings achieved a better strength than smooth rounded large sized aggregates. They also opined that individual properties of aggregates and the magnitude of the size difference may lead to increase or decrease in concrete strength at a fixed cement content.

3. Material and method

3.1 Materials

This chapter discusses the detail of the approach employed in carrying out the study. It also describes the details of experimental procedure, materials selection and equipment used during the investigation. The preliminary tests, which were carried out on sample taken are also discussed. The major important is the composition of concrete used in this research. The curing procedure employed during testing, properties of hardened concrete. These include strength, durability and shrinkage.

3.1.1 Material Selection

The basic materials used in this research include

Ordinary Portland Cement

For this research work Unicem brand of ordinary Portland cement (OPC) used in general construction and building purpose which conforms to BS 812 (1978) requirement was used. The cement was obtained from Kenyatta market in Enugu state.

Fine Aggregate

The fine aggregate (FA) used for this research work was sharp river sand collected from Nyama river here in Enugu State. The fine aggregate conform to zone 1 (18.70) of "the aggregate zoning chart after being washed, surface dried and sieved.

Coarse Aggregate

The coarse aggregate used for the work were obtained from Nkalagu, Ebonyi State. The material after collection, was sieved, washed and surface dried. The coarse aggregate sizes were limited to 10 - 37.5 or 40mm.

Water

The water used for mixing and using the concrete was clean, odourless and free from visible impurities. It was sourced from Enugu state water corporation, Enugu state.

3.2 Methods

The various test carried out in the course of this project work, were done in accordance to appropriate BS codes specification.

3.3 Determination of Particle Size Distribution for Coarse and Fine Aggregate (Sieve Analysis)

The distribution of particles size for both fine and coarse aggregate were obtaining by sieve analysis of the materials through a set of BS sieve. This helps to determine the various zones into which the aggregate fall and to remove materials that fall outside the range of sizes required for the test.

3.3.1 Sieve analysis of fine aggregate

- **Aim:** To determine the particle size distribution of an aggregate by sieve analysis.
- **Apparatus:** The analysis requires a set of test sieves of the following sizes:

9.5mm, 4.75mm, 2.36mm, 1.18mm, 600mm, 300mm, 150mm, receiver and lid, weighing balance, wire brush, head pan, shovel, stop watch, washing bowel and towel.

- **Procedure:**
  - Collect sufficient representative sample from stockpile for laboratory test.
  - Reduced this sample by quartering as many times as possible to obtain a required quantity for the test.
  - Wash the sample thoroughly until the water is clean.
  - Dry in a well-ventilated oven for 24 hours under the temperature range of ±110 °C
  - On the following day, collect the sample and allow it to cool before the sieve commences.
  - Arrange the sieve sizes in descending order, starting from 9.5mm down to receiver.
  - Introduce the dry sample into the arranged sieve, cover with lid on top and with the receiver at the bottom and place on the sieve shaker, then switch on the shaker for 3-minutes.
  - Collect the samples retained on each sieve using wire brush to collect it and weigh it.

3.3.2 Sieve analysis of coarse aggregate

- **Aim:** To determine the particle size distribution of coarse aggregate.
- **Apparatus:** The analysis requires the following set of sieves as recommended by

BS410: 50mm, 37.5mm, 25mm, 19mm, 13.2mm, 9.50mm, 4.75mm, and receiver weighing balance, wire brush, evaporating plates, head pan, washing bowel.

- **Procedure:**
  - Collect sufficient representative sample from stockpile for laboratory test.

  - Reduced these samples by quartering as many times as possible to obtain a required quantity for the test.
  - Wash the sample thoroughly in the washing bowel until the water become clean.
  - On the following day collect the sample and allow it to cool before the weighing commences.
  - Arrange the sieve sizes in descending order, starting from 50mm down to 4.75mm.
  - Introduce the dry sample into the arranged sieve, cover with lid on the top and with the receiver at the bottom. Shake the sieves manually for about 3-5 minutes.
  - Collect the samples retained on each sieve using wire brush then weigh the sample.

3.4 Specific gravity

Specific gravity can be defined as the ratio of the weight of an aggregate to the weight of an equal volume of water. The specific gravity of an aggregate particle depends on whether the aggregate is completely dry or whether it has absorbed water. The particle size of an aggregate also affect the specific gravity, therefore, when comparing different aggregate it is essential that the test be made on particle of the same grading and the standard method strictly followed.

3.5 Method

The method of test in Bs 812 part 2 1975 usually give three results:

- The specific gravity on an oven dry basis calculated from oven dried weight and the gross or bulk particle volume,
- Specific gravity on a standard and surface dried basis, calculated from the standard dried weight and the gross or bulk particle volume,
- Apparent specific gravity on an oven dried basis but calculated from the oven dried weight and the particle volume exchanging the accessible pores.

3.5.1 Specific gravity test of fine aggregate

- **Aim:** To determine the specific gravity and water absorption percentage of fine aggregate.
- **Apparatus:** Weighing balance, pycnometer bottles, well ventilated oven, evaporating dishes, absorbent cloth and distilled water.
- **Procedure**
  - Collect sufficient representative sample from the stockpile for laboratory test.
  - Wash the sample thoroughly until the water become clean.
  - Decant the water and introduce distilled water to cover the sample to stay in water for 24 hours.
  - On the following day, decant the water and spread the sample on surface dry.
  - Divide the surfaced dry sample into two portions, sample A and sample B.
  - Weigh the empty pycnometer bottle A as x, and pycnometer bottle B as X2.
  - Introduce the saturated surface dry (SSD) sample into the empty pycnometer bottle A, hence weigh as Ki and B as Kg.
  - Introduce distilled water into the bottle and ensure that foam is properly removed by injecting water into the bottle to remove the air bubbles before weighing bottle A as Bi and bottle B as 62-
  - Sample weight alone is - = and - =
  - Empty the bottle A and bottle B's content into an evaporating dish and decant the water properly, label them and put in the oven to oven dry for 24 hours under the temperature range of ±110°C.
  - Fill the bottle A and bottle B with distilled water and weigh bottle A as C1 and bottle B as C2.
  - On the following day remove the sample from oven, allow it to cool before taking the weight of sample A as D1 and sample B as D2.

3.5.2 Specific gravity test of coarse aggregate

- **Aim**: To determine the specific gravity and water absorption percentage.
- **Apparatus**: Weighing balance, pycnometer bottle, evaporating dish, well ventilated oven, absorbent cloth and distilled water.
- **Procedure**
  - Collect sufficient representative sample from the stockpile for laboratory test.
  - Wash the sample until the water is clean.
  - Decant the water and soak with distilled water the water for 24 hours.
  - On the following day, decant the water and spread the sample to surface dry.
  - Divide the saturated surface dry sample into two portion, sample A and B.

- Weigh the empty pycnometer bottles A and B as Xi and X2.
- Introduce the saturated surface dry (SSD) sample into the two empty pycnometer bottles A and B and weigh as Ki and K2.
- Introduce distilled water into the bottle hence ensure that foam is properly removed by injecting water into the bottle A and B to remove the air bubbles before weight as Bi and B2.
- Sample weight alone is - = and - =
- Empty the bottle content into an evaporating dish and decant the water properly, label A and B hence put in the oven to oven dry for 24 hours under the temperature range of ±110°C.
- Fill the bottle A and B with distilled water and weigh as Ci and C2.
- Collect the oven dry sample on the following day hence weigh as D1 and sample B as D2.

3.6 Concrete mix design

Mix design can be defined as the process of selecting suitable constitutes of concrete and hence, determine their relative quantities with the purpose of producing an economical concrete which has certain properties, notably workability, strength and durability. This properly designed concrete mix should achieve the following objectives:

- The required concrete strength
- The workability of fresh concrete
- Should be very economical and durable

The required quality or strength of hardened concrete is achieved by choosing appropriate water cement ratio, amount of entrained air and curing condition which corresponds to realizing a good resistance to freezing and thawing, water tightness, water resistance and strength.

Although workability is difficult to measure, it can be readily judged by experience, since it is the property that determines the amount of work required to consolidate the concrete properly.

To achieve economy, the purpose of the mix design is to minimize the amount of cement required without sacrificing the quality of the concrete.

3.7 Mixing of concrete

Each of the ingredient weight already determined for each mix was measured and poured on a flat smooth and non-absorbent surface.

3.7.1 Procedure

Step 1: Weight of fine aggregate (22.72kg) was measured on a digital weighing balance and poured on flat smooth surface before the weight of cement (14.35kg) was measured, poured together with the fine aggregate and mixed them properly. And finally measured weight of coarse aggregate (61.39kg) and mixed them properly also. Step 2: The weigh free water content (190kg) was measured and was poured carefully and all ingredients were mixed thoroughly until uniform consistency was achieved.

3.8 Slump test

The slump test was carried out on each mix, in order to check the workability of the concrete (fresh concrete). The test was performed in accordance with BS 1881: part 2: 197

3.9 Concrete cubes casting

- **Objective:** To achieve the casting of concrete cubes
- **Apparatus:**
  - Cube mould of 150mm x 150mm cross section.
  - Tamping rod and scoop.
- **Procedure**
  - The materials were weighed as was obtained in the concrete mix design and then thoroughly mixed to form a gel like substance known as concrete.
  - The concrete were scooped into the cube in three layers with tramping of 25 times at each layer.
  - The surface of the cubes was scrapped off and then kept to dry for 24 hours at room temperature after which curing commenced.

3.10 Curing of the cubes

- **Objectives:** To achieve the strengths at seven (7), fourteen (14, (21) days and twenty-eight (28) days while preventing loss of water by the cubes.
- **Apparatus:** Curing drums and distilled water.
- **Procedure:**
  - Distilled water was poured into the drums
  - The cubes were inserted and it was ensured they were covered by the water.
- **Precaution**
  - It was ensured the cubes covered by the water
  - Washing of hand or insertion of any particle or dirty materials into the curing tanks was avoided.

3.11 Crushing of cubes

- **Aim:** To obtain the strength (failure load) of the cubes at the days of crushing.
- **Equipment:** Crushing machine and weighing balance
- **Procedure:**
  - At each specified day the cubes were brought out from the curing tank and kept to achieve surface drying
  - The sample was then weighed and crushed.
  - The failure load were read from the crushing machines and recorded.
  - The compressive strength's was computed from the strength value (failure load). This was achieved by dividing the failure load by the cross sectional area of the cubes.
- **Precaution**
  - Error due to parallel was avoided in reading the strength values on the crushing machine.
  - Proper placing the cubes for crushing was ensured using the crushing machine.

3.12 Compressive strength test

The three specimens of the samples (each set labeled by date of cast, mix number, group number and mould number) were air dried, weighed and placed in the crushing machine at the end of each curing age. Once the sample is air dried, it will be crushed to obtain the crushing load of the sample, three samples were crushed for each curing age and total of 12 samples was crushed for each mix. Strength test will be used after curing for 28 days for durability studies on the concrete.

The result of the tests carried out on this research work is presented in the next chapter of this report.

4 Results

The results of the laboratory test on the aggregate and concrete samples are presented and analysis in this chapter.

4.1 Sieve Analysis Result

Table 1 Average sieve analysis result for fine Aggregate

B.S Sieve Sizes	Weight Retained (g)	Weight % Retained	Cumulative % Retained	Cumulative % Passing
9.5	0	0	0	100
4.75	16	31	31	96.9
2.38	28	5.43	8.53	91.49
1.18	64	12.4	20.93	79.07
0.6	131	25.39	46.32	53.58
0.3	197	38.18	84.5	15.50
0.15	80	15.50	100	0
∑	516		263.38	

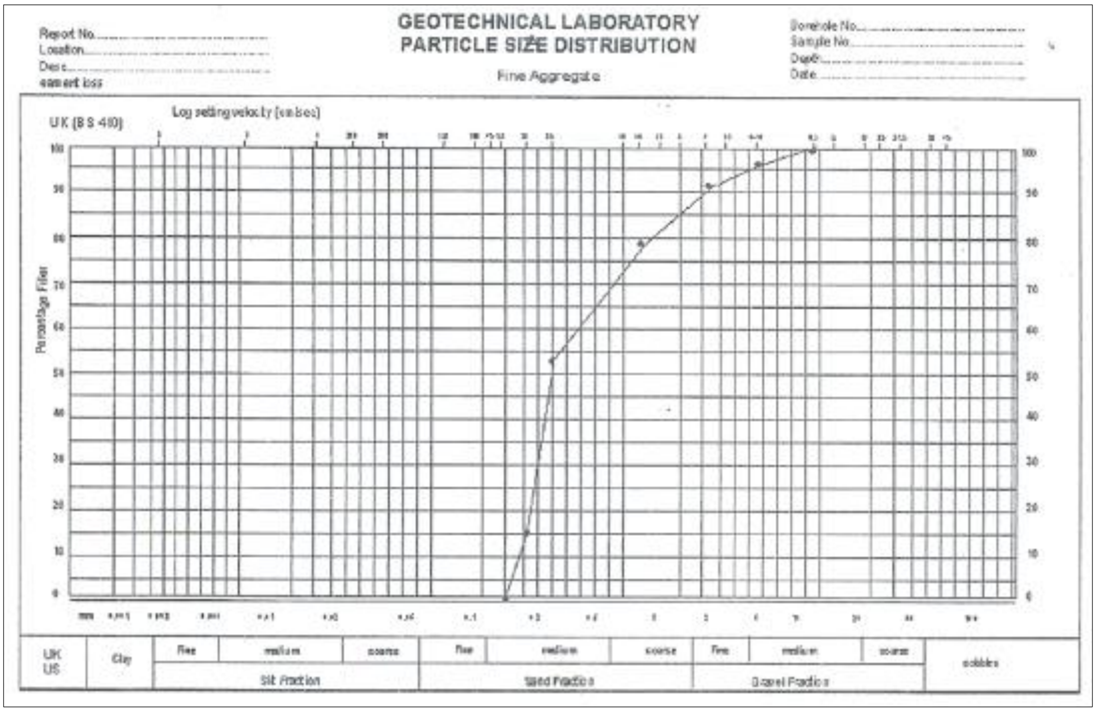

Figure 1 Geotechnical Laboratory Particle Size Distribution for Fine Aggregates

Fineness modulus = $\frac{263.38}{100}$ = 263

Percentage passing sieve 600um sieve is 53.58%, the aggregate falls under zone 2.

Table 2 Sieve analysis result for Uncrushed Coarse Aggregate

B.S Sieve Sizes	Weight Retained (g)	Weight % Retained	Cumulative % Retained	Cumulative % Passing
18	0	0	0	100
13	3	0.49	0.49	99.51
9.5	77	12.48	12.97	86.51
4.75	4.33	70.18	83.15	3.91
2.38	104	16.85	100	0

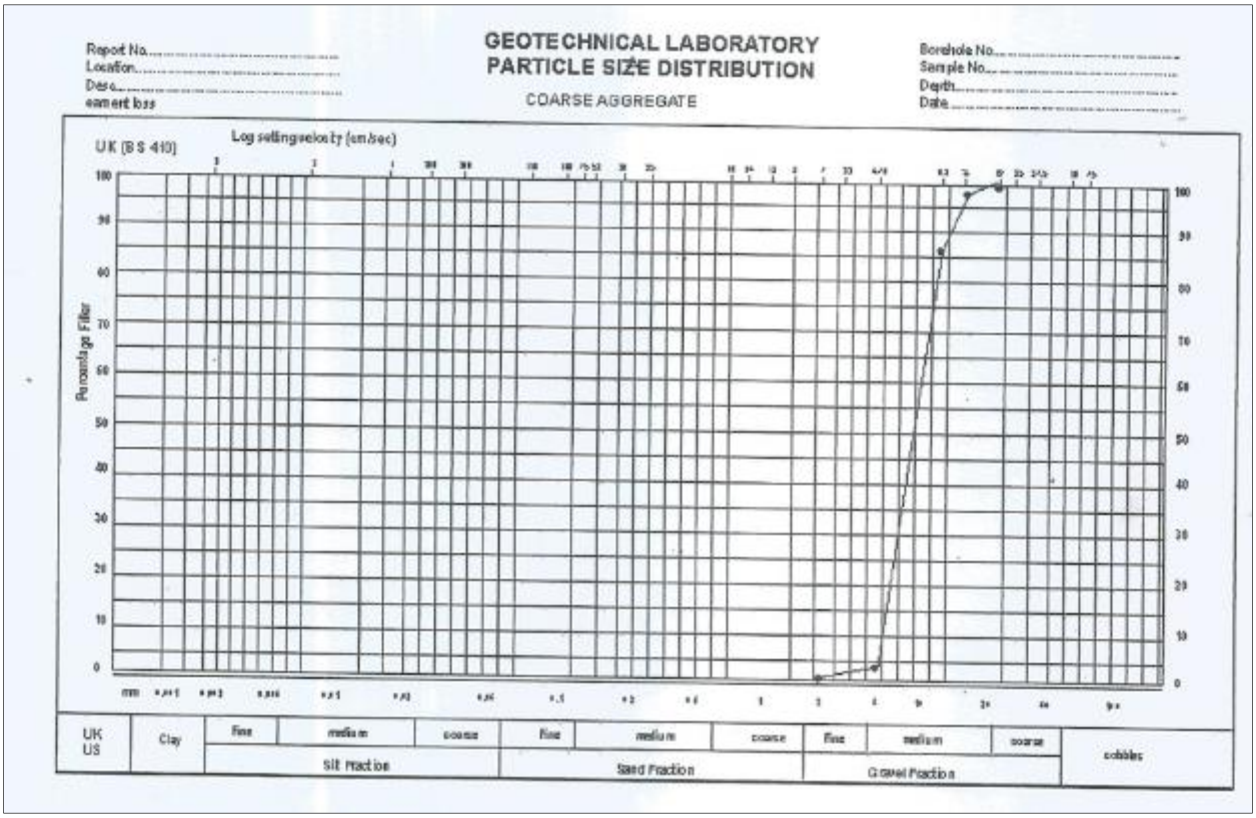

Figure 2 Geotechnical Laboratory Particle Size Distribution for Coarse Aggregate

Table 3 Sieve Analysis for Crushed Coarse Aggregate

B.S Sieve Sizes	Weight Retained (g)	Weight % Retained	Cumulative % Retained	Cumulative % Passing
33	0	0	0	100
25	0	0	0	100
22	31.7	6.10	6.10	93.9
18	210.0	40.70	48.8	53.20
16	170.0	33.00	79.8	20.20
13	65.0	12.60	92.4	7.60
9.5	25.0	4.85	97.25	2.75
4.5	14.0	2.70	99.95	0.15
I	515.7			

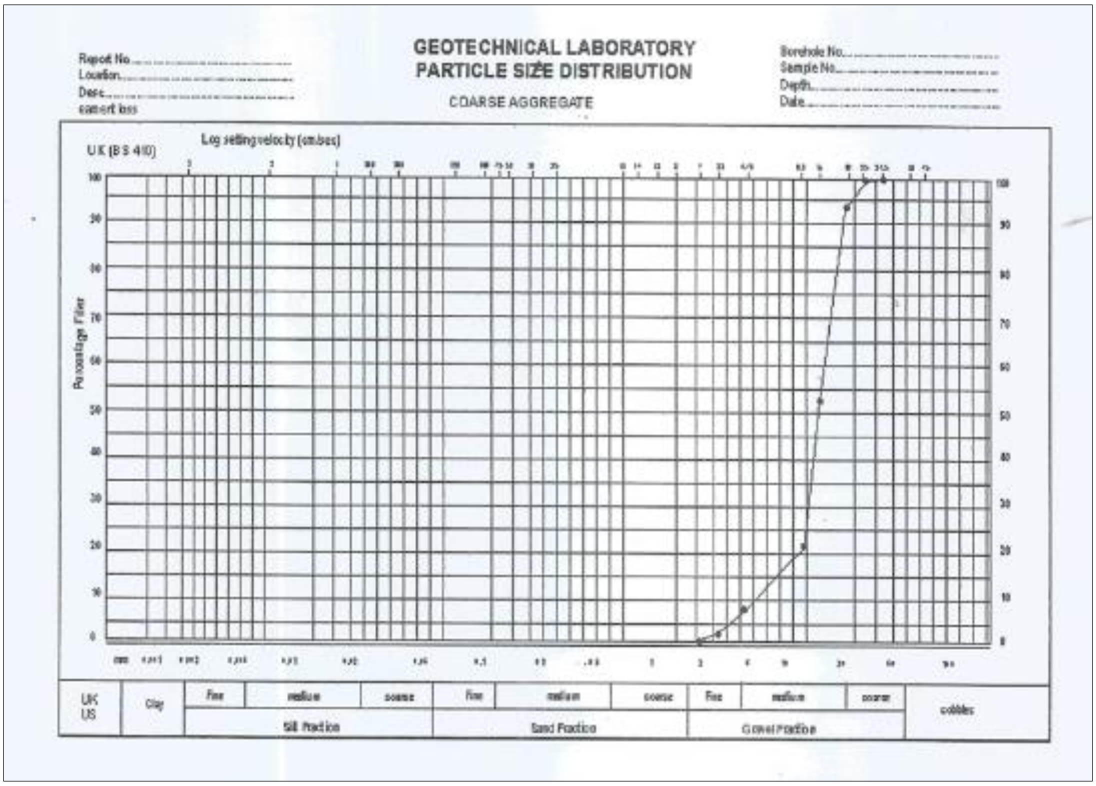

Figure 3 Geotechnical Laboratory Particle Size Distribution for Course Aggregate

4.2 Specific Gravity Test Results

4.2.1 Specific Gravity Test Result for Fine Aggregate (sand) Weight of empty bottle = x Weight of empty bottle + sample = k Sample weight = k - x = A Weight of bottle + sample + water = B Weight of bottle + water = C

Table 4 Specific Gravity Results for Fine Aggregate

Sample ID	Sample A	Sample B	Sample C	Sample D	Sample E
X	435	430	430	425	420
K	1000	1075	1050	985	925
A	565	645	620	550	475
B	1800	1840	1820	1800	1745
C	1465	1445	1445	1465	1445

Specific Gravity on SSD Basis

$$A= \frac{565}{565-(1800-1465)} = 2.45$$

$$B= \frac{645}{645-(1840-1445)} = 2.58$$

$$C= \frac{620}{620-(1240-1445)} = 2.53$$

$$D= \frac{550}{550-(1800-1465)} = 2.56$$

$$E= \frac{495}{495 - 1245 - 1445)} = 2.54$$

$$Average = \frac{2.45 + 2.58 + 2.53 + 2.56 + 2.54}{5} = 2.54$$

Table 5 Specific Gravity Results for Uncrushed Coarse Aggregate

Sample ID	Sample A	Sample B	Sample C	Sample D	Sample E
X	430	435	430	435	435
K	1015	1075	1085	1090	1035
A	585	640	655	655	600
B	1810	1870	1855	1880	1845
C	1445	1465	1445	1465	1465

Specific Gravity on SSD Basis

$$A = \frac{585}{585 - (1810 - 1445)} = 2.65$$

$$B = \frac{640}{640 - (1870 - 1465)} = 2.72$$

$$C = \frac{655}{655 - (1855 - 1465)} = 2.67$$

$$D = \frac{655}{655 - (1880 - 1445)} = 2.73$$

$$E = \frac{600}{600 - (1845 - 1465)} = 2.73$$

$$Average = \frac{2.65 + 2.72 + 2.67 + 2.73 + 2.73}{5} = 2.7$$

Table 6 Specific Gravity Test Results for Crushed Coarse Aggregate

Sample ID	Sample A	Sample B	Sample C	Sample D	Sample E	Average
X	435	435	435	435	435	
K	845	910	850	900	860	
A	410	475	415	465	525	2290
B	1765	1710	1725	1730	1795	8725
C	1460	1460	1460	1460	1460	7300

Specific Gravity on SSD Basis

$$A = \frac{A}{\mathrm{A} - (\mathrm{B} - \mathrm{C})}$$

$$A = \frac{2290}{2290 - (8725 - 7300)} = 2.65$$

4.3 Compressive Test

This test was carried out on the specimen after 28 days of curing using a digital universal testing machine. The load at failures of the test specimen was recorded and compressive strength and density where surface dried of each specimen evaluated using the following formula:

$$\text{Characteristics strength } = \frac{\text{load(N/mm2)}}{area}$$

$$\text{Density } = \frac{\text{mass (kg/ mm3)}}{Volume}$$

$$Volume = 150 \text{ x } 150 \text{ x } 150 = 3375000\text{mm}^3$$

$$Area = 150 \text{ x } 150 = 22500\text{mm}^3$$

Table 7 Compressive strength of Uncrushed Coarse Aggregate mix Concrete

Duration (days)	Cube reference	Mass (kg)	Density (kg/m)	Average density (kg/m)	Cross-section area (mm²)	Stress (N/mm³)	Average stress (N/mm³)
7 Days	A	12085	2280.189		22500	16.40	
	B	11200	2113.208		22500	18.76	
	C	120.01	2264.340		22500	19.45	
14 Days	A	12312	2323.019		22500	25.89	
	B	13254	2500.755		22500	24.05	
	C	12876	2429.434		22500	21.39	
21 Days	A	12268	2314.717		22500	26.63	
	B	12380	2335.849		22500	26.45	
	C	14562	2747.547		22500	26.07	
28 Days	A	13084	2468.679		22500	28.15	
	B	12352	2330.566		22500	28.11	
	C	13305	2510.377		22500	28.45	

Table 8 Compressive strength of Crushed Coarse Aggregate mix Concrete

Duration (days)	Cube reference	Mass (kg)	Density (kg/m)	Average density (kg/m)	Cross-section area (mm²)	Stress (N/mm³)	Average stress (N/mm³)
7 Days	A	12085	2280.189		22500	19.49	
	B	12380	2462.264		22500	16.34	
	C	12352	2468.679		22500	18.32	
14 Days	A	13254	2319.623		22500	22.19	
	B	12332	2314.717		22500	19.30	
	C	12014	2371.698		22500	22.22	

21 Days	A	12382	2336.226	2311.006	22500	28.15	27.20
	B	13084	2327.925		22500	26.70	
	C	12025	2268.868		22500	26.75	
28 Days	A	13204	2491.321		22500	28.50	
	B	12580	2459.623		22500	26.65	
	C	13036	2266.762		22500	26.38	

Table 9 B Graphical Comparison Strength of Uncrushed and Crushed Coarse Aggregate mix Concrete

Days	**7**	**14**	**21**	**28**
Stress (N/mm2)Uncrushed	18.2	23.79	26.38	28.24
Stress (N/mm2) crushed	18.05	21.24	27.2	27.18

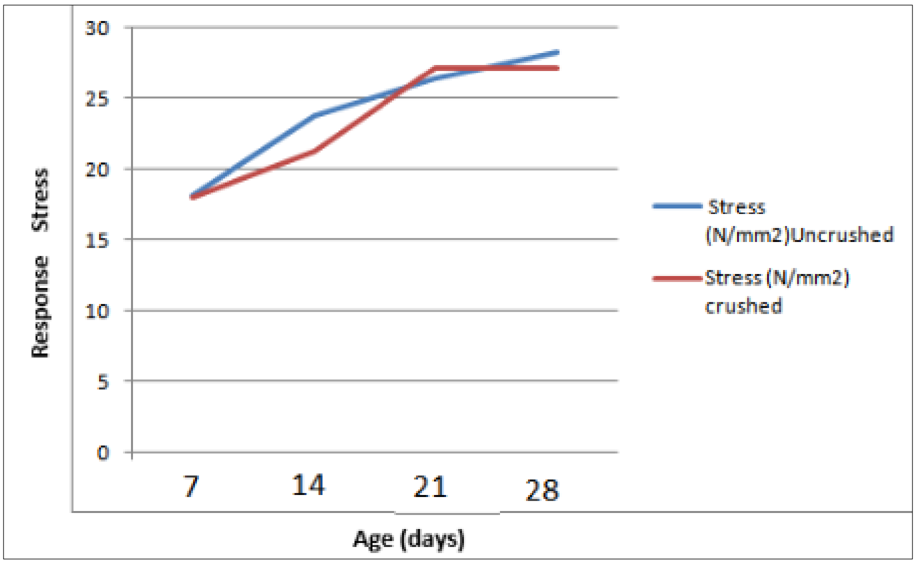

Figure 5 Graphical Comparison Strength of Uncrushed and Crushed Coarse Aggregate mix Concrete

4.4 Comprehensive Strength Result

Table 10 and 11 show the 28 days compressive strength result of concrete mixture materials obtained from the laboratory tests for both the response and control points

Table 10 28 days compressive strength result for the response (Y_i)

Response	**Replicate**	**Average weight (kg)**	**Volume (m3)**	**Average Bulk Density**	**Crushing Load (RN**	**Area (mm2)**	**Compressive Strength**	**Aver. Compr. strength**
Y_1	A B	8.12	0.003375	2405.93	645000 635000	22500	28.67 28.22	28.45
Y_2	A B	8.07	0.003375	2391.11	617000 593000	22500	27.42 26.36	26.89
Y_3	A	7.93	0.003375	2349.63	605000	22500	26.89	26.58

	B				591000		26.27	
Y_4	A B	7.87	0.003375	2331.82	580000 585000	22500	25.78 26.00	25.89
Y_{12}	A B	8.09	0.003375	2397.04	630000 635000	22500	28.00 28.22	28.11
Y_{13}	A B	8.03	0.003375	2379.26	616000 608000	22500	27.37 27.02	27.20
Y_{14}	A B	7.91	0.003375	2343.70	590000 610000	22500	26.22 27.11	26.67
Y_{23}	A B	7.90	0.003375	2340.74	605000 593000	22500	26.89 26.36	26.63
Y_{24}	A B	7.84	0.003375	23.22.96	590000 600000	22500	26.22 26.67	26.45
Y_{34}	A B	7.80	0.003375	2311.11	585000 588000	22500	26.00 26.17	26.07

Table 11 28 days compressive strength results for the control points

Response	Replicate	Average weight (kg)	Volume (m3)	Average Bulk Density	Crushing Load (RN	Area (mm2)	Compressive Strength	Aver. Compr. strength
C_1	A B	7.95	0.003375	2355.56	592000 601500	22500	26.31 26.73	26.90
C_2	A B	8.08	0.003375	2394.07	603000 607000	22500	26.80 27.00	26.90
C_3	A B	7.83	0.003375	2320.00	597000 587000	22500	26.54 26.09	26.27
C_4	A B	7.80	0.003375	2311.11	584000 590000	22500	25.96 26.22	26.09
C_{12}	A B	8.10	0.003375	2400.00	632000 635000	22500	28.09 28.22	28.15
C_{13}	A B	8.04	0.003375	2382.22	605500 596000	22500	26.91 26.49	26.70
C_{14}	A B	7.97	0.003375	2361.48	600000 604000	22500	26.67 26.84	26.75
C_{23}	A B	8.15	0.003375	2414.81	639000 643500	22500	28.40 28.60	28.50
C_{24}	A B	7.88	0.003375	2334.81	599000 600300	22500	26.62 26.68	26.65
C_{34}	A B	7.80	0.003375	2322.96	597200 590000	22500	26.54 26.22	26.38

4.5 Regression model for compressive strength

Substituting the response compressive strength values of table 4.1 in equations 3.21 – 3.31 gives the following

$$\propto_1 = \quad y_1 \quad = 28.45 \ \ldots\ldots\ldots(4.1)$$

$$\propto_2 = \quad y_2 \quad = 26.89 \ \ldots\ldots\ldots\ldots(4.2)$$

$$\propto_3 = \quad y_3 \quad = 26.58 \ \ldots\ldots\ldots\ldots(4.3)$$

$$\propto_4 = \quad y_4 \quad = 25.89 \ \ldots\ldots\ldots\ldots\ldots\ldots(4.4)$$

$\propto_{12} = \quad 4y_{12} - 2y_1 - 2y_2$

$$= 4(28.11) - 2(28.45) - 2(26.89) = 1.76\ldots\ldots\ldots\ldots(4.5)$$

$\propto_{13} = \quad 4y_{13} - 2y_1 - 2y_3$

$$= 4(27.20) - 2(28.45) - 2(26.58) = 1.26\ldots\ldots\ldots(4.6)$$

$\propto_{14} = \quad 4y_{14} - 2y_1 - 2y_4$

$$= 4(26.67) - 2(28.45) - 2(25.89) = -2.00\ldots\ldots\ldots\ldots(4.7)$$

$\propto_{23} = \quad 4y_{23} - 2y_2 - 2y_3$

$$= 4(26.63) - 2(26.89) - 2(26.58) = 0.42 \quad \ldots\ldots\ldots\ldots(4.8)$$

$\propto_{24} = \quad 4y_{24} - 2y_2 - 2y_4$

$$= 4(26.45) - 2(26.89) - 2(25.89) = 0.24\ldots\ldots\ldots\ldots(4.9)$$

$\propto_{34} = \quad 4y_{34} - 2y_3 - 2y_4$

$$= 4(26.07) - 2(26.58) - 2(25.89) = 0.66\ldots\ldots\ldots(4.10)$$

From equation(4.1 – 4.10) the coefficient od the Scheffe's second degree polynomial are presented in table 4.3

Table 12 Coefficient of scheffe's second degree polyminial for the regression model

$\propto_1$	$\propto_2$	$\propto_3$	$\propto_4$	$\propto_{12}$	$\propto_{13}$	$\propto_{14}$	$\propto_{23}$	$\propto_{24}$	$\propto_{34}$
28.45	26.89	26.58	25.89	1.76	-1.26	-2.00	-0.42	0.24	-0.66

Substituting the values of these co-efficient into equation 8.19 yields

$$28.45x_1 + 26.89\, x_2 + 26.58\, x_2 + 25.89\, x_4 + 1.76\, x_1 x_2 - 1.26\, x_1 x_3$$

$$- 2.00\, x_1 x_4 - 0.42\, x_2 x_3 + 0.24\, x_2 x_4 - 0.66\, x_3 x_4 \ldots\ldots\ldots\ldots\ldots\ldots(4.11)$$

Equation 4.16 is the regression model for the compressive strength of concrete mixture materials. The scheffe's model test results for compressive strength are obtained when the Pseudo mix ratio presented in table 3.1 and 3.2 are substituted in equation 4.1), Table 4.4 shows the experimental test result and Scheffe's model test result.

Table 13 Experimental test results and Scheffe's model test results

Symbol	Experimental test result	Scheffe's Model Test Result
Y_1	28.45	28.45
Y_2	26.89	26.89
Y_3	26.58	26.58
Y_4	25.89	25.89
Y_{12}	28.11	28.11
Y_{13}	27.20	27.20
Y_{14}	26.67	26.67
Y_{23}	26.63	26.63
Y_{24}	26.45	26.45
Y_{34}	26.07	26.07
C_1	26.52	25.68
C_2	26.90	27.71
C_3	26.27	26.23
C_4	26.09	26.19
C_{12}	28.15	28.22
C_{13}	26.70	26.53
C_{14}	26.75	26.83
C_{23}	28.50	28.39
C_{24}	26.65	26.73
C_{34}	26.38	26.47

4.6 Test of Adequacy of the Model

The test for adequacy of the model was done using fisher's test at 95% confidence level on the compressive strength at the control points subject to these two hypothesis.

4.6.1 Null Hypothesis

There is no significant difference between the laboratory test and the predicted model strength result.

4.6.2 Alternative Hypothesis

There is a significant difference between the laboratory test and predicted model strength. Table 4.5 shows the value generated that were used to compute the sample variances for the experimental and model compressive strength results the fishers test was used to validate the adequacy of the model using the two tailed test and rejecting the null hypothesis, if Fcal > F critical.

Table 14 Fisher's test result

	Y_e	Y_m	$Y_e - Y_{ee}$	$Y_m - Y_{mm}$	$(Y_e - Y_{ee})^2$	$(Y_m - Y_{mm})^2$
C_1	26.52	25.68	-0.45	-1.22	0.203	1.488
C_2	26.90	27.71	-0.07	0.81	0.005	0.656
C_3	26.27	26.23	-0.43	-0.67	0.185	0.449

C_4	26.09	26.19	-0.88	-0.71	0.774	0.121
C_{12}	28.15	28.22	1.18	1.32	1.392	1.742
C_{13}	26.70	26.53	-0.27	-0.37	0.073	0.137
C_{14}	26.75	26.83	0.22	-0.07	0.048	0.005
C_{23}	28.50	28.39	1.53	1.49	2.341	2.190
C_{24}	26.65	26.73	-0.32	-0.17	0.102	0.029
C_{34}	26.38	26.47	-0.52	-0.43	0/27	0.185
	269.73	268.998			5.398	7.002
	26.97	26.90				

$$\text{Yee} = \frac{269.73}{10} = 26.97(4.12)$$

$$\text{Ymm} = \frac{268{,}998}{10} = 26.90(4.13)$$

$$Se^2 = \frac{(\text{Ye} - \text{Yee})^2}{\text{N} - 1} = \frac{5.398}{9} = 0.600\ (4.14)$$

$$\text{Sm}^2 = \frac{(\text{Ym} - \text{Ymm})^2}{\text{N} - 1} = \frac{7.002}{9} = 0.778\ (4.15)$$

The test statistics is given by

$$\text{Fcal} = \frac{\text{S1}^2}{\text{S2}^2} \ldots\ldots\ldots (4.16)$$

S_1^2 is the greater of S_e^2 and S_m^2

S_2^2 is the greater of S_e^2 and S_m^2

$$\text{Fcrit} = \frac{0.778}{0.6} = 1.297$$

$$F_{crit} = F\propto (V_1\ V_2) =$$

$$F_{crit} = F_{0.05}\ (9\ 9) = 3.18$$

$$(F_{crit})^{-1} = (3.18)^{-1} = 0.314$$

From the fishers test statistics, F_{cal} = 1.297 and F_{crit} = 3.18.

Therefore $F_{cal} \propto F_{crit}$, indicating that the null hypothesis is accepted as there was no significant different between the experimental test result and model test result. Hence, the model is adequate.

5 Discussion of Result

The values of the compressive strength of concrete at 28days curing age were obtained using the Scheffe's model formulated in equation (4.11). the highest compressive strength value of 28.45 N/mm² corresponding to a mix ratio of 0:50:1:2:4 was obtained while the lowest compressive strength was found to be 25.89 N/mm² corresponding to a mix ration of 0.59 : 1: 4 : 3.3 for water, cement, sand and washed granite respectively ,. The result showed that the formulated model can be used to predict the compressive strength of C25 N/mm² concrete. The adequacy of the model using the Fisher's test revealed that there was no significant different between the laboratory tests and the predicted model strength result. Hence, the null hypothesis was accepted indicating that the Scheffe's model formulated can be used to predict the compressive strength of concrete.

6 Conclusion

The following conclusions were made

- The Scheffe's model equation $28.45x_1 + 26.89x_2 + 25.89\ x_2 + 1.76\ x_1\ x_2 - 1.26\ x_1\ x_3 - 2.00\ x_1\ x_4 - 0.42\ x_2\ x_3 + 0.24\ x_2\ x_4 - 0.66\ x_3\ x_4$ was formulated for predicting the compressive strength of concrete.
- The Scheffe's Model formulated was adequate and reliable at 95% confidence level for predicting the compressive strength of concrete
- The model revealed that the highest compressive strength value of 28.45N/mm^2 Corresponding to a mix ratio of 0.5 : 1 : 1 : 2 and a minimum compressive strength of 28.45N/mm^2 corresponding to a mix ratio of 0.59 : 1 : 1 : 2 for water, cement, sand and crushed aggregate respectively.

Recommendation

It was recommended that the Scheffe's model formulated can be used to produce grade C25 N/mm^2 concrete as the minimum predicted compressive strength value was 25.89 N/mm^2 .

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

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