Assessment of the Compressive Strength of Concrete Produced with Fine Aggregate from Different Locations in Minna

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ABSTRACT

The construction industry in Nigeria has been witnessing serious collapse of buildings resulting from the qualities of materials used in their construction. This continuous collapse necessitates the need to investigate some of the materials used in the production of the building components in order to ascertain their appropriateness. This research thus investigates the compressive strength of concrete produced using fine aggregate from different locations in Minna. Fine aggregates were obtained from Chanchaga, Maikunkele, Bosso, Lapai Gwari and Garatu areas of Minna and subjected to series of tests namely: sieve analysis, Specific gravity, bulk density, moisture content, and water absorption. Concrete samples were produced using the mix ratio 1:2:4 and the water/cement ratio of 0.6. These samples were subjected to both the slump test and compressive strength test. For each of the fine aggregates, nine cubes of concrete (150mm x 150mm x 150mm) were cast, cured and tested at 7, 14 and 28 days. The results obtained for the mean compressive strength of the concrete produced shows that they all have mean strength greater than 20N/mm^2 with fine aggregate from Chanchage having the highest mean of 25.17N/mm^2 at 28days of curing. Thus all the fine aggregates could be used in the production of structural lightweight concrete but for structures that require higher strength, the fine aggregate from Chanchaga is recommended

Keywords: *Building collapse, concrete, fine aggregate, compressive strength.*

1 INTRODUCTION

Concrete is one of the most popular artificial construction material on earth (Thandavamoorthy, 2014) and the most widely used construction material in Nigeria (Tsado, 2013). It is a composite material with natural aggregate as a major constituent. Traditionally, concrete is made up of cement, aggregate (coarse and fine) and water in an appropriate ratio which hardened up to form a rocklike mass (Gideon *et al*, 2015). This constituent has various influences on the strength of the concrete (Deodhar, 2009). Also, the strength, stiffness, and fracture energy of concrete for a given water/cement ratio depend on the type of aggregate used in its production (Abdullahi, 2012). Its quality could be impaired if the materials used in its production are not of good quality.

The collapse of buildings has been traced to many factors one of which is the qualities of the materials used during construction (Ayininuola and Olabisi, 2014, Ede 2010). The qualities of concrete depend on the type of cement, water, and aggregate used in its production. Since aggregate (coarse and fine) occupy up to 70 -75% of the concrete volume (Talbot and Richart, 1923), its quality need to be ascertained. The aggregates in concrete are of two types namely fine and coarse aggregate. The aggregate with size less than or equal to 5mm is termed fine aggregate while that with size above 5mm is termed coarse aggregate.

All aggregates for concrete works should be composed of hard particles and free of any amounts of clay, loam, and vegetable matter. The major characteristics of aggregates that affect the strength, durability, and workability of concrete are cleanness, grading, hardness, and shape. Usually, the aggregates are stronger than the concrete from which they are made. A coating of dirt or dust on the aggregate will reduce the strength of concrete because it prevents the particles from properly bonding to the mortar. A well-graded aggregate mix is essential to obtaining an economical concrete of good quality. If poorly graded, even clean, sound aggregates will require excessive water for workability, resulting in lower strength, or the mix will require an excessive amount of cement to develop a given strength.

Fine aggregate is one of the important constituents of concrete which contributes to the stability of the concrete produced (Gupta and Gupta, 2014). Various types of fine aggregates are being used in concrete production. The type of fine aggregate used changes the geometric properties of cement paste, and affect not only the shell formation during heat treatments but also the properties of concrete (Abdullahi et al., 2017).

The fine/coarse aggregate ratio will influence the packing of concrete. It also influences the workability of concrete in the fresh stage. Increase of the sand to coarse aggregate ratio can lead to an increase of cohesiveness but reduces the consistency. Increasing the sand/coarse aggregate ratio of concrete has proven to be the most effective measures for improving its cohesiveness (Li, 2011).

The commonly used fine aggregate in Nigeria is popularly referred to as sharp sand which may be sourced from the river or natural deposit. This is because of its tested nature which conforms to the British standard codes specifications. In Nigeria, especially Minna, sharp sand as fine aggregate used in construction are obtained from different locations but the location which gives the best quality of concrete is yet to be ascertained.

Production of concrete with fine aggregate from different locations in Minna will reveal the one that is most suitable for concrete work. Thereafter, in a construction project, the location of most suitable fine aggregate will be guaranteed and prevent usage of substandard material in the construction project so as to reduce the problem of collapsed structures.

2 METHODOLOGY

The approach of this study was to investigate the properties of the fine aggregates and fresh concrete and the compressive strength of the hardened concrete that is produced with it. Different concrete mixes were produced by using the fine aggregates from five different locations in Minna while using a uniform mix ratio 1:2:4 and water/cement ratio of 0.6. Nine cubes (150mm x 150mm x 150mm) were cast for each of the fine aggregates (BS 1881: Part 108:1983). These cubes were cured by completely immersing them in water for 7, 14 and 28 days (BS 1881: Part 111:1983).

2.1 MATERIALS

The materials described below were used for this study;

2.1.1 ORDINARY PORTLAND CEMENT

The cement used for this study is Ordinary Portland Cement (OPC). It was bought from a cement store beside Yellow house, Gidan Kwano, Minna, Niger State and conforms to BS EN 197-1 (2011) requirements.

2.1.2 AGGREGATES

The coarse aggregate used in the study was obtained from a quarry shop along Gidan Kwano to Kpakungu road. It was found to have conformed to PD 6682-1:2009+A1 (2013) as it was retained on BS sieve 5mm while the fine aggregates used also conformed to the specification of PD 6682-1:2009+A1 (2013) and passes through BS sieve 5mm. The samples of fine aggregates were obtained from the following five locations; Chanchaga, Maikunkele, Garatu, Bosso and Lapai Gwari within the region of Minna, Niger State.

All the aggregates were moisture-free before being used for concrete production.

2.1.3 WATER

The water used for the study was obtained from the borehole near the Civil Engineering Laboratory at the Main Campus, Gidan Kwano, Federal University of Technology Minna, Niger State. It conformed to BS EN 1008 (2002) specifications.

2.2 EXPERIMENTAL INVESTIGATIONS

The investigations include tests on all the fine and coarse aggregates, the fresh concrete and also the hardened concrete. The following tests were carried out on the aggregates used in order to determine their pr0perties.

i. Specific gravity,(G_s): This is the ratio of mass (weight in air) of a unit volume of material to the mass of the same volume of water at the same temperature. This test was carried out on the fine and coarse aggregates in accordance with BS EN 1097-6 (2000). The specific gravity is calculated as

$$Gs = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)} \qquad (1)$$

Where,
W1 = Weight of vessel (g)
W2 = Weight of vessel plus sample (g)
W3 = Weight of vessel plus sample plus water (g)
W4 = Weight of vessel plus water only (g)

ii. Bulk density: This is the weight of a given material required to fill a given volume of container. It is also a measure of how dense or closely packed a sample is. The bulk density of a sample depends on the particle size distribution, the shape of particles and how densely the aggregate is packed. It is expressed in kilogram per meter cube (kg/m^3). Bulk density could either be compacted or un-compacted (loose) bulk density. The test was carried out on the fine and coarse aggregates in accordance with BS EN 1097-3 (1998). The bulk density of the un-compacted and compacted is calculated from:

$$\text{Un-compacted Bulk Density} = \frac{W_2 - W_1}{V} \qquad (2)$$

$$\text{Compacted Bulk Density} = \frac{W_3 - W_1}{V} \qquad (3)$$

Where:
W_1 = Weight of mould (g)
W_2 = Weight of mould plus un-compacted sample (g)
W_3 = Weight of mould plus compacted sample (g)
V = Volume of mould

iii. Water Absorption: This is the increase in mass of aggregates due to the penetration of water into the pores of the particles during a period of time.

Water absorption is determined by measuring the decrease in mass of a saturated and dry sample after oven drying for 24 hours. Water absorption is expressed as a percentage of dry mass. This test was carried out in accordance with BS EN 1097-6 (2000). It is calculated as:

$$\text{Water Absorption} = \frac{W_3 - W_2}{W_4 - W_1} \times 100 \qquad (4)$$

Where:
W_1 = Weight of container (g)
W_2 = Weight of container plus sample (g)
W_3 = Weight of container plus wet sample (g)
W_4 = Weight of container plus oven dry sample (g)

iv. Moisture content (Mc): This is the amount of water that can be removed from a soil sample when it is dried at a temperature of 105°C. It is expressed in percentage as the relationship between the water content in the sample to the weight of the sample when it is completely dry. This test procedure was done on the fine and coarse aggregates in accordance with BS EN 1097-5 (2008). It is calculated as:

$$\text{Mc} = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \qquad (5)$$

Where:
W_1 = Weight of empty can (g)
W_2 = Weight of can plus sample (g)
W_3 = Weight of can plus oven-dried sample (g)

v. Porosity: This is the amount of void present in an aggregate. it affects the bond between the aggregate and cement, the resistance of concrete, freezing, and thawing and, chemical stability of the aggregate (Neville and Brooks, 2010). According to Neville (2010), higher durable concrete can be achieved through aggregate with lower porosity.

Porosity (%) = 1 - � $\frac{\text{ɯɯɯ} - \text{ccccccccccccccccccccuucccccccccuuccccccccc}}{\text{ccccccccccccccccccccuucccccccccuucccccccc}}$ �x 100 (6)

vi. Particle size distribution (sieve analysis): This test commonly referred to as gradation test can simply be summarized as the process of dividing a sample of aggregate into fractions of the same particle size. The test was carried out in accordance with BS EN 933-1 (2012).

The slump test was done on the fresh concrete to determine its workability in accordance with BS EN 12350-2 (2009) while the compressive strength test was done on the hardened concrete in accordance with BS EN 12390-2 (2009) and BS EN 12390-3 (2009).

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3 RESULTS AND DISCUSSION

This research aim at identifying the most suitable fine aggregate for concrete production in Minna and its environs. Here, the result of the physical properties of the fine and coarse aggregates as well as the workability test (slump test) done on fresh concrete mixes and the compressive strength test on the hardened concrete cubes at different curing ages are presented.

3.1 PROPERTIES OF FINE AND COARSE AGGREGATE

The particle size distribution curves of the fine and coarse aggregates are present in Figure 1. It showed that all the fine aggregates fall within a fine sand fraction with that obtained from Chanchaga being the most well graded. This shows that it requires less quantity of cement and water and is thus more economical and produce higher strength concrete, lower shrinkage and greater durability (Shetty, 2012). The coarse aggregate curve reveals medium gravel aggregate

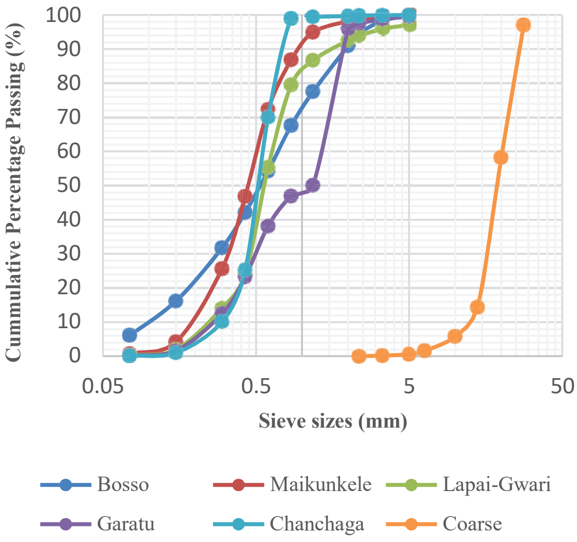

Figure 1: Particle size distribution of Fine and Coarse Aggregate

The results of the physical properties of the fine aggregates are as presented in Table 1 below.

The specific gravity of fine aggregates obtained from Lapai Gwari, Garatu, Maikunkele, Chanchaga, and Bosso are 2.58, 2.67, 2.63, 2.66 and 2.70 respectively. All the fine aggregates are within the standard range of 2.6 – 2.7 except that of Lapai Gwari. The specific gravity of the coarse aggregate (2.64) is also within the standard limit of 2.6 – 3.0 (Neville, 2010).

The results of bulk density for fine aggregates showed that all of them are in conformity with the standard limit of

1300-1800 kg/m^3. Also, the coarse aggregates bulk density is within the standard limit of 1500-1700 kg/m^3.

The results obtained for the porosity of the fine aggregates as shown in table 1 are 5.7%, 1.2%, 9.5%, 7.2% and 0.8% for Chanchaga, Maikenkele, Bosso, Lapai Gwari and Garatu respectively while the porosity for the coarse aggregate is 5.14%. The percentage porosity of these aggregates falls within the range of 1% to 15% (Neville, 2010). The lower values of porosity obtained for the aggregates specified that the aggregates can make a highly durable concrete (Neville, 1987). with fine aggregate from Garatu having the lowest value.

The results of water absorption test for the fine aggregate are 28.54%, 26.68%, 28.91%, 28.19%, and 24.08% respectively for Garatu, Lapai Gwari, Chanchaga, Maikunkele, and Bosso while that of coarse aggregate is 1.40%. This indicates a high water tolerance for the fine aggregates with Chanchaga having the tendency of absorbing more water than the others. Meanwhile, there is low water tolerance for the coarse aggregate.

The results of moisture content tests for the fine aggregates are 0.151%, 0.013%, 0.121%, 0.038% and 0.5045% for Garatu, Lapai Gwari, Chanchaga, Maikunkele, and Bosso respectively while that of coarse aggregate is 0.504%. These are within the standard ranges (Neville, 2010).

TABLE 1: Summary of the properties of fine and Coarse Aggregate used in the study

Properties		Bosso	Maikunkele	Lapai - Gwari	Garatu	Chanchaga	Coarse Aggregate
Specific gravity		2.70	2.63	2.58	2.67	2.66	2.64
Bulk density (kg/m^3)	Un-compacted	1545	1404	1444	1511	1388	1551
	Compacted	1708	1421	1556	1523	1472	1635
Water absorption (%)		24.08	28.19	26.68	28.54	28.91	1.40
Porosity (%)		9.5	1.2	7.2	0.8	5.7	5.14
Moisture content		0.089	0.038	0.013	0.151	0.121	0.504

3.2 WORKABILITY TEST RESULTS (SLUMP TEST)

The slumps obtained for the concrete made with the fine aggregates types are as shown in table 2. The nature of the slumps obtained during the experiment revealed a true slump for all the fine aggregates which indicate uniformity in the mix. The slumps are also classified as medium slump which indicates a highly durable and workable concrete except for Maikunkele with a slump of 30mm which is classed as low.

TABLE 2: Slump test result of concrete made from different fine aggregate types

Fine aggregate source	Trials	Water/ cement ratio	Mix ratio	Slump (mm)	Avg. slump	Slump Value	Type of slump
Lapai-Gwari	1	0.6	1:2:4	75	75	75	True slump
	2	0.6	1:2:4	75			
Maikunkele	1	0.6	1:2:4	32	30	30	True slump
	2	0.6	1:2:4	28			
Bosso	1	0.6	1:2:4	44	42	40	True slump
	2	0.6	1:2:4	40			
Chanchaga	1	0.6	1:2:4	45	45	45	True slump
	2	0.6	1:2:4	45			
Garatu	1	0.6	1:2:4	42	40	40	True slump
	2	0.6	1:2:4	38			

3.3 COMPRESSIVE STRENGTH TEST RESULTS

The results for the compressive strength test of hardened concrete for a constant mix ratio (1:2:4) and 0.6 water/cement ratio for 7, 14 and 28 days curing of concrete made from fine aggregates obtained from Lapai Gwari, Maikunkele, Bosso, Chanchaga and Garatu are as shown in Figure 2

The highest value of compressive strength was obtained for concrete made with the fine aggregate obtained from Chanchaga for all the days of the concrete curing.

From the values obtained for compressive strength, the concrete can be classified as lightweight concrete. The standard recommended in BS 1881: Part 116: (1983) and Barry (1999), indicates that a 28 days compressive strength range of 17.5N/mm^2 to 34N/mm^2 is specified for structural lightweight concrete, depending on factor such as aggregate grading, mix proportioning, and water/cement ratio. According to Neville (2010) concrete attain over 60% of their 28days strength at the age of 7 days; the compressive strengths obtained from concrete produced with all the fine aggregates were in conformity with this theory. Also, the graph showed that the compressive strength of concrete increase with curing ages.

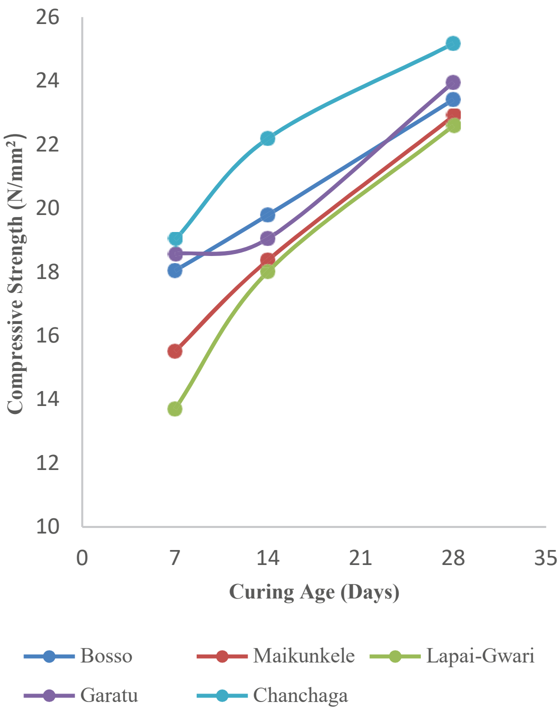

Figure 2: Compressive strength of concrete produced with fine aggregate from different locations

4 CONCLUSION

From the results obtained from the assessment of the compressive strength of concrete using fine aggregate obtained from different locations in Minna, the following conclusion can be drawn.

- The fine aggregate from Chanchaga is better graded in particle distribution than the other fine aggregates. Thus concrete produced from this will have better qualities than the others.
- The physical properties of fine aggregate obtained from different locations (sources) in Minna have varying values with most falling within the recommended standards. The specific gravity values ranges between 2.58 – 2,70, the bulk density from 1388kg/m^3 - 1708kg/m^3, the water absorption from 24.08% - 28.91%, the porosity of 0.8% - 9.5% while the moisture content ranges between 0.013 - 0.151.
- The fine aggregate from different locations in Minna produced concretes of different workability with constant mix ratio, w/c ratio, and coarse aggregate properties.
- All the fine aggregate used in the study produced concrete with mean strength greater than 20N/mm^2 with the fine aggregate obtained from Chanchaga having the highest mean compressive strength (25.17N/mm^2) at 28days of curing.

It then means that all the aggregates could be used in the production of structural lightweight concrete but for structures that require high strength, then the fine aggregate from Chanchaga is recommended.

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Response Surface Optimisation of the Adsorption of Cu (II) from Aqueous Solution by Crab Shell Chitosan

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ABSTRACT

Adsorption of Cu (II) from aqueous solution by crab-shell derived chitosan was evaluated and optimised by response surface methodology alongside comparison with commercial chitosan. The commercial and locally developed chitosan was found effective in removal of copper (II) ion from aqueous solution and the results of the copper ion percentage removal was 99.57% for locally produced chitosan and 99.80% for commercial chitosan at pH of 6.0. Optimum metal uptake (99.57%) was observed at pH 4.75, 120 minutes equilibration time and dosage of 2 g/50ml. The monolayer adsorption capacity of the commercial and locally developed chitosan was 1.44 mg/g and 1.49 mg/g respectively. The isotherms modelling indicated that the Langmuir isotherm was the best fit. The kinetics for the adsorption of copper, onto chitosan was best described by a pseudo-second-order kinetic model. It has been shown that chitosan are excellent precursors for the removal of copper from aqueous solution and consequently for its use in remediating polluted industrial effluents.

Keywords: Adsorption, Chitosan, Crab shells, heavy metals, Optimisation.

1 INTRODUCTION

Environmental pollution by discharge of industrial waste into water streams is a major problem because of the toxic nature of industrial waste. Among various industrial wastes, heavy metals are of great concern because of their bioaccumulation and non-biodegradable nature (Bailey, Olin, Bricka, & Adrian, 1999). Methods of metal ion removal include filtration, chemical precipitation, adsorption, electrode position and membrane systems or even ion exchange process. Among these methods, adsorption is one of the most economically favourable and a technically easy method (Karthikeyan, Rajgopal, & Miranda, 2005).To remove trace levels of heavy metal ions, adsorption by natural occurring materials is one of the most effective and low cost methods (Bailey et al., 1999). Numerous materials have been studied for use as adsorbent for the removal of copper from aqueous solutions. They include fish scales (Das, Bhowal, & Datta, 2016; Eletta & Ighalo, 2019), cabbage leaves (Kamar, Nechifor, Nechifor, Al-Musawi, & Mohammed, 2017), *Terminalia catappa L.* fruit shell (Hevira, Munaf, & Zein, 2015), tea leaves (Ghosh, Das, & Sinha, 2015), Pine bark (Cutillas-Barreiro et al., 2014) and many others.

Recently many statistical experimental design methods have been utilized in chemical process optimization (Gratuito,Panyathanmaporn, Chumnanklang, Sirinuntawittaya, & Dutta, 2008). Design of experiments is a very useful tool as it provides statistical models, which help in understanding the interactions among the parameters that have been optimized. Response surface methodology (RSM) is one of the experimental designing methods which can surmount the limitations of conventional methods collectively (Olmez, 2009). Response surface methodology is a combination of mathematical and statistical techniques used to determine the optimum operational conditions of the process or to determine a region that satisfies the operating specifications (Alam, Muyibi, & Toramae, 2007). The main advantage of response surface methodology is the reduced number of experimental trials needed to evaluate multiple parameters and their interactions (Karacan, Ozden, & Karacan, 2007). RSM has also been reportedly used in the optimisation of adsorption process (Garg, Kaur, Sud, & Garg, 2009; Ghosh et al., 2015; Kumar & Phanikumar, 2013; Madala, Mudumala, Vudagandla, &