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Federal University of Technology, Minna, Nigeria

Effect of Aggregate Washing on Compressive Strength of Concrete Produced Using Bida Natural Stone

[1]Kolo, D. N., [1]Aguwa, J. I., [1]Tsado, T. Y., [1]Alhaji, B. & [2]Joseph, O. F.
[1]Department of Civil Engineering, Federal University of Technology Minna, Nigeria
[2] Department of Civil Engineering, Kogi State Polytechnic, Itakpe Campus, Nigeria
Email: daniel.kolo@futminna.edu.ng

Abstract
Concrete is the most widely used construction material in the world, second to water as the most utilised substance on earth. Coarse aggregate is an essential component in concrete production; it has effect on the workability and mechanical properties of concrete. Bida Natural Stone (BNS) which is the by-product of Precambrian deposits of Bida trough was used as coarse aggregate, utilising unwashed and washed aggregates. A total of 80 concrete cubes of 150 × 150 × 150 mm were cast and used for this study, compressive strength tests were conducted after 28 days curing. The result of physical properties test conducted proved that BNS is suitable for concrete production. The result of compressive strength tests conducted shows that concrete produced using washed aggregate results in an increase in average compressive strength of about 11.46 % when compared to that produced using unwashed aggregate. Hence, construction professionals and workers utilising this aggregate (BNS) in the Bida basin are encouraged to practice aggregate washing before concrete works.
Keywords: *Bida Natural Stone, Concrete, Compressive Strength, Unwashed Aggregate, Washed Aggregate*

1 INTRODUCTION

Concrete is a man-made composite, a major constituent of which is natural aggregate such as gravel and sand or crushed rock. Alternatively, artificial aggregate such as blast furnace slag, expanded clay, broken bricks and steel shots may be used where appropriate. Concrete is a composite material which has gained wide acceptance as a useful material in the construction industry and extensively utilised in the Civil engineering projects. It is the most widely used construction material in the world, second to water as the most utilised substance on earth (Alhaji, 2016). Aggregates ideally constitute 75% of concrete as such are extremely important in the quality of concrete produced, this makes it important that they meet certain standards in order to achieve a strong, durable and economical concrete. It is obtained by mixing cementitious material, water and aggregate (and sometimes admixtures) in required proportion. The mixture when place in form and allowed to cure, hardens into a rocklike mass known as concrete. The hardening of concrete is caused by chemical reaction between cement and water and continues for a very long time and consequently the concrete grows stronger with age (Bamigboye *et al.,* 2015). The hardened concrete may be considered as an artificial stone in which the void of larger particles (coarse aggregate) are filled by the smaller particle (fine aggregate) and void of fine aggregate are filled with cement. The cementitious material and water form a cement paste which in addition to the filling of the void of fine aggregate coats the surface of fine and coarse aggregate together to form a compact mass (Bamigboye *et al.,* 2015). In its hardened state concrete is a rocklike material with high compressive strength while in its plastic state it can be easily moulded into virtually any shape. It may be used as an architectural advantage or solely for decorative purposes. Normal concrete has a comparatively low tensile strength and for structural application it is normal practice to either incorporate steel bars to resist any tensile force (reinforced concrete) or to apply compressive forces to the concrete to counteract this tensile forces (pre-stressed concrete).

The use of Bida Natural Stone (BNS) for concrete production is gaining wide acceptance especially among the dwellers of the Bida basin because the production of crushed granite is labour intensive and expensive. However, despite the wide acceptance of its use, the body of literature is still not robust with research related to the use of BNS as coarse aggregate for concrete production.

The cost of producing concrete keeps increasing as such researchers over the years have devoted much time towards incorporating other materials aside the conventional concrete producing materials. The practice has been to incorporate agricultural waste or naturally sourced materials. BNS is one of such naturally sourced materials, the usage of BNS for structural members mainly in building construction is gaining momentum as such it is justifiable to conduct proper research on concrete produced using BNS. The life of dwellers of Bida basin will significantly be improved invariably saving cost and ultimately creating awareness among construction professionals on the need to look inwards and utilise this naturally sourced and readily available material. The use of this abundantly available material will create jobs for the locals who will be engaged on a large scale basis in digging out these stones. Furthermore, result of the studies conducted on BNS would establish confidence in its utilization in concrete production and stimulate construction.

The quest for the provision of adequate infrastructure for all has resulted in an increase in activities of the construction industry. This has resulted in the continuous utilisation of aggregates for concrete making, this practice leads to depletion of these aggregates. The situation clearly indicates that sourcing new materials and alternatives is timely and justifiable. The use of cheaper building materials without compromising on standards is vital to the infrastructure and economic growth of developing countries like Nigeria (Idagu*,* 2017). Bida natural aggregate (BNA) Bida is mostly found in Bida basin (Trough), it is a by-product of the Precambrian decomposition, transportation and deposition of rocks in this Basin. It is an extension of the Iullemmeden Basin which runs through Niger Republic and Mali in West Africa. Bida basin is found in Northern Nigeria and is delimited to the North East and South West by Basement Complex. BNA was utilized as coarse aggregate in this work (Alhaji, 2016).

2 MATERIALS AND METHODS

2.1 MATERIALS

Cement: in this work, ordinary Portland cement (OPC) was used. Cement is a kiln-dried and finely pulverized mixture of natural materials. The cement most commonly used for structural concrete is the ordinary Portland cement (OPC). The Cement used was obtained from the Building Materials Market Minna, Niger State. The bags of Cement were stored on a raised platform where adequate protection from external effect was guaranteed. The OPC conforms to BS 12 (1996).

Fine Aggregate: The sand was collected from Chanchaga river bed in Minna, Niger State. It was ensured that the sand was clean, sharp, free from clay and dirt's. Fine Aggregates generally refer to aggregates passing through sieve size 4.75 mm BS 882(1992).

Coarse Aggregate (Bida Natural Aggregate): The coarse aggregate used for this study was obtained from Bida town. The coarse aggregate conforms to specifications for natural aggregates as in BS 882 (1992).

2.2 METHODOLOGY

Casting of Concrete Cubes for Compressive Strength Test

The mix design method employed in this study is the British Standard mix design (DoE) method. The Concrete specimens tested were cast in 150 x 150 x 150 mm moulds for compressive strength test. The samples were thoroughly mixed with the aid of a Concrete mixer until the desired homogeneity of the mixture was achieved. The standard iron moulds of 150 x 150 x 150 mm were used, it was ensured that the moulds were well lubricated with oil in order to reduce friction and enhance removal of the cubes from the mould. Each mould was then filled with concrete in three layers each tampered 25 times. 80 cubes were cast in total, 40 cubes for the unwashed BNA and 40 for the washed BNA. The cubes were cured for 28 days using Ponding method of curing. Cube casting was performed in accordance to BS 1881 (1983).

Compressive Strength Test

Compressive strength tests on Concrete Cubes (80 Cubes) were determined using the Compressive testing machine. The weight of each cube was taken before crushing, this is however a destructive method of testing cubes. After crushing, the compressive strengths were calculated using Equation (1). The test was conducted in accordance with BS 1881:116.

$$F_{cu} = \frac{Average\ Load}{Area}\ (N/mm^2) \qquad (1)$$

3 RESULTS AND DISCUSSION

Result of the Physical Properties of Constituent Materials

Table 1 presents the results for specific gravity test performed on the Fine aggregate, an average specific gravity of 2.7 was obtained and is within the natural aggregates range of 2.6 – 2.7 (Neville and Brooks, 2008).

Table 1: Specific gravity result for Fine Aggregate

Trials	1	2	3
weight of cylinder	115.0	116.5	116.6
weight of cylinder + Sample	207.2	240.6	248.9
weight of cylinder + Sample + water	487.3	512.0	484.9
weight cylinder +Water	428.0	435.7	402.2
S.G	2.80	2.60	2.70
Average S.G		2.70	
S.G = Specific Gravity			

Table 2 presents the results for specific gravity test performed on the Coarse aggregate, an average specific gravity of 2.6 was obtained and is within the natural aggregates range of 2.6 – 2.7 (Neville and Brooks, 2008). This implies that the aggregate is suitable for construction work.

Figure 1and 2 presents the sieve analysis result obtained for fine aggregate and coarse aggregates respectively. As seen from Figure 1, the Coefficient of uniformity (C_u) of 3.5 was obtained. In order to classify a soil as well graded, the $C_u > 6$ (Alhaji, 2016), hence it is concluded that the fine aggregate is not well graded.

Table 2: Specific gravity result for Coarse aggregate

Trials	1	2	3
weight of cylinder	115.0	116.5	116.6
weight of cylinder + Sample	307.2	328.4	325.9
weight of cylinder + Sample + water	553.2	566.5	533.3
weight cylinder +Water	438.7	434.6	402.6
S.G	2.50	2.65	2.66
Average S.G		2.60	
S.G = Specific Gravity			

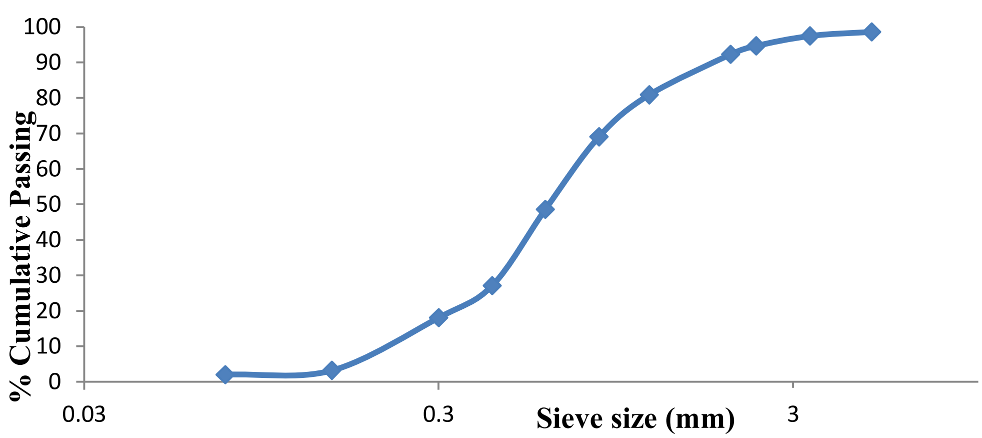

Figure 1: Particle Size Distribution for Fine Aggregate

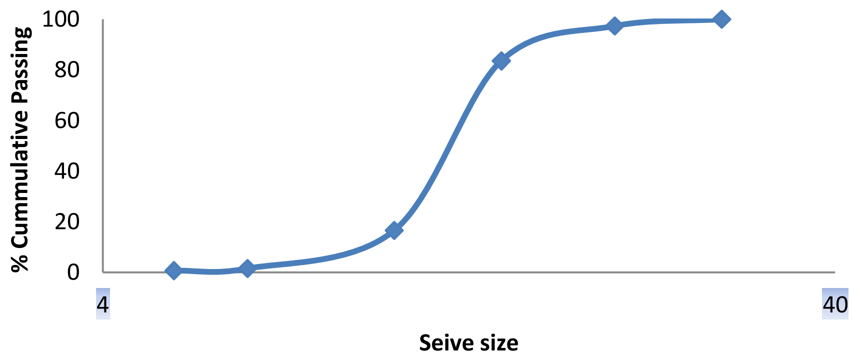

Figure 2: Particle Size Distribution for Coarse Aggregate (BNS)

Table 2 presents the results of compressive strength test conducted on the concrete cubes produced utilising unwashed and washed BNS respectively. A total of forty (40) concrete cubes of 150 x 150 x 150 mm were cast and crushed for each case, with an average compressive strength of 19.94 N/mm^2 for the unwashed aggregate and 22.52 N/mm^2 for the washed aggregate. Unwashed BNS aggregate exhibited lower average compressive strength values when compared to the concrete produced utilising washed BNS aggregate. This is probably due to impurities embedded therein. This result is in line with findings of research conducted by Ogunbiyi *et al.* (2017) and Ode and Eluozo (2016) where washed aggregates performed better than unwashed aggregates in concrete production.

Table 2: Compressive strengths of concrete at 28 days (Unwashed and Washed Aggregate)

Compressive Strength (Unwashed) (N/mm^2)	Average Compressive Strength (Unwashed) (N/mm^2)	Compressive Strength (Washed) (N/mm^2)	Average Compressive Strength (Washed) (N/mm^2)
18.67		29.33	
14.40		18.67	
14.67		32.00	
24.44		18.58	
15.64		16.80	
21.33		25.78	
16.00		33.78	
24.89		17.07	
24.89		28.00	
25.78		24.44	
23.56		25.33	
15.91		20.62	
16.53		32.44	
23.56		12.62	
17.24		32.44	
24.44		31.11	
22.67		23.11	
15.64		12.53	
19.02		27.56	
23.11	19.94	28.89	22.52
18.04		23.11	
13.78		16.53	
17.73		20.89	
19.82		21.42	
25.11		22.22	
18.49		16.44	

22.22	22.22
24.00	20.00
18.40	21.33
19.91	22.67
21.78	16.53
24.89	16.62
12.71	22.22
14.67	23.56
19.10	23.11
21.33	22.67
22.67	13.87
18.67	17.96
19.91	22.67
21.79	23.56

Statistical Analysis:

Confidence Limits for the Mean: Confidence limits are the maximum and minimum values which bracket the statistics of interest based on the data distribution at a certain confidence level. In order words, it refers to the maximum or minimum values above or below which you are confident (at a selected confidence level) that the statistics will occur. It was used to confirm the authenticity of the mean of the compressive strengths determined from tests. The limits commonly used are the 95% and the 99% confidence limits (Murray and Stephens, 1998).

The confidence limits for the mean of the compressive strengths determined at 95 and 99% are presented on Tables 3 and 4 respectively. For each case (unwashed and washed), the mean strength from test falls within the range of confidence intervals calculated for 95 and 99%. This confirms that the mean compressive strengths from tests are true ones.

Table 3: 95% Confidence Limits for compressive strengths of Unwashed and Washed aggregate

Mean Strength (N/mm^2)	Confidence Interval	Confidence level (95%)
19.94 (Unwashed)	18.74 - 21.13	1.19
22.53 (Washed)	20.74 – 24.29	1.77

Table 4: 99% Confidence Limits for compressive strengths of Unwashed and Washed aggregate

Mean Strength (N/mm^2)	Confidence Interval	Confidence level (99%)
19.94 (Unwashed)	18.34 - 21.53	1.59
22.53 (Washed)	20.14 – 24.89	2.38

Confidence Limits for the Standard Deviation: 95%, 99% or other confidence limits and intervals can be defined for χ^2 distribution. In this manner, it can be estimated within specified limits of confidence the population standard deviation (σ) in terms of a sample standard deviation (SD) (Spiegel and Stephens 1998). This is to confirm the authenticity of the standard deviation of the compressive strengths determined from tests. Tables 5 and 6 presents the confidence limits for the standard deviations computed for the compressive strengths of the concrete produced utilising both unwashed and washed BNS aggregates at 95 and 99% respectively. For each case, the standard deviation for the average compressive strengths from test falls within the range of confidence intervals calculated for 95 and 99%. This confirms that the standard deviations for the compressive strengths from tests are the true ones.

Table 5: 95% Confidence Limits for Unwashed and Washed aggregate Standard deviation for Compressive Strengths

Standard Deviation (SD)	Confidence Interval	Confidence Level (95%)
3.72 (Unwashed)	2.53 – 4.91	1.19
5.55 (Washed)	3.77 – 7.32	1.77

Table 6: 99% Confidence Limits for Unwashed and Washed aggregate Standard deviation for Compressive Strengths

Standard Deviation (SD)	Confidence Interval	Confidence Level (99%)
3.72 (Unwashed)	2.12 – 5.32	1.59
5.55 (Washed)	3.17 – 7.92	2.38

4 CONCLUSION

Based on the results of the laboratory experiments and analysis performed, the following conclusions are hereby made:

1. The specific gravity test conducted on the Bida natural stones (BNS) suggest it is adequate to be used for construction works.
2. Result of the concrete compressive strength test conducted on concrete produced utilising both unwashed and washed aggregates show that washed aggregate returned higher average compressive strength value. Using washed BNS results in an increase in average compressive strength of about 11.46 % when compared to the unwashed aggregate.

It has been justified in this research that washing coarse aggregates has the potential of increasing concrete compressive strength: as such construction professionals and workers utilising this aggregate (BNS) in the Bida basin are encouraged to practice aggregate washing (freeing it from impurities) before concrete works.

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