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THE EVALUATION OF ENGINEERING PROPERTIES OF SOME SELECTED AGGREGATES IN SOUTH WESTERN NIGERIA FOR CONCRETE PRODUCTION

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Abstract
The study was carried out to assess the suitability of sand available in South Western Nigeria for concrete production. Collected samples of sand were tested in the laboratory to determine their physical properties. The properties considered are gradation, specific gravity, water absorption, moisture content, bulking, and percentage silt content. The result of the sieve analysis indicates that while the gradation of some of the samples is within the specified values specified in standards, others do not conform. The values of the coefficient of uniformity and coefficient of curvature is between the range of 3.6 – 10 and 0.53 – 2.56 respectively. The values of the results of specific gravity, water absorption, the moisture content are within the range of 2.67 – 2.86, 0.67% – 2.04%, 0.75% – 3.17% respectively. Based on the fact that the result of the test on the properties of the samples tested are in accordance with the specifications in relevant codes as discussed in the body of this work, it can be concluded that most of the samples are suitable for concrete production while the gradation of some of the samples needed to be modified to conform to the required grading.

Keywords: Evaluation, Engineering, Properties, Aggregates, Concrete, Production.

1.0 INTRODUCTION

According to [1], aggregates can be classified into coarse and fine. However, further classification can be based on pathological, size, shape, texture, and weight depending on the interest or requirements of the user [2]. [3], defines fine aggregates as an inert natural or manufactured sand having particles sizes up to 5mm and conforming to [4]. While in [5], fine aggregate is defined as aggregate that completely passes the 9.5mm (3/8in.) sieve, almost entirely passing the 4.75mm (No. 4) sieve and predominantly retained on the 75µm (No. 200) sieve. Fine aggregate is one of the essential constituent materials of concrete. According to the specification of [6], it can consist of natural sand, manufactured sand, or a combination thereof. It constitutes about of the constituent materials of concrete. There are different types of fine aggregates depending on the source. Natural fine aggregates refer to sand obtained from different sources. The various sources include pit, river, and sea. [7] stated that the most commonly used fine aggregate is natural river sand. However, pit sand is the most common source of sand in South-Western Nigeria.

Properties of sand affect the durability and performance of mortar because it is an essential component of cement mortar. According to [8], the workability and cost of concrete are greatly influenced by the quality of fine aggregate. In the opinion of [7], durability and performance of concrete is dependent on the properties of aggregate of which sand is a component. [9] stated that improper use of materials, poor workmanship, or use of faulty materials can result in failure or collapse of structures. While [10] posited that the collapse of structures can be due to a lack of standard use of materials. [11] as well as [12] stated that poor materials will result in the production of poor-quality concrete. The use of unsuitable, unsound, reactive, or aggregate is some other factor that contributes to concrete failure in buildings [13].

[8] posited that fine aggregates (sand) are generally

sourced locally from various locations where they are available in form of natural deposits or along river shores. Proper sourcing of materials is an essential process for the production of quality and durable concrete [8] advocated the necessity of provision of information to the local concrete industry and practitioners with regards to proper use of aggregates from different sources as a panacea of selection of substandard aggregates for concrete production.

2.0 MATERIALS AND METHODS

Samples of sand were collected from three different locations in each of the six states of South Western Nigeria for laboratory tests. The samples were collected and put into sacks which were subsequently transported from the various sources to the laboratory where tests on the physical properties of each sample were carried out. The tests that were carried out include sieve analysis, specific gravity, water absorption, moisture content, bulking, and percentage silt content. All the tests were carried out in accordance with relevant codes.

2.1 Sieve Analysis

The gradation of the samples was determined by carrying out sieve analysis in accordance with [14]. From the result of the sieve analysis carried out the fineness modulus was obtained by dividing the cumulative percentage passing by 100, while the coefficient of curvature, and coefficient of uniformity were determined using equations (1) and (2) respectively.

$$Cu = \frac{D60}{D30} \quad (1)$$

$$Cc = \frac{(D30)^2}{(D60)(D10)} \quad (2)$$

2.2 Specific Gravity

Test on the specific gravities of the samples were carried out in accordance with [15] and the values were determined using equation (3).

$$G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \quad (3)$$

Where; M1 is the weight of pycnometer, M2 is the weight of pycnometer and oven dried sample of sand, M3 is the weight of pycnometer, sand and water and M4 is the weight of pycnometer and water.

2.3 Water Absorption

Water Absorption Test was done in accordance with [15]. The formulae applied is:

$$A(\%) = \frac{W_{sat} - W_{dry}}{W_{sat} - W_{wet}} * 100 \quad (4)$$

Where; A is Water absoption (%), Wsat is weight of the saturated sample, Wdry is weight of the dry sample and Wwet is weight of the saturated sample immersed in water.

2.4 Moisture Content

Moisture Content test was carried out according [16] and the value was determined from the equation

$$M = \frac{M_1}{M_2} * 100 \quad (5)$$

Where; M is the moistture content (%), M1 is the weight of water from the samples the weight of water from the sample and M2 is the weight of oven dried sample.

2.5 Percentage Silt Content

Percentage silt content test was carried out in accordance with [4] and the values obtained from the equation;

$$V = \frac{V_1}{V_2} * 100 \quad (6)$$

Where; V is the percentage Silt content, V1 is the volume of the silt layer and V2 is the sand level below the silt.

2.6 Bulking

The bulking property of the sand samples were determine in accordance with the procedures stipulated in [17] The percentage bulking was calculated using the formulae:

$$B = \frac{b(100 - M)}{c} - 100 \quad (7)$$

Where b is the uncompacted bulk density of oven-dry fine aggregate determined according to 6.3.4; C is the uncompacted bulk density, as determined in accordance with 6.3.4, of fine aggregate at test moisture content; M is the test moisture content on oven-dry basis in accordance with [16].

3.0 RESULTS AND DISCUSSION

3.1 Result of Tests of Physical Properties of Sand

3.1.1 Sieve analysis of sand

The sieve analysis curve for all the sand samples is presented in figures 1 – 5. It was stated in [4] that the grading of sand shall comply with the overall limits given in Table 4 of [4] (see Table 1) with the additional proviso that not more than one in ten consecutive samples shall have a grading outside the limits for any one of the grading C, M or F, given in Table 4 of [4].

It is difficult to classify some of the samples into any of the zones or classes as stated in both [4] and [18] because they conform to the limit in some of the sieve sizes but failed in some.

Additionally, some of the samples comply with the requirement in more than one grading class or zone, while some of the samples satisfy the overall limit but did not fall within any of the additional limit C, M or F of [4], or zones I – IV of [18] (see Table 2). The recommendation of [4] for instances where sands do not comply with Table 4 of [4] an agreed grading envelope may be used if the supplier can guarantee that such materials can produce of the required quality.

Table 1: Grading Limits for Fine Aggregates

Sieve Size	Percentage by mass passing BS sieves			
	Overall Limits	Additional Limits for grading		
		C	M	F
10.00 mm	100	-	-	-
5.00 mm	89 to 100	-	-	-
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 µm	15 to 100	15 to 54	25 to 80	55 to 100
300 µm	5 to 70	5 to 40	5 to 48	5 to 70
150 µm	0 to 15	-	-	-

Source: Table 4 BS 882:1992

Note: Individual sands may comply with the requirements of more than one grading. Alternatively, some sands may satisfy the overall limits but may not fall within any one of the additional limits C, M or F. In this case and where sands do not comply with Table 4 an agreed grading envelope may also be used provided that the supplier can satisfy the purchaser that such materials can produce concrete of the required quality. an Increased to 20 % for crushed rock fines, except when they are used for heavy duty floors.

The sieve analysis curve for all the sand samples from Ekiti State are presented in Figures 1. The percentages passing the 5mm sieve size in all the three locations are lower than the overall grading limits specified in [4]. Also, the percentage passing the 2.36mm sieve size in locations 2 and 3 are lower than the grading limits specified in [4]. However, the percentage passing the lower sieve sizes of 1.18mm, 600µm, 300µm and 150µm for samples from all the locations are within overall grading limits specified in [4]. Consequently, the sand from all the locations can neither be classified into zones as specified in [18] nor the classes specified in [4].

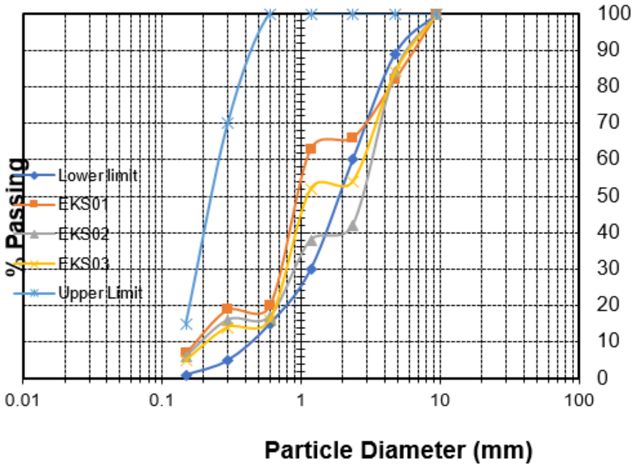

Figure 1: Sieve Analysis Curve of Sand Obtained from Ekiti State

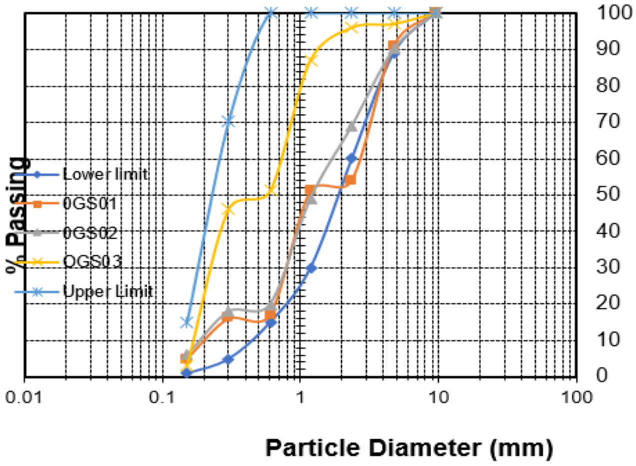

Figure 2: Sieve Analysis Curve of Sand Obtained from Ogun State

From the sieve analysis curve for all the sand samples from Ogun State presented in Figure 2, samples from all the locations fall within the percentages passing all the sieve sizes except that of location 1 which has a slightly lower value for the 2.36 sieve size as specified in [4].

In Figure 3 the sieve analysis curve and the percentage passing the various sieve sizes for samples from Ondo State indicates that only the samples from location 3 falls entirely within the range of the overall grading limits stated in [4]. It can be classified as class C according to [4] and Zone I according to [18].

While samples from locations 1 and 2 are in conformity with the overall grading limits in the smaller sieve sizes of 1.18mm to 0.15mm, the percentage passing the bigger sieve sizes are lower than the values stated in [4]. Consequently, samples from these locations cannot be classified in accordance with stipulations in either [4] or [18].

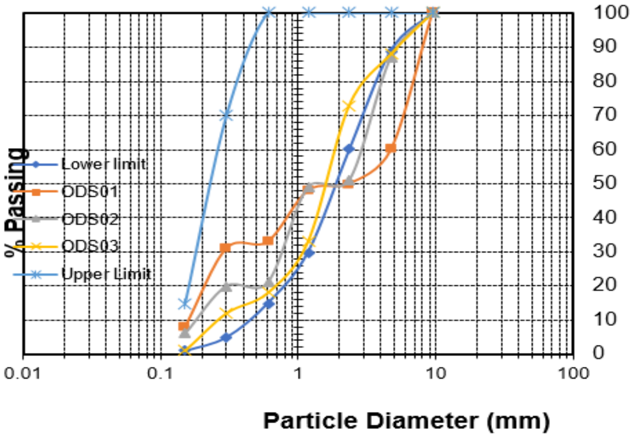

Figure 3: Sieve Analysis Curve of Sand Obtained from Ondo State

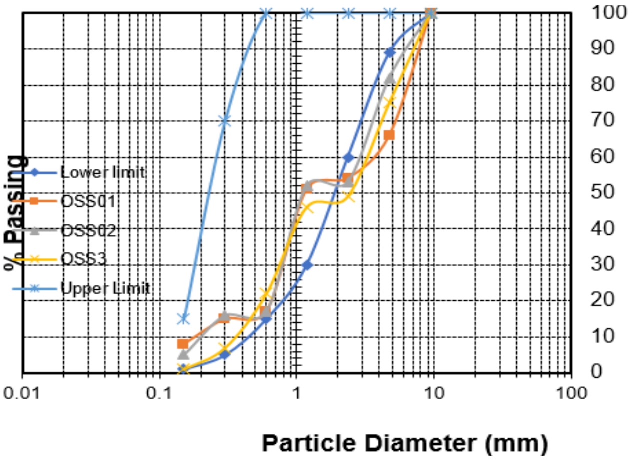

Figure 4: Sieve Analysis Curve of Sand Obtained from Osun State

Observations from the sieve analysis curve and percentage passing the various sieve sizes for samples from Osun State as presented in Figure 4 reveals that samples from all the locations have lower values of percentage passing the 5mm and 2.36mm sieve sizes than the overall grading limits. It however falls within the limits in smaller sieve sizes of 1.18 to 0.15mm. Due to variations in gradations for the various sieve sizes, class and zone classifications are difficult. Figure 5 presents the sieve analysis curve of samples from Oyo State. From Figure 5, it can be deduced that all the samples from the three locations fall within the overall grading limits. Sample from location 1 can be classified as class M or zone II according to [4] and [18] respectively, sample from location 2 is in class F and that of location 3 is class M zone 2.

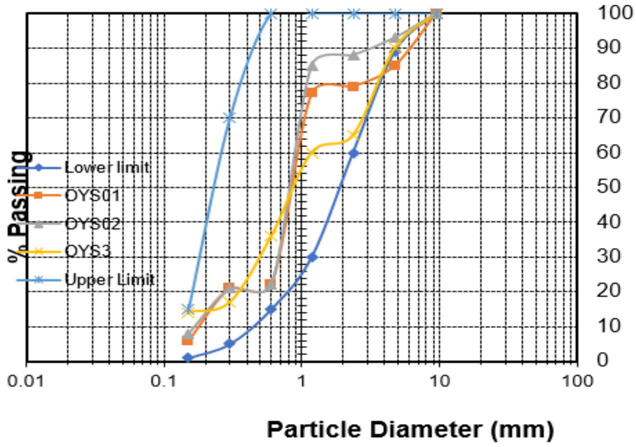

Figure 5: Sieve Analysis Curve of Sand Obtained from Oyo State

3.1.2 Fineness modulus of sand

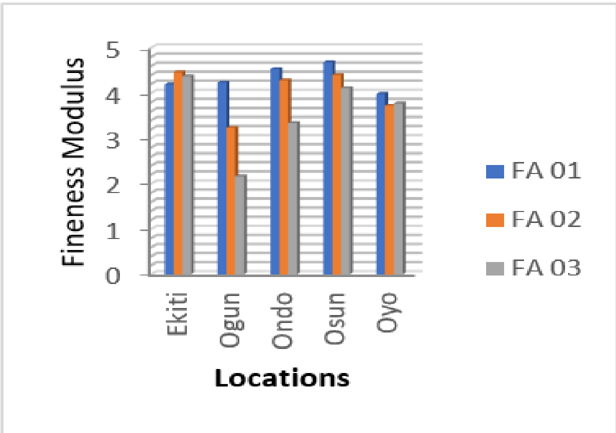

Figure 6: Bar chart of the Fineness Modulus of sand

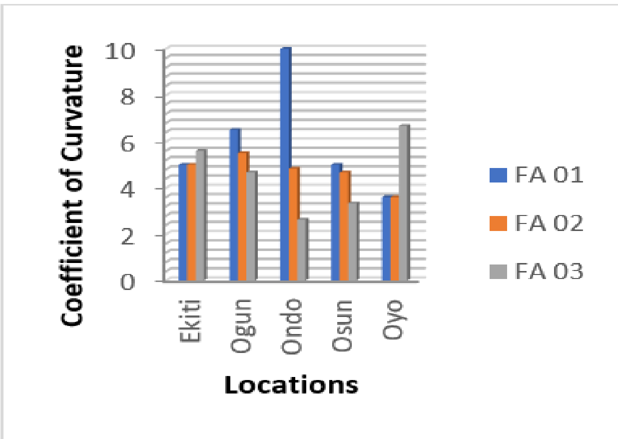

Figure 7: Bar chart of the Coefficient of Curvature of Sand

The values of the fineness modulus for most of the samples are higher than the maximum value recommended in literature. Only the samples from locations two and three in Ogun State, location three in Ondo State and all the locations in Oyo state falls within the recommended value of 2 – 4. Samples from all other locations are higher than the recommended values as can be seen in Figure 6. According to [19], this method is not widely used today but the concept of being able to describe particle-size distributions by an index number remains useful for many purposes.

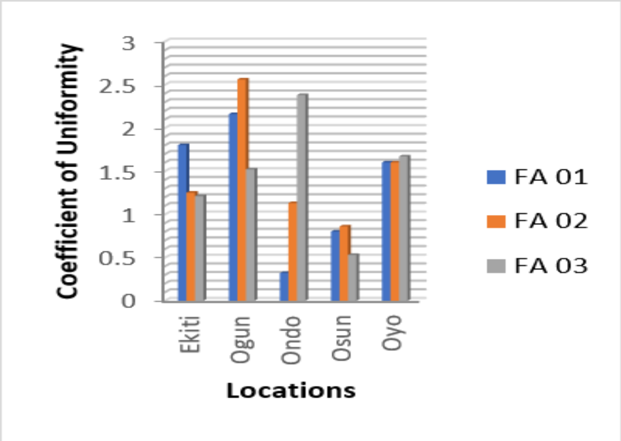

Figure 8: Bar chart of the Coefficient of Uniformity of Sand

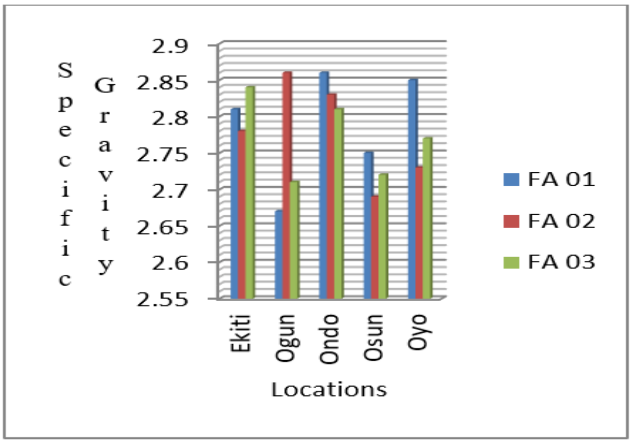

Figure 9: Bar chart of the Specific Gravity of Sand

According to the unified classification system sand can be classified as well graded if the coefficient of uniformity Cu is greater than 6 and the coefficient of curvature is between 1 and 3 i.e., Cu ≥ 6 and 1 < Cc < 3. The range of values of D10 are 0.18 – 0.2, 0.17 – 0.2, 0.08 – 0.28, 0.2 – 0.4 and 0.08 – 0.19 for Ekiti, Ogun, Ondo, Osun and Oyo States respectively. That of D30 are 0.75 – 0.9, 0.22 – 0.8, 0.3 – 1.18, 0.8, 0.19 – 0.5; while D60 has the range of 1.1 – 1.32, 0.75 – 1.19, 1.09 – 1.36, 1.2 – 1.3 and 0.9 – 1.03 for Ekiti, Ogun, Ondo, Osun and Oyo States respectively. The result of the Cu and Cc presented in Figures 7 and 8, only the sample from location 3 in Oyo State meet up with both criteria, that implies that that is the only sample that can be described as well graded. While most of the samples from all other locations have satisfactory values for Cc, they fail to meet up with the criteria for Cu and as such cannot be classified as well graded.

3.1.3 Specific gravity of sand

[20] gave the range of the Specific gravity of aggregates to be between 2.6 and 2.7 while [21] gave the range as 2.6 – 2.8. However, [22] stated that the specific gravity of aggregates ranges from 2.5 to 3.0 while [23] gave a range of 2.4 to 2.9 but [15] specified the minimum value of apparent specific gravity for both fine and coarse aggregate as 2.6. The range of values of the specific gravity of all the samples of sand tested in the study is between 2.67 and 2.86 which are higher than the specified value in the British standard and within the ranges given by [21], [20], [22] and [23], hence also very suitable for use in the concreting work.

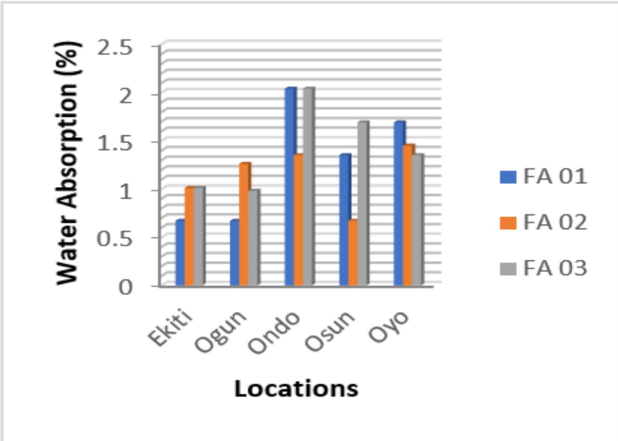

Figure 10: Bar chart of the Water Absorption of Sand

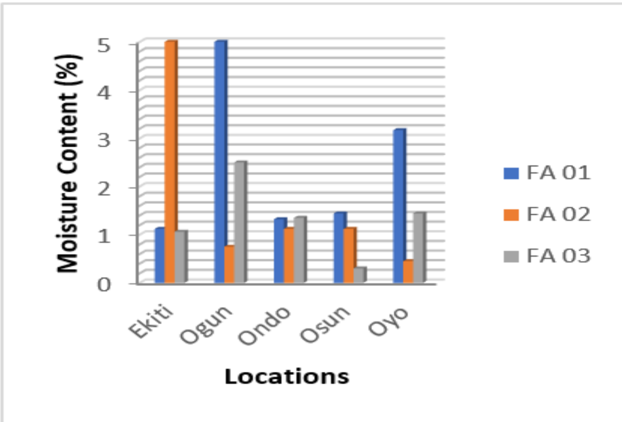

Figure 11: Bar chart of the Moisture Content of Sand

3.1.4 Water absorption of sand

The Specification for water absorption of aggregates according to [24] is 3%. The water absorption values of all the samples as presented in Figure 10 are all lesser than the specified 3%. This is an indication that all the samples have acceptable water absorption values for concrete production. This further implies that concrete works produced with sands from the various locations are not likely to be susceptible to absorb water, hence deterioration of structures due to water absorption will be minimal and consequently, the structure will be durable.

3.1.5 Moisture content of sand

The result of the moisture content of sand samples from all locations is presented Figure 11. The result shows that values obtained in Ondo and Osun States alongside those from locations one and three in Ekiti State, locations two and three in Ogun State and locations two and three in Oyo State are in accordance with the specified values of moisture content of less than 3% stated in relevant standards and literature [24]. The sample from location one in Oyo State with the value of 3.17% is very close to the specified value but those from location two in Ekiti State and location one in Ogun State with 5% are at very wide variation from the specified value.

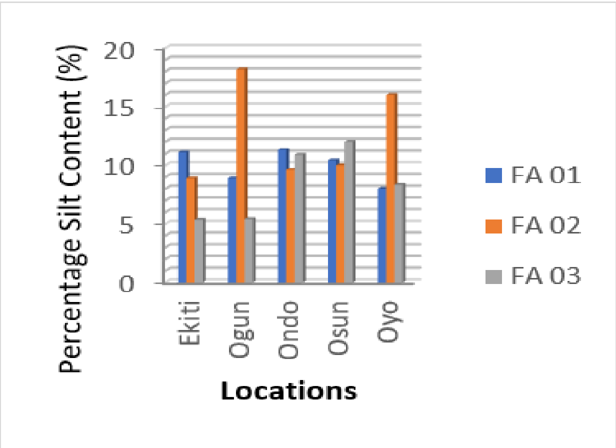

Figure 12: Bar chart of Percentage Silt Content of Sand

3.1.6 Percentage silt content of sand

From the results of the percentage silt content obtained and presented in Figures 12, only samples of the sand obtained from location three in Ekiti and Ogun State as well as that of location one in Oyo State conforms to the specification of 8% stated in stated in [4] respectively. Samples from location two in Ekiti, location one in Ogun State and location three in Oyo State are close to the specified limit but all others are outside the specified limit. The effect of high percentage silt content of sand on concrete includes reduction in the bonding between cement and aggregate, increase in water/cement ratio and an attendant reduction in concrete strength and durability.

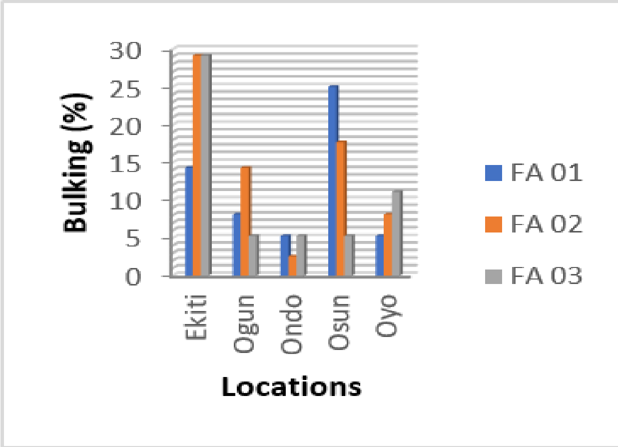

Figure 13: Bar chart of Bulking of Sand

3.1.7 Bulking of sand

There is no specified limit for bulking of sand in literature but [25] stated that sand may have a bulking value of as high as 30 percent of the original dry volume of sand in fine sands and 15 percent in the case of coarse sands. From the result of the bulking test for samples of sand as presented in Figure 13, it is clear that samples from locations 2 and 3 in Ekiti State and location 2 in Osun State have high values of 29.13%, 29.13%, and 17.25% respectively, and can be classified as fine sand. However, samples from all other locations have values less than 15% and as such can be classified as coarse sand. Bulking properties of sand are not needed in concrete mix design but it is required when volume batching is to be used in proportioning the constituent materials of concrete to make up for the reduction in the volume of sand as a result of bulking.

4.0 CONCLUSION

From the results of the laboratory tests conducted on samples of sand collected, it can be concluded that:

The gradation of some of the samples conform to specified standard curves and falls within the range of either class C, M, or F, some did not conform and could not be classified into any of the three classes. The values of coefficient of uniformity and coefficient of curvature indicate poorly graded aggregate, with a few that is well graded. The specific gravity, water absorption, and moisture content of all the samples are within the range specified in the relevant codes and standards. Most of the samples have a percentage silt content that is greater than the permissible specification in the codes.

REFERENCES

[1] Neville A. M. and Brooks J. J. "Concrete Technology", *2nd edition. Prentice-Hall,* 2010

[2] Akor, S. E, Usman, N. D., Bulus, M. S. and Gambo, M. J. "The impact of the texture of aggregates on the strength of concrete, Journal of Management and Technology", *Federal Polytechnic, Idah*, Nigeria, Vol. 8, 2008.

[3] Abdullahi, M. "Effects of aggregate type on compressive strength of concrete International", *Journal of Civil and Structural Engineering*. 2 (3) 791–800, 2013.

[4] BS EN 882: 2004: "Specification for aggregates from natural sources for concrete", *British Standards Institution*, London.

[5] ASTM (American Society for Testing and Materials). "Standard Terminology Relating to Concrete and Concrete Aggregates", C125. *West Conshohocken*, PA, USA, 2003.

[6] ASTM C33-03 (American Society for Testing and Materials). "Standard Specification for Concrete Aggregates", 2010.

[7] Narayana, S., and Manjunatha, M. "Effectof different types of fine aggregates on mechanical properties of concrete - A review", *The Indian Concrete Journal*, 2016, pp 69 – 72

[8] Ajagbe, W. O., Tijani, M. A., Arohunfegbe, I. S., Akinleye, M. T., "Assessment of Fine Aggregates from Different Sources in Ibadan and Environs for Concrete Production", *Nigerian Journal of Technological Development*, Vol. 15, No. 1, March 2018 *PP8 – 13*

[9] Usman, N. D., Kolawole, R. A., Akoh, S. E., and Kwari, J. M. "The Performance of Various Sources of Fine Aggregates Used in Construction Within Bauchi Metropolis", *Nigeria Sabs Conference* 10th – 12th October 2013.

[10] Oloyede, S. A., Omoogun, C. B. and Akinjare, O. A. "Tackling Causes of Frequent Building Collapse in Nigeria", *Journal of Sustainable Development* Vol. 3, No. , 2010, pp. 127-132

[11] Bosede, A. F. and Sunday, G. M. "An Investigation on the Causes of Building Collapse in Nigeria", *Journal of Environmental Sciences and Resources Management*, 6 (1), 2014, pp12 – 22.

[12] Fakere, A. A, Fadairo, G., and Fakere, R. A. "Assessment of Building Collapse in Nigeria: A Case of Naval Building", Abuja, Nigeria. *International Journal of Engineering and Technology* 2(4), 2012, pp581 – 591.

[13] Gollu, V. K., Allam, D., and Erla, S. "Causes of Concrete Failure", *International Journal of Advanced Technology in Engineering and Science*, 4 (4); 2016, pp198 – 206

[14] BS EN 933 – 1:1997, Test for Geometrical Properties of Aggregates "Determination of Particle Size Distribution – Sieving Method", *British Standards Institution* London.

[15] BS EN 1097 – 6: 2020, Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate.

[16] BS 812-109: 1990: "Methods for determination of moisture content", *British Standards Institution* London.

[17] BS 812 – 2 Testing aggregates, Part 2. Methods of determination of density

[18] IS 383:2016, Coarse and Fine Aggregate for Concrete -Specification, Third Revision, Bureau of Indian Standards

[19] CRD-C104-80: Method of Calculation of the Fineness Modulus of Aggregate.

[20] Neville A. M., 2011, "Properties of Concrete", 5th edition. *Pearson Education Limited*, 2011

[21] Shetty M. S. "Concrete Technology Theory and Practice", *S. Chand & Company Ltd*. Ram Nagar, New Delhi - 110 055, 2005

[22] Arumugam. "Effect of Specific Gravity on Aggregate Varies the Weight of Concrete Cube" SSRG *International Journal of Civil Engineering (SSRG-IJCE)* – Volume 1 Issue3 August 2014, pp 1 – 8.

[23] Nemati, K. M., "Concrete Technology", Aggregates for Concrete 2015, pp 1-16,

[24] BS 8007:1987, Code of practice for the design of concrete structures for retaining aqueous liquids

[25] Koirala, M. P., and Joshi, Er, B. R. "Construction sand, Quality and supply management in infrastructure project", *International Journal of Advances in Engineering & Scientific Research*, Volume 4, (Issue 4), 2017; pp 01–15.