Chapter 10
Print ISBN: 978-93-90149-02-5, eBook ISBN: 978-93-90149-08-7

An Appraisal of the Variation in the Physico–mechanical Properties of Granitic Aggregates: Focus on Some Quarry Sites in Ogun State, Nigeria

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DOI: 10.9734/bpi/etert/v5

ABSTRACT

Coarse aggregate is an essential constituent of concrete constituting about 60% to 80% of concrete depending on the mix ratio. Granite is reported to be the most widely distributed plutonic rock in the earth crust. It is predominantly available in various parts of Ogun State of Nigeria. Its different properties have been known to strongly influence the fresh and hardened state properties of concrete. In this study, samples of four different sizes of granites (9.5 mm, 12.5 mm, 19 mm and 25 mm) were obtained from four different quarry sites across the state. Sieve analysis was carried out on samples from all the locations while the physical properties such as specific gravity, moisture content and water absorption and the Mechanical properties such as aggregate impact value and aggregate crushing value of the samples were evaluated. The result of the sieve analysis reveals that there are variations in the gradations of samples from the various locations. The results of the specific gravity, moisture content and water absorption vary from 2.61 to 2.86, 0.69 to 1.22%, 0.16 to 2.13% respectively. While the aggregate impact value and aggregate crushing value vary from 18.30 to 28.12% and 6.21 to 9.45% respectively. It was therefore concluded that there are variations in the physical and mechanical properties of granites produced in Ogun State of Nigeria. The observed variations occur in relation to the various sizes and for the different quarry sites.

Keywords: Variation; physical properties; mechanical properties; granite.

ABBREVIATIONS

UCS : Unconfined Compressive Strength
SPSS : Statistical Package for Social Sciences
GPS : Global Positioning System
AIV : Aggregates Impact Values
ACV : Aggregates Crushing Values
SSD : Saturated Surface Dry

1. INTRODUCTION

The use of Granite in the building construction industry is fast replacing the use of washed and unwashed gravel in Nigeria. In the opinion of [1], a wide range of granitic rock is present in masonry constructions, depending on their petrographic features, such as grain size and internal texture. This according to [2] necessitates the characterization of granites so as to be able to provide important input data for the design of the structures founded on or in the rock. Granite is the most widely distributed plutonic rock in the earth crust. In the opinion of [3], variation in the nature of coarse aggregates affects the compressive strength of concrete. They recommended that the integrity of aggregates should be investigated to ascertain their performance in structural membersGranitic rocks

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are defined as the intrusive igneous rocks that are widely used in the construction industries as dimension stone, aggregates etc. due to their high strength, abrasion resistance and durability [4,5].

Observation by [4] indicated that there is a considerable variation in the physical properties like specific gravity, water absorption, dry and saturated densities and Unconfined Compressive Strengths (UCS) of the rock samples of different locations. According to [6] the observed variations in the measured physical properties of rocks are due to the anisotropic nature of the rocks. These variations can occur in rocks within the same locality, but few distances apart. Thus, similar or the same rock type within the same locality may not be suitable for the same geologic and engineering purpose. In the opinion of [7], slight variation in this parameter can lead to significant variation in UCS which can cause serious disruption of engineering designs.

It was also stated by [7] that the physical and engineering properties of such rocks are known to be affected by many factors. These variations in the physical and strength properties of rock according to [7] depend upon many factors which include geological, lithological, physical, mechanical and environmental factors. Research findings by [2] indicated that the physical properties like specific gravity, water absorption and densities of rock samples collected from different locations vary considerably. Rocks exhibit a vast range of physical and mechanical properties which reflect vast varieties of structures fabric and compound, some basic properties measurements which are essential for describing rocks [8]. It therefore pre - supposes that the physical and mechanical properties of granites will also exhibit a wide range of variation from location to location.

The study is therefore aimed at verifying this supposition. To this end laboratory tests were carried out to determine the physical and mechanical properties of various sizes of aggregates produced in different parts of Ogun State in Nigeria. Subsequently, the coefficient of variation was determined by analysis using SPSS statistical software.

2. MATERIALS AND METHODS

2.1 Procurement of Materials

Procurement of granites were made from four different quarry sites located at Omoologede along Abeokuta – Igboora road and Papa Adeosun along Abeokuta – Ibadan road in Abeokuta North Local Government Area and Odeda Local Government Area respectively. The other two locations are at Ishara in Remo North Local Government Area and Ago – Iwoye in Ijebu North Local Government Area. All the quarry sites are in Ogun State of Nigeria.

Table 1. GPS locations of quarry sites from where samples of granites for the study were collected

Location name	GPS location
Ago Iwoye	6.93°N; 3.93°E
Ishara	6.98°N, 3.68°E
Papa Adeosun	7.21°N, 3.15°E
Omoologede	7.25°N, 3.05°E

2.2 Laboratory Tests on Materials

Laboratory tests carried out on the Physical properties include sieve analysis, specific gravity, water absorption and moisture content. While the tests carried out on the Mechanical properties are Aggregate Impact Value (AIV) and Aggregate Crushing Value (ACV).

2.3 Sieve Analysis of Fine Aggregate

Sieve Analysis of Fine Aggregate was carried out in accordance with the specifications in [9].

2.4 Test on Specific Gravity and Water Absorption of Aggregate

The specific gravity and absorption tests were conducted in accordance with [10], while the results were obtained using equations 1 and 2 respectively.

$$SG\ is = \frac{A}{B-C}. \tag{1}$$

$$AB = \frac{B-A}{A} \times 100\% \tag{2}$$

Where SG is the bulk specific gravity, AB is percentage of absorption (%), A is weight of oven-dry sample in air (g), B is weight of SSD sample in air (g) and C is the weight of SSD sample in water.

2.5 Tests on Moisture Content of Aggregate

The moisture content test was carried out in accordance with [11] and the results were evaluated using equation 3

$$MC = \frac{(M2-M3)}{(M2-M1)} \text{ x } 100 \tag{3}$$

Where MC is Moisture Content (% dry mass), M1 = weight of empty container, M2 = weight of container + sample and M3 = weight of container + oven dry sample, M_1 is M2 is and M3. The result is reported to the nearest 0.1% of the dry weight.

2.6 Tests on Aggregate Impact Value and Aggregate Crushing Value Specific Gravity of Aggregate

The Aggregate Crushing Value (ACV) and Aggregate Impact Value (AIV) were the mechanical properties determined by laboratory experiment in accordance with the specifications in [12,13] respectively. The results of AIV and ACV were evaluated using equation 4.

$$P = \frac{B \times 100}{A} \tag{4}$$

Where P is Percentage fines A is the mass of surface-dry sample (g) and B is the mass of the fraction passing the 2.36 mm sieve (g).

2.7 Analysis of Test Results

Test results were analysed using SPSS software. The software was used to determine the standard deviation, mean, and variance of test results. The coefficient of variation was determined by dividing the value of the standard deviation by the mean value.

$$Cv = \sigma/x \tag{5}$$

Where Cv is the coefficient of variation, σ is the standard deviation of test results and x is the mean value of test results.

3. RESULTS AND DISCUSSION

3.1 Variation in Gradation

Tables 1 – 4 presents the result of the sieve analysis of granite samples from all the locations. There are variations in the gradation of samples from the various locations as can be seen in Table 1. The percentage passing each of the sieve sizes vary from one sample to the other.

Table 2. Particle size distribution for 9.5 mm coarse aggregates in all locations

Sieve size(mm)	Cumulative % passing					
	Lower Limit	Ago Iwoye	Ishara	Papa Adeosun	Omologede	Upper limit
12.5	100	99.91	100	100	100	100
9.5	85	98.76	99.66	99.67	99.35	100
4.75	0	10.39	14.58	4.42	5.35	25
2.36	0	3.15	0.14	0.10	0.36	5
Pan	0	0	0	0	0	0

Table 3. Particle size distribution for 12.5 mm coarse aggregates in all locations

Sieve size(mm)	Cumulative % passing					
	Lower Limit	Ago Iwoye	Ishara	Papa Adeosun	Omologede	Upper limit
19.0	100	100	100	100	100	100
12.5	85	80.9	74.54	99.07	99.04	100
9.5	0	53.81	7.54	85.52	30.17	50
4.76	0	0	0	14.13	5.47	10
2.36	0	0	0	0.09	0.15	0
Pan	0	0	0	0	0	0

Table 4. Particle size distribution for 19 mm coarse aggregates in all locations

Sieve size(mm)	Cumulative % passing					
	Lower Limit	Ago Iwoye	Ishara	Papa Adeosun	Omologede	Upper limit
25	100	100	97.73	100	100	100
19.0	85	68.92	71.62	97.73	58.32	100
12.5	0	3.97	0.96	51.34	8.17	70
9.5	0	0	0	2.33	0.42	25
4.76	0	0	0	0	0	5
2.36	0	0	0	0	0	0
Pan	0	0	0	0	0	0

Table 5. Particle size distribution for 25 mm coarse aggregates in all locations

Sieve size(mm)	Cumulative % passing		
	Ishara	Papa Adeosun	Omoologede
37.5	100	100	100
31.5	100	73.41	95.92
25	73.47	0	72.23
19.0	4.87	0	6.31
12.5	0	0	0
9.5	0	0	0
Pan	0	0	0

3.2 Variation in Values of Specific Gravity

Results of standard deviation, mean, coefficient of variation and variance is presented in Table 6. From Table 6, it was observed that 25 mm granites had the highest value of coefficient of variation of 11.87 while 12.5 mm had the least value of 0.88. 19 mm granite size had the highest value of variance of 0.013, while both the 12,5 mm and 25 mm granites had the least values of 0.001. It therefore implies that 12.5 mm granites with the least coefficient of variation had smaller residuals relative to the predicted value and 25 mm with higher coefficient of variation had the greater dispersion in the variable. However, all the various sizes had low values of coefficient of variation thus suggestive of a good model fit. The analysis of variation of granite samples on the basis of the source that is location of quarry sites as presented in Table 7, indicates that samples from all the sites had low coefficient of variation. The sample from Ago Iwoye had the highest value of 3.73 and that of Omoologede had the least value of 1.05. Granite sample from Ago Iwoye also had the highest value of variance of (0.011) while sample from both Omoologede and Papa Adeosun had the least value of 0.001.

Table 6. Statistical analysis for specific gravity of aggregates for all the granite sizes

Aggregate size	Σ	X	C_v	Variance
9.5 mm	0.0709	2.728	2.6	0.005
12.5 mm	0.0238	2.695	0.88	0.001
19 mm	0.1139	2.715	4.19	0.013
25 mm	0.3055	2.707	11.87	0.001

Table 7. Statistical analysis for specific gravity of aggregates for all the quarry sites

Aggregate size	σ	X	Cv	Variance
Omoologede	0.0289	2.745	1.05	0.001
Papa – Adeosun	0.037	2.665	1.39	0.001
Ishara	0.0695	2.67	2.57	0.005
Ago – Iwoye	0.1026	2.747	3.73	0.011

In all, the values of the specific gravity for all the granite sizes and sites fall within the range if values of 2.4 to 2.9 stipulated in literatures and relevant codes [14,15,16,17].

3.3 Variation in Values of Water Absorption

Results of standard deviation, mean, coefficient of variation and variance of the water absorption for the various sizes and for the different quarry sites are presented in Tables 8 and 9. The observations on the results are discussed below.

Table 8. Statistical analysis for water absorption of aggregates for all the granite sizes

Aggregate size	σ	X	Cv	Variance
9.5 mm	0.0591	1.163	5.08	0.003
12.5 mm	0.0887	1.11	7.9	0.008
19 mm	0.1546	0.9025	17.13	0.024
25 mm	0.0896	0.7467	11.64	0.008

For the water absorption for the various sizes of granites, Table 8 reveals that 19 mm granites had the highest value of coefficient of variation of 17.13 while 9.5 mm had the least value of 5.08. 19 mm granite size had the highest value of variance of 0.024, while 9,5 mm granites had the least values of 0.003. It therefore implies that 9.5 mm granites with the least coefficient of variation had smaller residuals relative to the predicted value thus suggestive of a better model fit than other sizes while 19 mm with higher coefficient of variation has the greater dispersion in the variable. Both 12.5 mm and 25 mm granites have a variance of 0.008 but different values of coefficient of variations of 7.9 and 11.64 respectively. However, the analysis of results of sample based on the different quarry sites as presented in Table 9 reveals that the coefficient of variations are higher than the values obtained for the specific gravity. This implies a higher dispersion in the variables. The coefficient of variations for Ishara is the highest and that of Papa – Adeosun is the least. The same trend was observed in the value of the variance.

Table 9. Statistical analysis for water absorption of aggregates for all the quarry sites

Aggregate size	Σ	X	Cv	Variance
Omoologede	0.2226	1.0325	21.56	0.50
Papa – Adeosun	0.1504	1.0725	14.03	0.023
Ishara	0.2439	0.9225	26.44	0.059
Ago – Iwoye	0.1656	1.0633	15.58	0.027

Although there are variations in the values of water absorption of aggregates from one site to the other, the results obtained is in line with specifications in [7], which states that aggregates should comply with either [18] or [20] and have an absorption, as measured in accordance with [21], generally not greater than 3%.

3.4 Variation in Values of Moisture Content

Tables 10 and 11 present results of standard deviation, mean, coefficient of variation and variance of the moisture content for the various sizes and for the different quarry sites. Indications from Table 10 reveals that the value of the coefficient of variation of 63.86 for 9.5 mm is the highest and very high compared to other sizes. This implies much greater dispersion in the variable than all other sizes and gives an indication of poor model fit. However the coefficient of variation of other sizes are relatively low and represents a good model fit. In the case of the variance, 9.5 mm granites also had the highest value of 0.141 while 19 mm had variance. Results obtained in the analysis for the various quarry sites as presented in Table 11 also had very high coefficient of variation for samples obtained from all the quarry sites. This implies that there is very high dispersion in the variables thus representing a poor model fit.

Table 10. Statistical analysis for moisture content of aggregates for all the granite sizes

Aggregate size	Σ	X	Cv	Variance
9.5 mm	0.3757	1.70	63.86	0.141
12.5 mm	0.1698	0.74	12.61	0.029
19 mm	0.1915	0.235	4.5	0.000
25 mm	0.0802	0.080	1.5	0.006

Table 11. Statistical analysis for moisture content of aggregates for all the quarry sites

Aggregate size	Σ	X	Cv	Variance
Omoologede	0.4919	0.690	70.77	0.042
Papa – Adeosun	0.7485	0.733	102.19	0.560
Ishara	0.9191	0.793	115.97	0.845
Ago – Iwoye	0.6970	0.853	81.68	0.486

3.5 Variation in Mechanical Properties

The analysis of the results obtained from the tests on the mechanical properties of granite samples obtained from the different quarry sites is presented in Table 12. The coefficient of variations for both the Aggregates Impact Value and Aggregates Crushing Values are moderately low. This is an indication of a moderate dispersion in the variables and a fairly good model fit. However the variance of the AIV is high possibly because of the higher values of the test results as well as the mean value while the values for ACV is low perhaps due to low values of the test results as well as the mean value.

Table 12. Statistical analysis of mechanical properties of aggregates for all the quarry sites

Mechanical properties	Σ	X	Cv	Variance
AIV	4.5372	24.37	18.61	20.586
ACV	1.4377	7.545	19.06	2.067

Variations in the mechanical properties from the various sites notwithstanding, the results obtained are in line with recommendations in reviewed literatures. In [19] the specification for the maximum AIV for concrete is 25% which is greater than the obtained values between 18.3 and 28.12%, while the ACV values of between 6.21 and 9.45% is less than recommended value of 30% [14].

4. CONCLUSION

It can be stated that the coefficient of variation for the Specific Gravity & Water Absorption are low for all sizes and from all the sites while the Moisture Content is low for 25 mm, 19 mm, 12.5 mm and very high for 9.5 mm and for all sites. There is low coefficient of variation for the Aggregates Impact Values. The Aggregates Crushing Values for all sizes and from all the sites also has the same low coefficient of variation. This is in line with the findings of previous researchers that there are variations in the physical properties of rocks. This is expected since granites are products of rocks. The observed variations which can be attributed to geological, lithological, physical and environmental factors are in accordance with the findings of [22] and [5].

ETHICAL ISSUES

This book chapter is an expanded form of a journal article published by me in Nigerian Journal of Technology (NIJOTECH), Faculty of Engineering, University of Nigeria, Nsukka. The Citation is: S. S. Omopariola and A. A. Jimoh, Variation in the Physico–Mechanical Properties of Granitic Aggregates in Ogun State, Nigeria, Nigerian Journal of Technology (Nijotech) Vol. 37, No. 4, October 2018, Pp. 880 – 884.

ACKNOWLEDGEMENT

I give all glory to God for His infinite mercy and the enabling grace to publish this book chapter. I am also grateful to the editor Nigerian Journal of Technology (NIJOTECH), Faculty of Engineering, University of Nigeria, Nsukka for granting me the permission to publish the journal article "Variation in the Physico–Mechanical Properties of Granitic Aggregates in Ogun State, Nigeria," in an expanded form as a book chapter. I am greatly indebted to my supervisor and co author for his immense contribution to the success of the research work. To my colleague Dr A.J. Olarewaju I say thank you. Finally I greatly appreciate my wife Olubunmi Omopariola and all my Children Faith, Favour Faithfulness, Fortune and Florence for all round support and prayers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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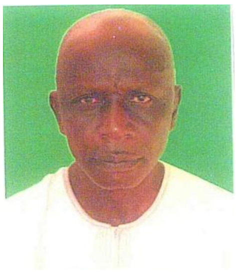

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