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COMPARISON OF SPLIT TENSILE STRENGTH OF CONCRETE USING BASALT AND GRANITE AS COARSE AGGREGATES

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Abstract

This work aims at comparing the splitting tensile strength of basalt concrete mix with granite concrete mix. A total of 24 cylindrical concrete specimens of diameter 100mm and length 200mm were made in the laboratory. The British standard mix design method was used to obtain four different mix designs for batching the ingredients comprising ordinary Portland cement, river sand, water, granite and basalt with two mix designs each corresponding to basalt and granite samples. The specimens were cured for 28 days and tested for splitting tensile strength. The results show equivalent values of splitting tensile strength for basalt and granite samples with values for granite samples slightly higher than those of basalt samples. The average splitting tensile strength of the basalt samples B1, B2, B3, B4, B5 and B6 are 11.10 N/mm^2, 10.37 N/mm^2, 11.37 N/mm^2, 10.13 N/mm^2, 11.60 N/mm^2, 10.25N/mm^2 respectively while that of the granite samples G1 and G2 are 11.52 N/mm^2 and 10.58N/mm^2 respectively. The corresponding mix ratios are 1:1.96:2.81 for B1, B3, and B5 samples, 1:2.25:2.75 for B2, B4, and B6 samples, 1:1.80:2.75 for G1 sample and 1:2.07:2.76 for G2 sample.

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1.0 INTRODUCTION

The aggregates for concrete can be fine or coarse. Fine aggregates include particles passing through 5.0mm British Standard test sieves and retained on 0.075mm sieve while the coarse aggregates include the particles that are retained on the 5.0mm British Standard test sieves [1]. The American society for testing and materials [2] defines fine aggregate as entirely passing 4.75mm (sieve no. 4) and retained in 0.075mm (sieve no. 200) while coarse aggregates are those retained in 4.75mm (sieve no. 4). [3] Stated that about 80 percent of the total volume of concrete is made of aggregates. Hence, the characteristics of aggregates such as shape, texture and grading have immense influence on the workability, bleeding, pumpability and segregation of fresh concrete. These characteristics also affect strength, stiffness, density, shrinkage, creep, permeability and durability of hardened concrete [4].

Basalt is a magnesium-rich igneous rock composed of minerals including Silicon, Iron and Calcium and Trace minerals. It is a natural occurring product, environmentally friendly with no evidence of elutriation and leaching into ground water. It is also non-toxic and safe to aquatic animals and plant-life in general [5]. Basalt has been adopted effectively as coarse aggregates in concrete production by various researchers [5 - 8]. [6] Stated that the compressive strength of granite ranges from 100mPa to 210mPa, porosity from 1.5% to 3.0% and absorption from 0.2% to 0.5% while the compressive strength of basalt ranges from 120mPa to 260mPa, porosity from 1.0% to 3.0% and absorption from 0.1% to 0.4%. Aggregates can be classified in terms of weight as light weight, normal weight or heavy weight aggregates. Example of light weight aggregates are slag, slate and other light stones. Examples of normal weight aggregates are sand, gravel and crushed stones while hematite, barite magnetite, steel and iron punching are example of heavy weight aggregates.

According to method of production, aggregates could be natural, such that it is taken from native deposits without any alteration in their nature except washing, grading or crushing; examples are sand, gravel and crushed stones. Aggregates could also be bye products such as blast furnace slag and fly ash while some aggregates could be processed such as burnt clays and processed fly ash.

1.1 Literature Review

[7] Observed that the percentage increase in compressive and splitting tensile strength are higher for low strength mix proportions compared to percentage increase in compressive and splitting tensile strength for high strength mix proportions. [8] Carried out an experimental study on the use of basalt coarse aggregates on concrete mixes in India. In the experiment the percentage replacement of limestone with basalt coarse aggregates were 0%, 25%, 50%, 75% and 100%. The main objective was to evaluate the feasibility of using basalt as coarse aggregate in concrete mixes to obtain economical and high strength concrete. The laboratory experiment considered the workability, compressive strength and aggregate properties. Two separate categories of samples were made using design mixes M40 and M50 for each set respectively. In each category, the samples are made by changing "the percentage of replacement of limestone coarse aggregate with basalt aggregate starting from 0 to 100% with varying increment of 25% by weight of coarse aggregate and they are represented as 0%, 25%, 50%, 75% and 100% respectively". In the other category, the initial procedure is maintained. More so, mineral admixture of 7.7% by weight of cement which is replaced. Cubes with size 150mm by 150mm by 150 mm were made. The samples are demoulded after 24 hours and immersed in a water container for 7 days and 28 days curing [8].

[8] Reported that the results were impressive with the compressive strength of concrete increasing with increase in the percentage of basalt. The workability of concrete also improved as there was increase in slump value as the percentage of basalt increases. [8] Concluded that the experimental results in compressive strength showed that the increment in basalt percentage improves the compressive strength over the conventional limestone mix. This is as a result of the fact that basalt is heavier and more durable with lower water absorption value compared to limestone. Also higher workability is achieved for increased basalt aggregate content mix which lowers the cost of labour. Since basalt is a natural aggregate also occurring in abundance at low cost, an economical and improved concrete is achieved by using basalt aggregate as coarse aggregate in concrete mixes.

2.0 MATERIALS AND METHODS

The materials used include river sand, cement, water, crushed basalt of size 20mm and crushed granite of size 20mm. The basalt samples were obtained from Ikom, Cross River State of Nigeria while the granite samples were obtained from Akamkpa, Cross River State of Nigeria. The mix design was done in accordance with the British standard procedure for concrete mix and the summary of mix design showing all the mix ratio is presented in Table 1. The river sand and basalt coarse aggregates were placed in standard sieves shakers and the results of sieve analysis performed on basalt is presented in Table 2 while that of river sand is presented in Table 3.

Table 1: Summary of mix design

S/N	Sample No.	Mix ratio	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)
1	B1, B3, and B5	1:1.96:2.81	410	802	1153	205
2	B2, B4, and B6	1:2.25:2.75	394.23	887	1084	205
3	G1	1:1.80:2.75	410	736	1127.5	205
4	G2	1:2.07:2.76	394.23	815	1088	205

Table 2: Percentage by mass of graded basalt coarse aggregate

S/N	Sieve size (Passing)	Sieve size (Retained)	% Mass	Value (g)
1	4.75mm (No. 4)	2.36mm (No. 8)	10	100
2	2.36mm (No. 8)	1.18mm (No. 16)	25	250
3	1.18mm (No. 16)	600µm (No. 30)	25	250
4	600µm (No. 30)	300µm (No. 50)	25	250

5	300µm (No. 50)	150µm (No. 100)	15	150
		Total	**100**	**1000**

Table 3: Sieve analysis of river sand

Sieve (mm)	Mass (g)	% retained	% passing of Sand	Minimum Limit by BS410	Maximum Limit by BS410
2.360	5	1.0	99.0	90	100
1.180	21	4.2	94.8	75	100
0.600	77	15.5	79.3	55	90
0.300	179	35.9	43.4	35	59
0.150	160	32.1	11.3	8	30
0.075	46	9.2	2.1	0	10
PAN	10	2.0			
Total	**498**				

To ensure that the sand particle sizes are in line with specifications, the graph of percentage passing against particle size known as particle size distribution curve for fine aggregate is presented in Figure 1. From Figure 1, it shows that the river sand used for the experiment as indicated by the red line located within the envelope meets the specification of the minimum and maximum sizes as required by BS 410. The figure which illustrates the grading curve also shows the particle size distribution which fits within the limits set out in BS 882 (1992).

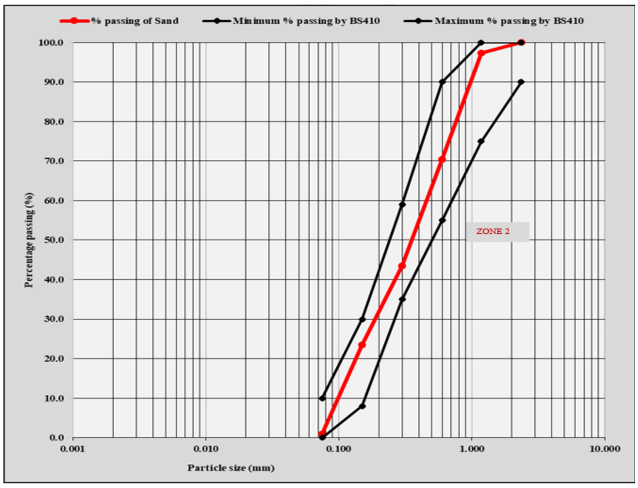

Figure 1: Particle size distribution curve for fine aggregate.

Several tests were carried out in the laboratory on the basalt coarse aggregate in accordance to British Standard specifications, to determine the engineering properties and confirm its applicability for use in the manufacture of concrete. The X-ray diffraction approach was utilized to obtain the mineralogical composition of the basalt samples. Other tests include: Aggregate Impact Test, Aggregate Crushing Test, Specific Gravity and Water Absorption, Soundness Test and Los Angeles Abrasion Test. The following expressions were used for the computations:

$$\text{Aggregate Impact Value (AIV)} = \frac{M_3}{M_2 - M_1} \times 100 \quad (1)$$

$$\text{Aggregate Crushing Value (ACV)} = \frac{M_3}{M_2 - M_1} \times 100 \quad (2)$$

$$\text{Specific gravity} = \frac{[M_2 - M_1]}{[M_4 - M_1] - [M_3 - M_2]} \quad (3)$$

$$\text{Apparent specific gravity} = \frac{[M_2 - M_1]}{[M_2 - M_1] - [M_3 - M_2]} \quad (4)$$

$$\text{Water absorption} = \frac{[M_4 - M_1] - [M_2 - M_1]}{[M_2 - M_1]} X100\ \% \quad (5)$$

Equation 5 can be simplified as:

$$Water\ Absorbed\ (g) = Wet\ Weight - Dry\ Weight$$

$$Water\ Absorption\ (\%) = \frac{Wet\ Weight - Dry\ Weight}{Dry\ Weight} X100$$

Where the experimental setup was labelled as follows: Mass of bottle only (M_1), Mass of bottle plus sample (M_2), Mass of bottle plus sample plus water (M_3), Mass of bottle filled with water (M_4)

The Splitting Tensile Strength test was carried out in a compression testing machine. The cylindrical specimens were cast using steel moulds of diameter 100mm and length 200mm. Concrete samples for same compressive strength test were taken for the experiment. Three cylinders each were made from B1, B2, B3, B4, B5, B6, G1 and G2 making a total of 24 cylinders. The cylindrical samples were demoulded after 24 hours and cured in a curing tank for 28 days.

The splitting tensile strength were computed from the expression [9]

$$T = \frac{2P}{\pi LD} \quad (6)$$

Where P is the applied load and L and D are the length and depth of the specimen respectively.

3.0 RESULTS AND DISCUSSIONS

The results of observation of X-ray diffraction analysis on basalt specimen are shown in Table 4.

Table 4: Chemical composition of Ikom Basalt

Element	Content (%)
Al_2O_3	13.4890
SiO_2	46.0494
P_2O_5	15.1785
K_2O	1.4800
CaO	7.2923
TiO_2	1.7210
MnO	5.0928
Fe_2O_3	5.4558
SrO	0.0872
Na_2O	3.0045

Sb_2O_3	0.0051
PbO	0.0030
Loss on Ignition	1.1414

The laboratory results for the specific gravity of basalt alongside granite, cement and river sand are presented in Table 5, other engineering properties of basalt are presented in Tables 6, 7, 8, 9 and 10. The summary of engineering properties of basalt and average split tensile strength with the developed mix ratios are presented in Tables 11 and 12 respectively.

Table 5: Specific Gravity of Basalt, Granite, Cement and River Sand

	A	B	A	B	A	B	A	B
Sample Type	**Basalt**		**Granite**		**Cement**		**River Sand**	
Mass of Bottle (M_1) g	482	470	479	486	460	474	484	485
Mass of Bottle + Sample (M_2) g	882	990	893	880	662	654	980	985
Mass of Bottle + Sample + Water (M_3) g	1874	1958	1884	1880	1388	1385	1890	1892
Mass of Bottle full of Water (M_4) g	1614	1608	1620	1629	1251	1262	1580	1580
Mass of Water used ($M_3 - M_2$) g	992	968	991	1000	726	731	910	907
Mass of Sample used ($M_2 - M_1$) g	400	520	414	394	202	180	496	500
Specific Gravity, $G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$	2.86	3.06	2.76	2.76	3.11	3.16	2.67	2.66
G_s AVERAGE	2.96		2.76		3.14		2.67	

The water absorption test report for basalt and granite is presented in Table 6.

Table 6: Water absorption of Basalt and Granite

S/N	Sample Type	Weight of Sample before Test (g)	Weight of Sample after 24hrs (g)	Weight of Water Absorbed (g)	Water Absorbed
1	Granite	1200	1218	18	1.5
2	Basalt	1200	1221	21	1.7

The results of Los Angeles abrasion performed on basalt and granite samples are presented in Table 7.

Table 7: Los Angeles abrasion values for Basalt and Granite

S/N		Basalt	Granite
1	Weight of sample Wi (g)	5000	5000
2	Weight of sample retained on 1.7mm sieve W_2 (g)	3444	2824
3	Weight of sample passing 1.7mm sieve ($W_1 - W_2$)	1556	2176
4	% Aggregate abrasion value = $100(W_1 - W_2)/W_1$	**31.12**	**43.52**

The results of aggregate impact value performed on basalt and granite specimen are presented in Table 8 while the results of aggregate crushing value performed on basalt and granite samples are shown in Table 9.

Table 8: Aggregate impact values for Basalt and Granite

S/N		Basalt	Granite
1	Weight of mould only W_1(g)	1789	1789
2	Weight of mould plus sample W_2(g)	2749	2391
3	Weight of sample = W_2-W_1=W_3	960	602
4	Weight after impact W_4(g)	2438	2387
5	Weight passing sieve 2.36mm = W_5(g)	37	69
6	Aggregate impact value (%) = $100(W_5)/W_3$	**3.85**	**11.46**

Table 9: Aggregate crushing values for Basalt and Granite

S/N		Basalt	Granite
1	Weight of mould only W_1(g)	10982	10982
2	Weight of mould plus sample W_2(g)	15032	14625
3	Weight of sample = W_2-W_1=W_3	4050	3643
4	Weight after impact W_4(g)	15032	14625
5	Weight passing sieve 2.36mm = W_5(g)	463	611
6	Aggregate crushing value (%) = $100(W_5)/W_3$	**11.43**	**16.77**

The results of soundness test performed by soaking the basalt and granite aggregates in sodium sulphate (Na_2SO_4) solution is shown in Table 10.

Table 10: Soundness test results for Basalt and Granite

S/N		Basalt	Granite
1	Initial weight of sample = W_1 (g)	1000	1000
2	Weight of sample after soaking in Na_2SO_4 and oven drying	1018	1008
		1020	1008
		1020	1010
		1022	1010
		1022	1012
3	Average weight of sample after soaking in Na_2SO_4 and oven drying = W_2 (g)	1020.40	1009.6
4	Soundness = $100(W_2 - W_1)/W_1$	**2.04**	**0.96**

The summary of engineering properties of basalt compared with granite are presented in Table 11.

Table 11: Summary of engineering properties of Basalt compared with Granite

S/N	Property	Basalt	Granite	Acceptable limits
1	Specific gravity	2.96	2.76	> 2.6, BS 812 Part 112:1990
2	Water absorption	1.7	1.5	< 2 , BS 812 Part 112:1990
3	Los Angeles abrasion	31.12	43.52	< 45, BS 812 Part 110:1990
4	Aggregate impact value	3.85	11.46	< 25, BS 812 Part 112:1990

5	Aggregate crushing value	11.43	16.77	< 35, BS 812 Part 112:1990
6	Soundness	2.04	0.96	< 10, ASTM C33-01 BS 812:121, 1989

The summary of average splitting tensile strength for samples at 28 days is presented in Table 12 while the summary of average splitting tensile strength for samples B1, B2, B3, B4, B5, B6, G1 and G2 at 28 days are presented in Figure 2.

Table 12: Summary of average splitting tensile strength for samples at 28 days

S/N	Age of curing (Days)	Average splitting tensile strength in N/mm^2							
		B1	B2	B3	B4	B5	B6	G1	G2
1	28	11.10	10.37	11.37	10.13	11.60	10.25	11.52	10.58

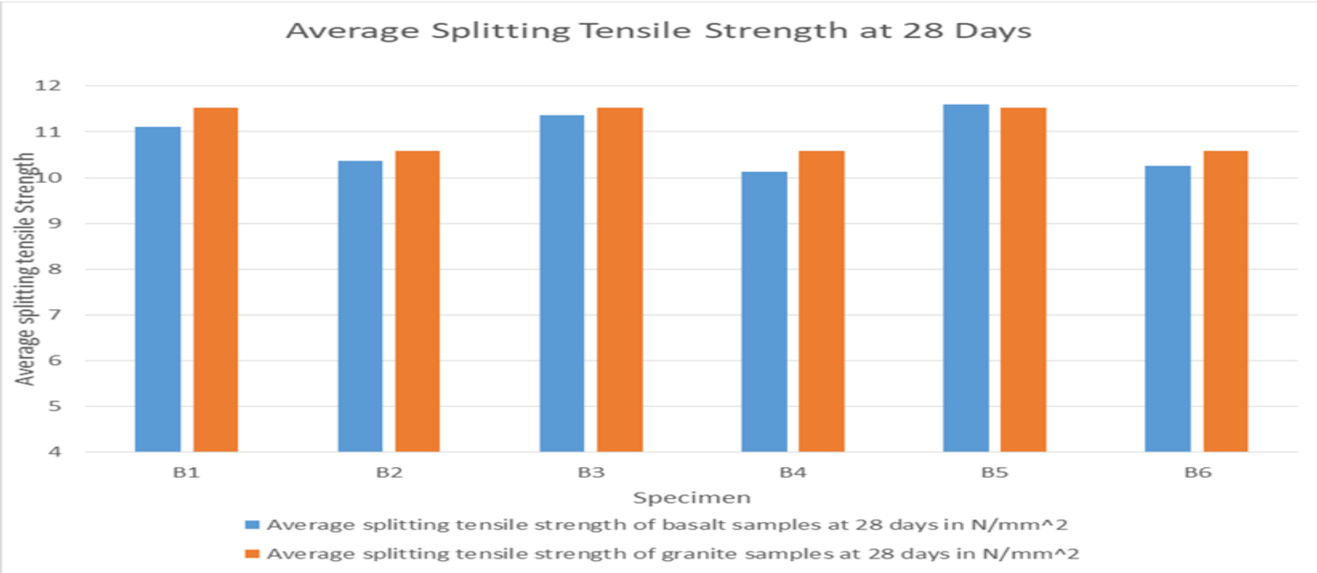

Figure 2: Summary of average splitting tensile strength at 28 days for all samples

The chemical composition of basalt aggregates is as shown in Table 4. The specific gravity of aggregate is an important engineering property as it relates the weight of the aggregate to its volume which in turn predicts the strength of the aggregate. From Table 5, it can be seen that the specific gravity of basalt is 2.96 while that of granite is 2.76. This is also indicative of the fact that strength of basalt is higher than that of granite. These values are satisfactory as there are greater than 2.6 (BS 812 Part 112:1990).

The water absorption of aggregates is also a critical property in the choice of aggregates for concrete production. High quality aggregates for high strength concrete are expected to be of low water absorption, hence, the lower the water absorption, the higher the quality of aggregate. From Table 6, it can be noticed that the water absorption for basalt was found to be 1.7 while that of granite is 1.5. These values of water absorption are all less than 2 which is the maximum limit prescribed by BS 812: Part 112:1990.

The Los Angeles abrasion gives the "resistance of aggregates" to abrasion. All the tests for engineering properties of aggregate are geared towards predicting the long term effects of the performance of aggregates to ascertain whether the samples are fit for usage. From Table 7, it can be noticed that the Los Angeles value for granite is 31.12 percent showing a higher resistance to abrasion compared to granite whose Los Angeles abrasion value is 43.52 percent. These Los Angeles abrasion values are satisfactory for basalt and granite as there are less than the maximum prescribed value of 45 percent (BS 812: Part 110:1990).

The aggregate impact value which predicts the resistance of the aggregate to impact shows a better performance for basalt compared to granite. From Table 8, the aggregate impact value for basalt is 3.85 percent while that of granite is 11.46 percent. This shows good performance rating for basalt and granite as the aggregate impact values are less than the maximum prescribed value of 25 percent (BS 812: Part 112:1990). Similarly, the aggregate crushing test shows a better performance by basalt compared to granite. From Table 9, it can be seen that the aggregate crushing value for basalt is 11.43 percent while that of granite is 16.77 percent. However, the aggregate crushing values for basalt and granite are satisfactory as the obtained values are less than the maximum prescribed value of 35 percent (BS 812: Part 112:1990).

The soundness test shows a better performance by granite compared to basalt. From Table 10, it can be noticed that the soundness value for granite is 0.96 while that of basalt is 2.04. This indicates a higher durability index for granite compared to basalt. However, the performance of granite and basalt are satisfactory as these values are far below the maximum of 10 percent prescribed by BS 812:121, 1989. From the engineering properties investigated, it can be seen that basalt and granite are good materials for utilization as coarse aggregates in the making of concrete. This is due to the results obtained which meets the minimum standards prescribed by BS 812:121, 1989.

The average splitting tensile strength of concrete for B1, B3 and B5 is 11.36 N/mm^2 compared to that of G1 which is 11.52 N/mm^2 with the percentage difference being 1.38% which is insignificant. This shows an equivalent splitting tensile strength for the basalt samples compared to the granite samples. Similarly, the average splitting tensile strength of concrete for B2, B4 and B6 is 10.25 N/mm^2 compared to G2 which is 10.58 N/mm^2 with the percentage difference being 3.11% which is also insignificant. This also shows slightly higher splitting tensile strength for the granite samples in this category compared to the basalt samples.

An effective comparison of the results of this present work could not be done with previous researchers' works due to variations in quality, origin and properties of the constituent materials as well as the mix ratios. However a summary of their results are stated here. The researchers [6] obtained the splitting tensile strength of 3.25 and 2.75 N/mm^2 for basalt and granite concretes respectively with the quantities of concrete components summarized as cement (325 kg/m^3), sand (676 kg/m^3), coarse aggregate (1274, 1166 kg/m^3 for basalt, granite) and water (189 kg/m^3), the properties of the basalt aggregates were aggregate crushing value (4 %), water absorption (0.6 %) and porosity (1.96 %). A significant difference can be observed from their results.

In his work [7] obtained splitting tensile strength at 28 days for M50 concrete as 8.36 N/mm^2 for 100 percent basalt concrete and splitting tensile strength at same age of curing for M60 concrete as 8.53 N/mm^2 for 100 percent basalt concrete. The mix proportions for M50 were stated as: water (171 kg/m^3), cement (430 kg/m^3), sand (634 kg/m^3), and basalt (1231 kg/m^3), and while M60 concretes were: water (135 kg/m^3), cement (450 kg/m^3), sand (660 kg/m^3), and basalt (1245 kg/m^3).

4.0 CONCLUSIONS

The work relates the characteristics and performance of concrete when basalt and granite are used independently as coarse aggregates in concrete making. The experiments show robust performance by basalt samples compared to the granite samples as the percentage difference between the splitting tensile strength of basalt concrete samples and that of granite is very insignificant. The investigation asserts that where basalt as a natural coarse aggregate is available in commercial quantities, a less expensive and durable concrete can be achieved by utilizing basalt as coarse aggregate for concrete making.

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