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Effects Of Aggregates 19 mm And 25 mm Maximum Sizes On The Properties Of Concrete

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***Abstract*—This study investigated the properties of fresh and hardened concrete containing Powermax cement which is a new brand of portland cement produced locally in Nigeria and of grade 42.5 N. Coarse river sand with fineness modulus of 3.0 with water cement ratio of 0.4 was used to produce the said concrete using mix ratio 1:1.5:3 (cement:sand:granite). The coarse aggregate sizes namely 19 mm and 25 mm were also used along separately. The cement was subjected to specific gravity, fineness, consistency, setting time, chemical and composition compositions laboratory tests and analyses. The two types of coarse aggregates used were subjected individually to crushing, impact and abrasion tests. Aggregate gradation tests were also carried out on both fine and the two coarse aggregates separately. Each brand of fresh concrete produced was subjected to slump and compaction factor tests. Compressive, flexural and tensile splitting strength tests were carried out on hardened concrete specimens. At the 28th day curing, concrete containing 25 mm aggregate had compressive strength of 37.3 N/mm² while using 19 mm aggregate has 44.4 N/mm². Significantly, it is the use of nominal maximum size of grade 19 mm coarse aggregate at 28 days curing for infrastructures that satisfied the minimum requirement value for compressive strength of 40 N/mm², flexural strength of 4.5 N/mm² and tensile strength of 2.5 N/mm². Based upon the research carried out here the use of 19 mm is the better preferred option for economic justification because by the choice premature failure of the hardened concrete has been prevented.**

Keywords—Water, fresh, hardened, concrete, specimens, compressive

1. INTRODUCTION

Choosing between nominal maximum sizes of 19 mm and 25 mm granites by aggregate gradation in the production of concrete can be a concern regarding strength optimization when provided with a brand of cement. Concrete is a construction material that is useful in the development of structures and infrastructures. The hardened material called concrete is usually formed by the addition of water, portland cement and aggregates to form fresh concrete of a particular consistency that must have acceptable workability by quality control Falade (1999) and Akiije (2016).

Drinkable water is usually suitable in the production of cement concrete although some non-drinkable water may also be useful depending upon the degree of impurities Mamlouk and Zaniewski (2006). According to (Wright, 2004) the gradation of aggregates is the blend of particle sizes in the mix whilst affects the density, strength, and economy of the concrete structure. Fine aggregate are of natural sand, river bed sand, manufactured sand, or a combination thereof with particles that are typically smaller than 4.75 mm. The maximum percent of silt which is material passing the 0.075 mm sieve that may be contained in the fine aggregate must not exceed 2 to 5 percent of the total (AASHTO T 21, 2014).

Coarse aggregate consists of gravel, crushed gravel, crushed stone, air-cooled blast furnace slag, or crushed concrete, or a combination of with particles generally larger than 4.75 mm. Table 1 is showing limits for deleterious substances and physical properties of coarse aggregate for concrete Wright (2004). Specifications generally require that the unit weight of coarse aggregate to be used in cement concrete should not be less than 1120 kg/m³.

This research aims at investigating the potentials of concretes while using nominal maximum 19 mm and 25 mm coarse aggregates individually. In the process, Powermax brand of portland cement that is made in Nigeria was employed whilst optimizing concretes produced of two different aggregates independently. Specifically the objectives of this research are to:

1. Define individually the specific chemical and metallic composition properties of the Powermax cement used together with the determination of its initial and final setting times;
2. Determine the particle size distribution for both the fine and individual coarse aggregates along with their fineness modulus, coefficient of uniformity and coefficient of curvature;
3. Determine the crushing, impact and abrasion values of coarse aggregates used;
4. Define and compare the two different concretes produced by the nominal maximum sizes of 19 mm and 25 mm granites used independently while using same river sand, water and Powermax cement;
5. Determine and compare individually the workability of each of the two different types of fresh concretes

prepared through their slump tests and the compacting factor tests separately; and

6. Carry out laboratory tests to destruction of hardened concrete specimens in order to determine compressive, flexural and tensile strengths.

The main scope of work in this study therefore includes using Powermax cement which is 42.5 N and separately employing 19 mm and 25 mm nominal maximum aggregate granites along with the use of river sand and potable water. Concrete materials mixture ratio of 1:1.5:3 with water ratio of 0.4combined to produce fresh concrete which later hardened and subjected to curing by water ponding before testing at different ages. Significantly, this study provides information upon the differences that occurred in relationship to the developed strengths while individually using the two types of aggregates separately. The justification for this research work is in the enlightenment whilst deriving due economy from the optimization of the potentials of the two different aggregates compared based upon strength and durability of each concrete produced.

TABLE 1: LIMITS FOR DELETERIOUS SUBSTANCES AND PHYSICAL PROPERTIES OF COARSE AGGREGATE FOR CONCRETE

Maximum Allowable (percent)				
Typical Uses	Weathering Exposure	Clay Lumps and Friable Particles	Chert (less2.4 sp. gr. SSD)	Sum of Clay Lumps; Friable Particles, and Chert
Bridge decks and other uses where surface disfigurement due to pop outs is objectionable	Severe	2.0	3.0	3.0
	Moderate	3.0	3.0	5.0
	Negligible	5.0	5.0	7.0
Pavements, base courses, and sidewalks where a moderate number of pop outs can be tolerated	Severe	3.0	3.0	5.0
	Moderate	5.0	5.0	7.0
	Negligible	5.0	8.0	10.0
Concealed concrete not exposed to weather	All types	10		
General requirements, all types of construction and weathering regions:				
Maximum allowable material finer than No. 200 sieve (0.075 mm) = 1.0%				
Maximum allowable coal and lignite = 0.5%				
Maximum wear, Los Angeles abrasion test = 50%				
Maximum loss, magnesium sulphate soundness test (five cycles) = 18%				

Source: Wright, 2004

2. MATERIALS AND METHODOLOGY

2.1. Materials Classifications

Powermax cement was employed in the production of concrete while employing, river sand, water and nominal maximum size of 25 mm and 19 mm granites individually. Powermax cement used is of Type I of which its properties conformed to AASHTO T 85 (2009). The relative density or specific gravity of cement used was determined according to ASTM C 188 (2005) whilst the bulk density was determined as its weight per unit volume. The cement fineness determination was carried out by the percent passing the 0.045 mm sieve in accordance to ASTM C 430 (2008). The hydrated cement prepared was subjected to initial and final setting time tests based on measurements by the Vicat apparatus according to ASTM C 191 (2013).

Ogun river sand from Lagos environs was oven dried in the laboratory at the average temperature of 100±2°C to pave way for gradation test. The gradation test was performed on the fine aggregate sample that passed through sieve 9.5 mm and retained on 0.15 mm after agitation of nest of the sieves according to AASHTO T 27 (2014). In the process, a nest of sieves with apertures 9.5mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.60 mm, 0.30 mm and 0.15 mm were used for the grain-size classification. The specific gravity of the fine aggregate used was also determined according to AASHTO T 84 (2013) specification.

Separate nominal maximum size 19 mm granite and similarly of 25 mm granite quarried at Abeokuta environs in Ogun State of Nigeria and sold at Bariga in Lagos were oven dried in laboratory separately for the purpose of sieve analysis tests according to AASHTO T 27 (2014). The specific gravity of each of the coarse aggregates used was determined separately according to AASHTO T 84 (2013) specification. The bulk density of each of the coarse aggregates used was determined separately according to AASHTO T 19 (2014) specification.

Potable water found in the concrete laboratory of the department of Civil and Environmental Engineering, University of Lagos was used in the production of the cement concrete specimens and it was considered free of chloride ions, oil, alkalis and acids.

2.2. Proportioning of the Concrete Mixtures

Equation 1, is a useful model for the determination of cement concrete per volume batch V_{cb} of production Gambhir (2004) and it is given by

$$V_{cb} = \frac{w}{\gamma_w} + \frac{c}{\gamma_w S_c} + \frac{f_a}{\gamma_w S_{fa}} + \frac{ca}{\gamma_w S_{ca}} \quad (1)$$

In Equation 1, w is the weight of water, γ_w is the density of water whilst c is the weight of cement, fa is the weight of fine aggregate, ca is the weight of coarse aggregate and their respective specific gravity are Sc , Sfa

and Sca respectively. The expressions in Equation 1 are useful modalities for the possibility of obtaining absolute concrete volume V_{ca} per 50 kg bag of portland cement in m³. Akiije (2017) expressed the Equation 1 terms in a tabular approach for easier approach in determining the proportion of concrete constituents as in Table 2

In this study, Powermax Portland cement was mixed by water cement ratio (w/c) 0.4 and using individually 19 mm and 25 mm nominal maximum granites using same river sand with a mixing ratio of 1:1.5:3 for laboratory concrete specimens production.

Table 3 is showing proportioning of the concrete mixture constituents for the laboratory specimens production which are to pave ways for fresh and hardened concrete tests. Table 4 is showing the modelling of absolute volume and absolute weight of concrete proportioning per batch of Table 3. Table 5 is showing the simulation of absolute volume and absolute weight of concrete per batch in relationship to Table 4.

TABLE 2: EXPRESSIONS FOR THE COMPUTATION OF THE ABSOLUTE VOLUME AND ABSOLUTE WEIGHT OF CONCRETE PER BATCH

Label	Water	Cement	Fine Aggregate	Coarse Aggregate	Sum
Assumed Proportion	w/c	c	β	ω	
Bulk Density	γ_w	γ_c	γ_{fa}	γ_{ca}	
Applied Ratio by Weight	w/c	c	$\frac{\beta \times \gamma_{fa}}{\gamma_c}$	$\frac{\omega \times \gamma_{ca}}{\gamma_c}$	
Specific Gravity	S_w	S_c	S_{fa}	S_{ca}	
Absolute concrete volume Vca, per 50 kg cement bag, m³	$\frac{w/c \times 50}{\gamma_w \times S_w}$ = j	$\frac{\alpha \times \gamma_c \times 50}{\gamma_w \times \gamma_c \times S_c}$ = k	$\frac{\beta \times \gamma_{fa} \times 50}{\gamma_w \times \gamma_c \times S_{fa}}$ = l	$\frac{\omega \times \gamma_{ca} \times 50}{\gamma_w \times \gamma_c \times S_{ca}}$ = m	Vca = j+k+l+m
Applied Ratio by Volume	j/k	k/k	l/k	m/k	
Absolute concrete constituents volume Vcca, per 33 litre of cement bag, m³	j	Vc	$Vc \times l/k$	$Vc \times m/k$	Vcca = j+33+33xl/k +33xm/k
Batch concrete volume Vcab with air entrainment of 2 % and 7% wastage, m³	j/ Vca* Vcspb	k/ Vca*V	l/ Vca*V	m/ Vca* Vcspb	Vcspb
Concrete weight Wca for a unique production batch	$\frac{V_{cspb} \times 50}{Vca} \times w/c$ = n	$\frac{V_{cspb} \times 50}{Vca}$ = o	$\frac{V_{cspb} \times 50}{Vca} \times \frac{\beta \times \gamma_{fa}}{\gamma_c}$ = p	$\frac{V_{cspb} \times 50}{Vca} \times \frac{\omega \times \gamma_{ca}}{\gamma_c}$ = q	n+o+p+q
Concrete weight Wca for one bag of cement, kg	Vca *50* w/c = r	Vca*50 = s	Vca*50* $\frac{\beta \times \gamma_{fa}}{\gamma_c}$ = t	Vca*50* $\frac{\omega \times \gamma_{ca}}{\gamma_c}$ = u	r+t+u+v
Concrete weight Wca for less than one bag of cement, kg	r*w/c* (Vcspb-j)/j = e	(Vcspb-Vca)/ Vca*50 = f	s* $\frac{\beta \times \gamma_{fa}}{\gamma_c}$ *(Vcspb-j)/j = g	s* $\frac{\omega \times \gamma_{ca}}{\gamma_c}$ *(Vcspb-j)/j = h	e+f+g+h
Concrete weight Wca for 1 metre cube of concrete	f*w/c	1/(Vca*50)	1/(Vca*t)	1/(Vca*u)	

TABLE 3: PROPORTIONING OF THE CONCRETE MIXTURE COMPUTATION FOR THE LABORATORY SPECIMENS PRODUCTION

	Water Cement Ratio (w/c)					Cement	River Sand	Granite		Volume of each concrete specimen per batch with entrainment air of 2 % and 7% wastage, Vcspb = 0.2112 x (1-0.02+0.07) = 0.222 m³
Mix Ratio	0.4					1	1.5	3		
Concrete Tests	Compressive Strength					Flexural Strength		Tensile Strength		
Concrete Shapes and Dimensions	Concrete Cubes					Concrete Beams		Concrete Cylinders		
	(150 mm x 150 mmx 150 mm)					550 x 150 x 150		(300 mm x 150mm)		
Curing Ages (Days)	7	28	56	91	120	7	28	7	28	
19 mm granite	3	3	3	3	3	3	3	3	3	0.222 m³
25 mm granite	3	3	3	3	3	3	3	3	3	0.222 m³
Total	30					12		12		0.444 m³

TABLE 4: MODELLING OF ABSOLUTE VOLUME AND WEIGHT OF CONCRETE PROPORTIONING PER BATCH OF TABLE 3

	C	D	E	F	G	H
5	**Label**	Water	Cement	Fine Aggregate	Coarse Aggregate	Total
6	**Assumed Proportion**	0.4	1	1.103	2.288	
7	**Bulk Density**	1000	1109	1509	1454	
8	**Applied Ratio by Weight**	=D6*E7/E7	=E6*E7/E7	=F6*F7/E7	=G6*G7/E7	
9	**Specific Gravity**	1	3.15	2.6	2.6	
10	**Absolute concrete volume Vca, per 50 kg cement bag, m³**	=D8*50/1000/D9	=E8*50/1000/E9	=F8*50/1000/F9	=G8*50/1000/G9	=SUM(D10:G10)
11	**Applied Ratio by Volume**	=D10/E10	=E10/E10	=F10/E10	=G10/E10	
12	**Absolute concrete constituents volume Vcca, per 33 litre of cement bag, m³**	=D10*1000	33	=E12*F11	=E12*G11	=SUM(D12:G12)
13	**Batch concrete volume Vcab with air entrainment of 2 % and 7% wastage, m³**	=D10/$H$10*$H$13	=E10/$H$10*$H$13	=F10/$H$10*$H$13	=G10/$H$10*$H$13	0.222
14	**Concrete weight Wca for a unique production batch**	=E14*D8	=H13/H10*50	=E14*F8	=E14*G8	=SUM(D14:G14)
15	**Concrete weight Wca for one bag of cement, kg**	=E15*D8	=H10/H10*50	=E15*F8	=E15*G8	=SUM(D15:G15)
16	**Concrete weight Wca for less than one bag of cement, kg**	=E15*D8*(H13-H10)/H10	=(H13-H10)/H10*50	=E15*F8*(H13-H10)/H10	=E15*G8*(H13-H10)/H10	=SUM(D16:G16)
17	**Concrete weight Wca for 1 metre cube of concrete**	=E17*D8	=1/H10*50	=1/H10*F15	=1/H10*G15	=SUM(D17:G17)

TABLE 5: SIMULATION OF ABSOLUTE VOLUME AND ABSOLUTE WEIGHT OF CONCRETE PER BATCH IN RELATIONSHIP TO TABLE APPLIED RATIO BY WEIGHT

	C	B	C	D	E	F
5	**Label**	Water	Cement	Fine Aggregate	Coarse Aggregate	Total
6	**Assumed Proportion**	0.400	1.000	1.103	2.288	
7	**Bulk Density**	1000	1109	1509	1454	
8	**Applied Ratio by Weight**	0.400	1.000	1.500	3.000	
9	**Specific Gravity**	1	3.15	2.6	2.6	
10	**Absolute concrete volume Vca, per 50 kg cement bag, m³**	0.020	0.016	0.029	0.058	0.122
11	**Applied Ratio by Volume**	1.260	1.000	1.817	3.635	
12	**Absolute concrete constituents volume Vcca, per 33 litre of cement bag, m³**	20.000	33.000	59.977	119.942	232.920
13	**Batch concrete volume Vcab with air entrainment of 2 % and 7% wastage, m³**	0.036	0.029	0.052	0.105	0.222
14	**Concrete weight Wca for a unique production batch**	36.270	90.676	136.027	272.027	535.000
15	**Concrete weight Wca for one bag of cement, kg**	20.000	50.000	75.008	150.000	295.008
16	**Concrete weight Wca for less than one bag of cement, kg**	16.270	40.676	61.020	122.027	239.992
17	**Concrete weight Wca for 1 metre cube of concrete**	163.379	408.448	612.736	1225.345	2409.909

2.3. Fresh concrete production, workability tests, specimens casting and demoulding

The constituents of concrete produced are water, cement, sand and granite which were batched as shown in the Table 6 below before mixing. In Table 6 lines 1, 2, 3 and 4 are relevant for concrete production by weight while lines 1, 5, 6 and 7 are relevant for concrete production by volume. Batching of concrete was carried out in this research by weighing technique in the concrete laboratory of the department of Civil and Environmental Engineering, Faculty of Engineering, University of Lagos.

The slump test was carried out in accordance to AASHTO T 119 (2013) upon the fresh concrete produced within 4 minutes of finishing the mixing of same on the platform. Sump test is a useful assessment for measuring the consistency for the workability value of the fresh concrete produced. The compacting factor test was also carried out according to BS 1881 (2011) upon the fresh concrete produced immediately after carrying out the slump test and within 6 minutes of finishing the mixing of same on the platform. The compacting factor test helps to define the fresh concrete workability based upon its compact or dense ability.

Demoulding of the specimens of the concrete samples was carried out about 24±2 hours of casting and then cured by being covered using fresh water in a tank having the average temperature of 23±1.7°C till the day of each testing.

2.4. Hardened Specimen Strength Tests

Three sample specimens were tested on each testing day as per curing age as shown Table 2 and the average of each set was considered as the characteristics mean strength in N/mm². Compressive characteristics mean strength values were individually carried out in accordance to BS EN 12390 (2009). Flexural strength test was also carried out according to ASTM C 78 (2016). Each hardened concrete cylinder specimen was subjected to tensile splitting strength test in accordance to ASTM C 496 (2011).

Equations employed to determine characteristics strength of each specimen for compressive, flexural and split tensile strengths are Equations 2, 3 and 4 respectively.

$$\text{Compressive strength} = \frac{P}{bd} \quad (2)$$

$$\text{Flexural strength} = \frac{PL_f}{bd^2} \quad (3)$$

$$\text{Tensile splitting strength} = \frac{2P}{\pi L_t \phi} \quad (4)$$

Where for Equations 2, 3 and 4;

P = Maximum applied load
b = Width of specimen
d = Depth of the specimen
L_f = Beam span length = 400 mm
L_t = Cylinder span length =300 mm
ϕ = Cylinder diameter = 150 mm

TABLE 6: BATCHING OF CEMENT CONCRETE CONSTITUENTS BY BOTH VOLUME AND WEIGHT

	LABEL	19 mm Granite				25 mm Granite			
1	Concrete Materials Constituents	Water	Cement	Sand	Granite	Water	Cement	Sand	Granite
2	Applied Ratio By Weight For Concrete Materials Constituents	0.400	1.000	1.500	3.000	0.400	1.000	1.500	3.000
3	First Batch Of Constituents For Concrete Production, Kg	20	50	75	150	20	50	75	150
4	Second Batch Of Constituents For Concrete Production, Kg	16.27	40.68	61.02	121.88	16.25	40.63	60.94	121.88
5	First Batch Of Constituents For Concrete Production, Litres	20.000	33.000	59.977	119.942	20.000	33.000	59.977	119.942
6	Second Batch Of Constituents For Concrete Production, Litres	16.25	26.85	40.27	80.55	16.25	26.85	40.27	80.55
7	Applied Ratio By Volume For Concrete Materials Constituents	1.260	1.000	1.817	3.635	1.260	1.000	1.817	3.635
8	Specimens Per Each Granite Type	15 cubes, 6 beams and 6 cylinders				15 cubes, 6 beams and 6 cylinders			
9	Total Number Of Specimens	30 cubes, 12 beams and 12 cylinders							

3. RESULTS AND DISCUSSIONS

The results and discussions of the findings in this research work are as following.

3.1. The cement properties and trends

Powermax cement used in this research potentials regarding Chemical composition, Potential compound composition, Physical and mechanical properties are discussed in Tables 7 to 9 accordingly.

3.2. The aggregates properties and trends

Table 10 is showing the physical properties of the employed river sand that was used as fine aggregate along with individual grade 19 mm and grade 25 mm granites as coarse aggregates. Also, Figures 1, 2 and 3 show how justified the three aggregates used as uniformly graded aggregates based upon grain size distribution curves.

TABLE 7: CHEMICAL COMPOSITION IN PERCENT OF POWERMAX PORTLAND CEMENTS

Label	Mineral Composition (%) per each portland cement	Specification Requirements	Remarks in relationship to specification requirements as well as differences and similarities.
Silicon Dioxide , (SiO_2)	22.00	18.70 - 22.00	Complied
Aluminium Oxide, (Al_2O_3)	6.12	4.70 - 6.30	Complied.
Iron oxide, (Fe_2O_3)	1.28	1.60 - 4.40	Not complied.
Calcium Oxide, (CaO)	63.85	60.66 - 66.30	Complied
Sulphur Trioxide, (SO_3)	1.21	1.80 - 4.6	Not complied.
Sodium Oxide, (Na_2O)	0.54	0.11 - 1.20	Complied.
Potassium Oxide, (K_2O)	0.33	0.11 - 1.20	Complied.
Magnesium Oxide,(MgO)	2.82	0.70 - 4.20	Complied.

TABLE 8: POTENTIAL COMPOUND COMPOSITION OF THE NIGERIAN PRODUCED PORTLAND CEMENTS USED IN THIS STUDY

Compound Composition	Powermax Portland Cement	Specification Requirements	Remarks in relationship to specification requirements
Tricalcium Silicate, C_3S	45	40 - 63	complied
Dicalcium Silicate, C_2S	30	9 - 31	complied
Tricalcium Aluminate, C_3A	14	6 - 14	complied
Tetracalcium Aluminoferrite, C_4AF	5	5 - 13	complied

TABLE 9: PHYSICAL AND MECHANICAL PROPERTIES OF THE POWERMAX PORTLAND CEMENT USED IN THIS STUDY

Parameters	Cement	Specification Requirements	Remarks
Specific Gravity γ_G	3.15	3.13-3.15	Conformed
Bulk Density, γ_b kg/m³	1180	1000-1300	Conformed
Fineness, % retained on 45 µm	8	10 maximum	Conformed
Loss of Ignition , LOI	0.006	0.04-0.05	Does not conform
Fibre	0.00	0.00	Conformed
Insoluble Residue, IR	99.39	99.95-99.97	Does not conform
Initial Setting Time in minutes	2hrs. 40mins	0.75 hr. – 4 hr.	Conformed
Final Setting Time in minutes	4hrs. 59 mins	6.25 hr.– 10 hr.	Conformed

TABLE 10: PHYSICAL PROPERTIES OF AGGREGATES USED IN THIS STUDY

S/No	Physical Properties	Fine Aggregate River Sand	Coarse Aggregate 19 mm Granite	Coarse Aggregate 25 mm Granite
1	Percent of particles retained on the 4.75 mm sieve	3.62	100	100
2	Percent of particles passing the 4.75 mm sieve	96.38	0	0
3	Percent of particles passing the 0.075 mm sieve	0.10	0	0
4	Fineness modulus	3.000	-	-
5	Coefficient of uniformity (Cu)	2.43	1.68	1.840
6	Coefficient of curvature (Cc)	1.07	1.24	0.99
7	Bulk density	1509	1500	1454
8	Specific gravity	2.67	2.68	2.68
9	Moisture (water) absorption (%)	1.15	0.6	0.5
10	Aggregate crushing value (%)	-	19.15	18.14
11	Aggregate impact value (%)	-	11.95	10.12
12	Los Angeles abrasion value (%)	-	13.95	14.10

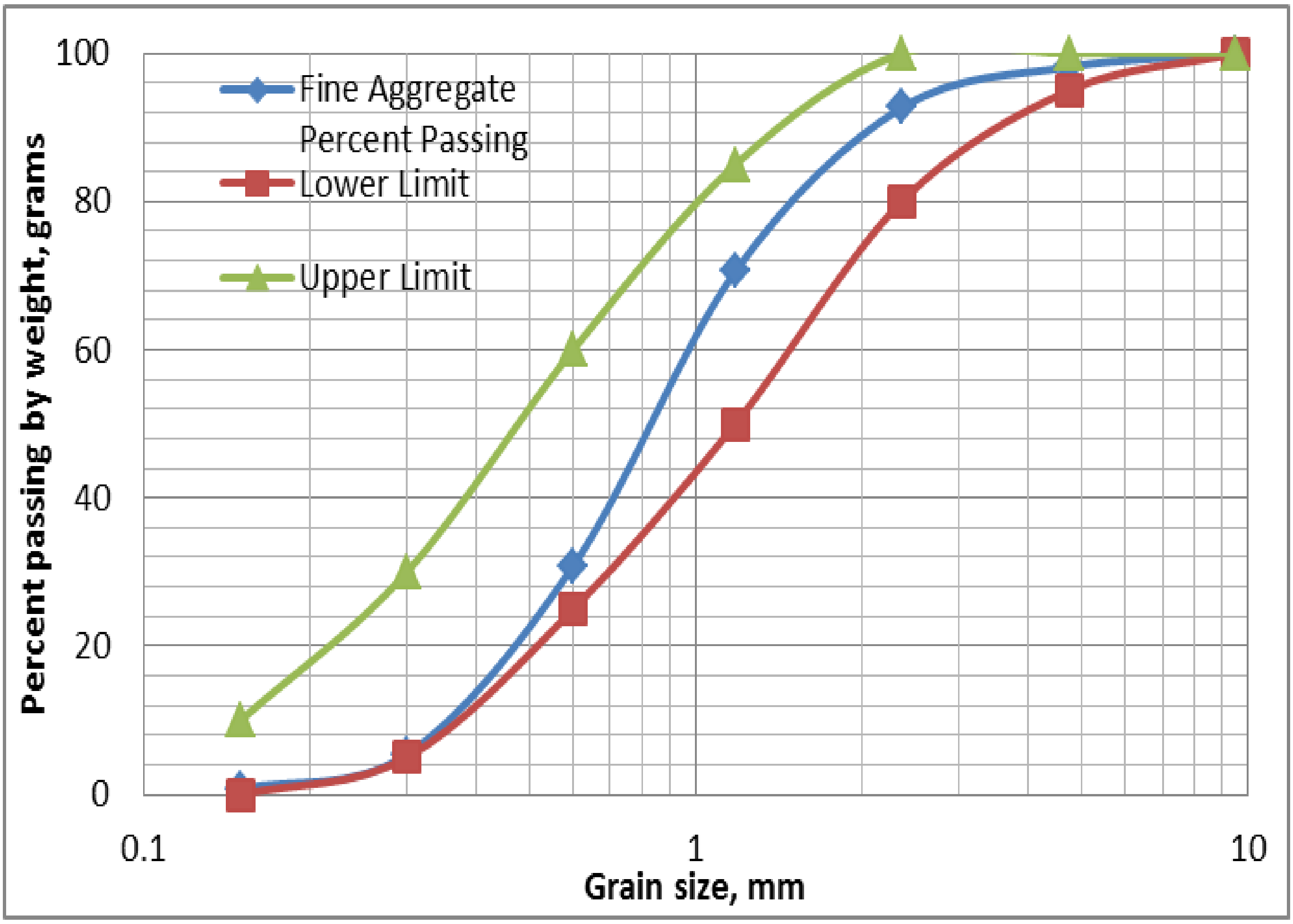

Figure 1: The river sand fine aggregate size distribution curve

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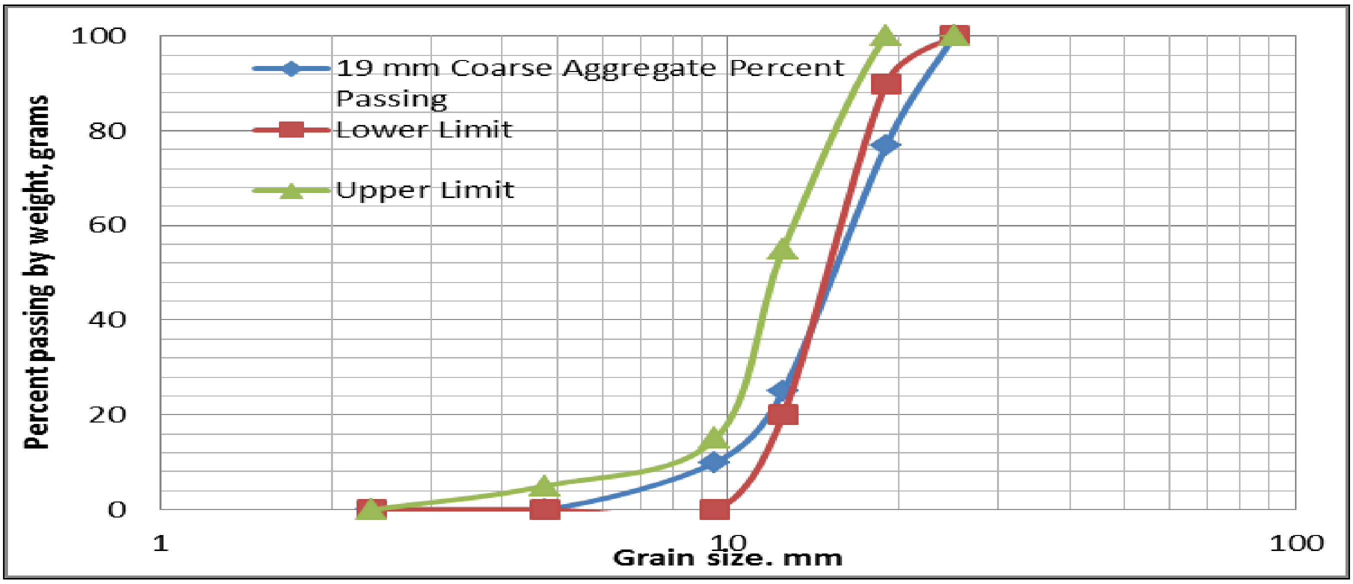

Figure 2: The coarse aggregate 19 mm granite grain size distribution curve

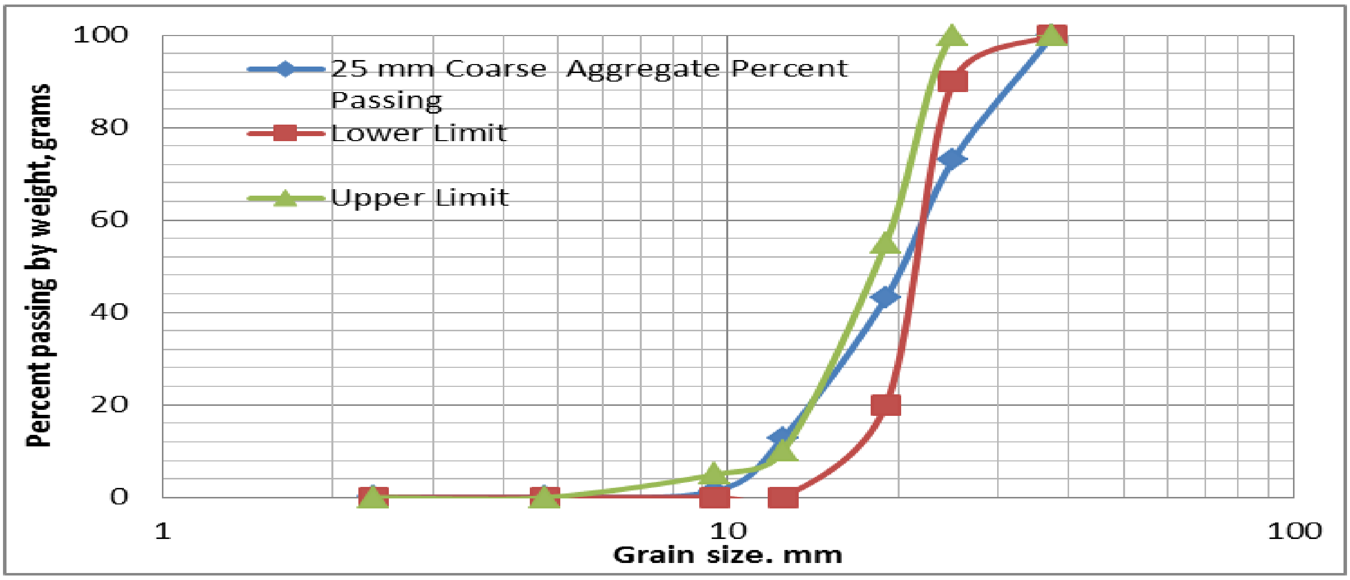

Figure 3: The coarse aggregate 25 mm granite grain size distribution curve

3.3. The concretes properties and trend

Workability properties of the fresh concretes produced in this research while comparing the 19 mm and 25 mm coarse aggregates separately using Powermax cement was examined by slump and compacting factor tests and the results are exhibited in Table 11. In Table 11, it could be seen that the compacting factor test results compared the two concretes better than that slump tests results for distinguishing them explicitly. It could be seen in Table 11 that the smaller the aggregate size the lower the slump and the smaller the compacting factor value. Compacting factor test results also distinguished the concrete using 19 mm and that of 25 mm whereas slump test results failed to distinguish the two fresh concrete by compactability state.

Properties of the hardened specimens regarding compressive, flexural and tensile strengths are in Tables 12 to 14. Table 12 showed that the 7 days curing compressive strength attained 75 percent of 28 days strength which is just only 44 percent when compared to 120 days strength. Also, 28 days curing compressive strength attained 79 percent that of 120 days. In Table 13, it is obviously found that at each testing day per cured specimen the strength of the nominal maximum size of 19 mm granite is higher than that of the 25 mm size. Also, as the curing day is increasing the difference in percent of the compressive strength of the two types of aggregates concretes is reducing. This is an indication that if more work is done on the use of nominal maximum size of 25 mm the strength can be improved upon. Table 14 is showing the relative flexural and tensile strengths values obtained upon testing hardened concrete specimens and it was found that the one of nominal maximum size of 19 mm granite is higher than that of the 25 mm size. Also, as the curing day is increasing the difference in percent of both the flexural and tensile splitting strengths of the two types of aggregates concretes are individually reducing.

TABLE 11: WORKABILITY PROPERTIES OF THE FRESH CONCRETES BY SLUMP AND COMPACTING FACTOR TESTS RESULTS

Label	Slump Tests Results			Compacting Factor Tests Results	
	Height of Slump (mm)	Slump Type	Degree of workability	Compacting Factor	Degree of Workability
19 mm granite aggregates employed in the concrete production	30	True slump	Medium (Plastic)	0.84	Low (Stiff-Plastic)
25 mm granite aggregates employed in the concrete production	35	True slump	Medium (Plastic)	0.88	Medium (Plastic)

TABLE 12: RELATIVE COMPRESSIVE STRENGTH OF HARDENED CONCRETE AS COMPARED TO 28 DAYS CURING

Mix ratio (1:1½:3); w/r (0.4)	Hardened Concrete Specimens Compressive Strength N/mm²									
Max. Normal Aggregate Size	19 mm					25 mm				
Curing ages	7 days	28 days	56 days	91 days	120 days	7 days	28 days	56 days	91 days	120 days
Relative compressive strength	25.0	44.4	54.2	58.4	60.5	18.5	37.3	46.3	54.2	56.3
Relative percentages to 28 days curing compressive strength	75	100	110	115	125	70	100	111	120	123

TABLE 13: RELATIVE COMPRESSIVE STRENGTH OF HARDENED CONCRETE AS COMPARED INDIVIDUALLY FOR 19 MM AND 15 MM AGGREGATE SIZES PER CURING AGES

Mix ratio 1:1½:3); w/r (0.4)	Hardened Concrete Specimens Compressive Strengths by Percent of Strength of Grade 19 mm Granite									
Max. Normal Size	19 mm	25 mm	19 mm	25 mm	19 mm	25 mm	19 mm	25 mm	19 mm	25 mm
Curing ages	7 days		28 days		56 days		91 days		120 days	
Compressive strength relationship per curing day N/mm².	25.0	18.5	44.4	37.3	54.2	46.3	58.4	54.2	60.5	56.3
Compressive strength relationship in percent per curing day	100	74	100	84	100	85	100	93	100	93

TABLE 14: RELATIVE FLEXURAL AND TENSILE STRENGTHS VALUES OBTAINED UPON TESTING HARDENED CONCRETE SPECIMENS

Mix Ratio (1:1½:3) w/r (0.4)	Hardened Concrete Specimens Flexural Strength				Hardened Concrete Specimens Tensile Strength			
Max. Normal Size	19 mm	25 mm	19 mm	25 mm	19 mm	25 mm	19 mm	25 mm
Curing ages	7 days		28 days		7 days		28 days	
N/mm²	3.8	3.1	4.8	4.4	2.3	1.6	2.9	2.1
Percent	100	82	100	92	100	70	100	72

4. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations proffered upon concretes produced using two different types of nominal maximum sizes of 19 mm and 25 mm are as described next.

4.1. Conclusions

Based upon the laboratory experiments that have been carried out in this research work, the following are the proffered conclusions.

1. Newly improved brands of Portland cements brands called Powermax used in this research conformed satisfactorily at very good level to American Society for Testing and Material (ASTM), American Association of State Highway and Transportation Officials (AASHTO), British and Nigerian relevant standard specification requirements.
2. Table 2 contained useful paradigm expressions for the computations of the absolute volume and weight of a batch for concrete production. While the absolute volume methodology is a useful model at construction site, the weight approach is a useful pattern for concrete mixture computation in the laboratory or at the manufacturing yard. Table 3 is a useful modelling module that forms a template through the use of Microsoft Excel spreadsheet for actualization of the volume and weight values of a batch for concrete production. Table 4 simulated accurately the results proffered by the modelling work of Table 3 and identified vividly the difference between the applied ratios by weight and that of volume. The methodology is useful in the laboratory for concrete research work or at the manufacturing yards for the material to be transported to the construction sites. Whereas the use

volumetric approach is beneficial at the construction site by labour work and the use of concrete mixer.

3. The cement brand used physical, chemical, potential compound compositions, fineness, specific gravity, bulk density, insoluble residue and loss of ignition properties conformed to the standards requirements satisfactorily as shown in Tables 5, 6 and 7. Also, each cement setting times and compressive strength also conformed favourably well with the specification standards as in Table 8.
4. As shown in Table 9 and Figure 1 the river sand used is a coarse uniformly graded fine aggregate. Also, considering Table 9, Figure 2 and Figure 3 the granites used which are of grade 19 mm and grade 25 mm individually were found to be uniform, well graded and dense coarse aggregate.
5. At 28 days curing, the use of 25 mm granite aggregate proffered concrete compressive strength of 37.3 N/mm² while using 19 mm proffered 44.4 N/mm². Significantly, it is the use of nominal maximum size of grade 19 mm granite aggregate at 28 days curing that satisfied design and construction minimum requirement value for compressive strength of 40 N/mm², flexural strength of 4.5 N/mm² and tensile strength of 2.5 N/mm² for 0.4 water cement ratio by mass.

4.2. Recommendations

The laboratory experiments carried out in this research have allowed for the following recommendations.

1. The use of compacting factor test as a measure of workability is endorsed here as a better method at a higher degree than that of slump test as shown in this research work for being related well to the results of compressive, flexural and tensile strength tests of the hardened concrete specimens.
2. The use of 1:1.5:3 concrete mixture of Powermax Portland cement, river sand of 3.0 fineness modulus, 19 mm granite and water-cement ratio 0.4 is the better preferred option for economic justification than using 25 mm granite as worked upon in this research to attain strength that satisfied the minimum standard specification for highway pavements and buildings foundations, column, beams and slabs.
3. Further work is necessary to define the possibility of making use of 25 mm granite whenever it is the only available aggregate to attain minimum compressive, flexural and tensile strength similarly as the use of 19 mm at 28 days water curing by submersion along with the use of 1:1.5:3 concrete mixture.
4. Further work is also necessary to define the possibility of making use of other cement brands to produce concrete to satisfy minimum of compressive, flexural and tensile strength tests of the hardened concrete specimens similarly.

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