Effects Of CONPLAST SP 430 Superplasticizer Using Four Nigerian Produced Cements Individually In Concrete Production For Highway Pavement

Isaac Akiije
Department of Civil and Environmental Engineering
Faculty of Engineering, University of Lagos, Akoka, Yaba, Lagos, Nigeria

***Abstract*—The purpose of this study is in the consideration of using CONPLAST SP430 superplasticizer upon attainment of desirable strength of concrete and optimizing same for highway pavement using four different new types of cement produced in Nigeria. In the facet, one normal cement type tagged 42.5Np and three rapid cement types tagged 42.5Rd, 32.5Rs and 32.5Rt were individually mixed with granites, sand and water plus CONPLAST SP430 superplasticizer for the production highway cement concrete pavement. Individual mixture was at a very low water-cementitious material ratio (w/cm) of 0.32 and concrete mix ratio of 1:1.5:3. Cement tests included specific gravity, fineness, consistency, setting time, chemical and metallic compositions. Tests carried out on the fine and coarse aggregates used included particle size distribution, specific gravity, chemical and metallic compositions. Laboratory tests that were also carried out on the coarse aggregate included crushing, impact and abrasion. Tests carried out on fresh concrete included slump and compaction factor while those on hardened concrete were compressive, tensile splitting and flexural strengths. At 28 days curing age, each of the compressive strength value for the concrete specimens produced based upon the four cements used are respectively 26.67 N/mm^2, 25.63 N/mm^2, 25.56 N/mm^2 and 25.11 N/mm^2. The concrete specimens' tensile splitting strength values are respectively 2.78 N/mm^2, 2.48 N/mm^2, 2.10 N/mm^2 and 1.89 N/mm^2 while that of the flexural strength amounts are respectively 5.274 N/mm^2, 4.208 N/mm^2, 4.208 N/mm^2 and 3.496 N/mm^2 for the cements used. The significance of this study is that although the required compressive and tensile splitting strength values are not satisfied, the flexural strength value is satisfactory for highway pavement only by cement tagged 42.5Np. The justification for this research is in identifying the newly Nigerian made cement among the readily available ones to produce enhanced concrete at a cheaper economy and satisfying the required standard strength specification for highway pavement design and its construction.**

Keywords—Superplasticizer, Pavement, Consistency, Aggregates, Strength, Durability

1. INTRODUCTION

Failure of rigid pavement is a great concern of which using superplasticizer to provide workable and appropriate consistency of fresh concrete at less water content and of a low permeability and high strength is a possible answer. Attempts have been made by many researchers upon increasing the strength and durability of concrete in relationship to workability. Falade (1999) researched on the effects of separation of grain sizes of fine aggregate on properties of concrete containing granite fines upon seven grain size ranges of granite fines with consideration to investigating appropriately their workability, density, compressive and flexural strengths. He concluded that the compressive and flexural strengths and density of the concrete produced increased with decreasing grain sizes, while the workability decreased with decrease in grain sizes. Akiije (2016) considered the effects of using 0.5, 0.55 and 0.6 water cement ratio separately with a Nigerian grade 42.5R portland cement. He remarked that fine and coarse aggregates, 42.5R Portland cement and water used are useful material for the production of concrete. However, he discouraged the use of 1:2:4 mix with individual water cement ratios 0.5, 0.55 and 0.6 while producing sustainable rigid pavement to ensure prevention of premature failure of public and private highway pavements. King (2007) considered supporting a sustainable future with microsilica concrete while using silica fume to enhance the properties of high performance through plastic properties, strength and durability. It was concluded in the research that microsilica can be used to produce high strength and high performance concrete provided that a suitable admixture is incorporated into the mix to reduce water content whilst ensuring adequate workability.

Admixture such as superplasticizer is an ingredient other than Portland cement, water and aggregates that are associated with the production of concrete for increasing strength and durability. Mamlouk and Zaniewski (2006) claimed that superplasticizer is a high-range water reducer whilst greatly increases the flow of the fresh concrete or reduces the amount of water required for a given consistency. They further claimed that superplasticizer is capable of providing a low water-cementitious materials ratio that is beneficial with early strength gain, high-strength concrete and reduced porosity. Conplast SP430 is being examined for the production of cement concrete in this study for Fosroc (2016) claimed that it is a chloride free superplasticising admixture based on selected sulphonated naphthalene polymer that is supplied as a brown solution which instantly disperses in water.

Portland cement is a material in powder form which turns into glue during hydration due to addition of water and then bonds the mixed aggregates to become concrete as in rigid pavement. Portland cement physical properties, chemical composition, specification, hydration, quality control and selection for use are paramount in the production of concrete. The more good or drinkable water is added to cement in the production of concrete the higher the workability and the lower the strength and less durability. According to Mamlouk and Zaniewski (2006) impurities in the concrete mixing water can affect its setting time, strength, long-term durability and chloride ions that can accelerate corrosion of reinforcing steel.

Granites and river sands are aggregates being frequently employed in combination with Portland cement and water with admixture in highway rigid pavements as presented in this study. However, each concrete material property varied from one location to another or from time of taking the material to another in particular river sand. Mamlouk and Zaniewski (2006) described basic properties of aggregate characteristics to include particle shape, surface texture, soundness, durability, toughness, absorption, specific gravity, bulk unit weight, voids in aggregate, gradation, deleterious constituents, alkali-aggregate reactivity, hardness, abrasion resistance, strength, and modulus of elasticity. Wright and Dickson (2004) claimed the portion of aggregate materials that retained on No.4 sieve with the particles larger than 2 mm are known as coarse aggregates while those that pass No.4 sieve but retained on a No. 200 sieve with particles larger than 0.075 mm are known as fine aggregates whereas material that passes a No. 200 sieve is referred to as fines. It is also pertinent to note that there is variation in aggregate materials proportioning.

The study in this research paper aims at investigating the characterization of concretes produced using four different types of newly Nigerian produced cements individually in the production of different concretes upon the characterisation and optimizing same while applying CONPLAST SP430 superplastizer on each. Specifically the objectives of this research are to:

1. Define the specific chemical and metallic composition properties of the cements used together with the determination of their initial and final setting times;
2. Determine the particle size distribution for both the fine and coarse aggregates along with their fineness modulus, coefficient of uniformity and coefficient of curvature;
3. Define and compare different concretes made of the four different types of cement individually while using same river sand, 25 mm granite, water and CONPLAST SP430 superplastizer as an admixture;
4. Determine and compare the workability of the fresh concretes prepared through the slump test and the compacting factor test and;
5. Carry out laboratory tests to destruction of hardened concrete specimens prepared in order to determine flexural, compressive and tensile strengths.

The main scope of work in this study therefore includes using individually four types of cement, water added with an admixture along with the use of one type of river sand and 25 mm granite. Significantly, this study provides information upon the use of CONPLAST SP430 superplastizer upon attainment of workable fresh concrete and also optimizing strength of concrete for highway pavement while four different types of cement at very low water-cementitious material ratio (w/cm) of 0.32 examined. The justification for this research work is in the enlightenment on the economy associated the use of CONPLAST SP430 superplastizer while optimizing among the four readily available Nigerian cements and easily obtainable aggregates for highway pavement strength and durability enhancement.

2. MATERIALS AND METHODOLOGY

2.1. Materials Classifications

This research work contains the following four different types of cement tagged 42.5Np, 42.5Rd, 32.5Rs and 32.5Rt, river sand, 25 mm granite, water and CONPLAST SP430 superplastizer. The four types of cement used for this investigation are produced in Nigeria and are relatively new. Each one of them is an ordinary Portland cement Type I whose properties conforms to AASHTO M 85 (2009). Type I Portland cement is suitable for general concrete construction and where no special properties are required. The cements were supplied in 50 kg per bag and were well protected in the laboratory from dampness by placing them on planks to avoid lumps development within the material. Each bag of cement when opened was used within 30 minutes for the purpose of casting the required specimens.

The relative density or specific gravity of cement used was determined according to ASTM C 188 (2015) whilst the bulk density was determined as its weight per unit volume. The cement fineness determination was carried out based upon percent passing the 0.045 mm sieve in accordance to ASTM C 430 (2008) procedure for comparison of the four different types of cements used for this research. The cement was subjected to initial and final setting time tests using measurements by the Vicat apparatus according to ASTM C 191 (2013). Atomic absorption spectrometer methodology with high performance of low detection limits and accuracy was adopted in the laboratory to carry out the cement chemical elements composition and metallic components using the absorption of optical radiation by free atoms in the gaseous state.

River sand from Lagos environs used was air dried in the laboratory at the average temperature of 34°C for the concrete production. The gradation test was performed on the sample that passed through sieve 9.5 mm and retained on 0.075 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, 0.15 mm and 0.075 mm were used for the fine sand grain-size classification. The specific gravity of the fine aggregate used was determined according to AASHTO T 85 (2009) specification.

25 mm granite quarried at Abeokuta environs in Ogun State of Nigeria and sold at Bariga in Lagos was air dried in laboratory for the purpose of sieve analysis tests and concrete production. In the process, a nest of sieves with apertures 37.5, 25 mm, 19.0 mm, 12.5 mm, 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.60 mm, 0.30 mm and 0.15 mm were appropriately used for grain-size classification of samples for the purpose of aggregate gradation. The test on size and gradation of coarse aggregates was performed according to AASHTO T 27 (2014). The specific gravity of the coarse aggregate used was determined separately according to AASHTO T 84 (2013) specification. The bulk density for the aggregates 25 mm granite used was determined separately according to AASHTO T 19 (2014) specification.

The kind of water used is drinkable and has no chloride ions as found in the concrete laboratory of the department of Civil and Environmental Engineering, University of Lagos.

2.2. Proportioning of the Concrete Mixtures

Four different types of cement used individually are of one normal cement type tagged 42.5Np and three rapid cement types tagged 42.5Rd, 32.5Rs and 32.5Rt water-cementitious material ratio (w/cm) used is 0.32 of which the portion of water is 0.31while that of CONPLAST SP430 superplastizer is 0.01. River sand and 25 mm granite aggregates were used whilst producing concrete with mixing ratio of 1:1.5:3 for highway pavement. For each cement type, concrete stiffness consistency and strength determination tests are based upon production of its specimens for flexural, compressive and tensile strengths. In the process each type of cement concrete is of 15 specimens of 550 mm x 150 mm x 150 mm beams, 6 specimens of 150 mm x 150 mm x150 mm cubes and 6 specimens of 300 mm x 150 mm cylinders. The total number of concrete beam specimens for flexural strength tests using the four cement types individually is 60 specimens. Also, the total number of concrete cube specimens for compressive strength tests using the four cement types individually is 24 specimens.

Correspondingly, the total number of concrete cylinder specimens for tensile strength tests using the four cement types individually is 24 specimens. Volume of each concrete specimen per batch Vcspb with entrainment air of 2 % and 7% wastage for each brand of cement is 0.222 m³ and for the four different types of cements is 0.888 m³ as shown in Table 1.

Table 1: Proportioning of the concrete mixture computation

	Water		CONPLAST SP430 Superplastizer			Cement	River Sand	Granite		Volume of each concrete specimen per batch with entrainment air of 2 % and 7% wastage, Vcspb = 0.2112(1-0.02+0.07) = 0.222 m³
Mix Ratio	0.31		0.01			1	1.5	3		
	water-cementitious material ratio (w/cm) = 0.32					1	1.5	3		
Concrete Tests	Flexural Strength					Compressive Strength		Tensile Strength		
Concrete Shapes and Dimensions	Concrete Beams					Concrete Cubes		Concrete Cylinders		
	(550 x 150 x 150) mm					(150 x 150 x 150) mm		(300 x 150) mm		
Curing Ages (Days)	7	28	56	91	120	7	28	7	28	
Powermax	3	3	3	3	3	3	3	3	3	0.222 m³
Dangote 3x	3	3	3	3	3	3	3	3	3	0.222 m³
Supaset	3	3	3	3	3	3	3	3	3	0.222 m³
5-Star	3	3	3	3	3	3	3	3	3	0.222 m³
Sub Total	12	12	12	12	12	12	12	12	12	
Total	60					24		24		0.888 m³

The proportion of water cement ratio, cement, fine aggregate and coarse aggregate determination was based upon the absolute volume method in order to ascertain the proportion that will probably give satisfactory strength, durability and economy when used for highway pavement. In the process of the absolute volume method, the specific gravity and bulk density of each material to produce concrete using a bag of 50 kg cement with other constituents was considered. Subsequently, the volume obtained to be useful at construction site is converted into weight for the determination of the batching of the concrete constituents for use in the laboratory. Portland cement concrete per batch V_{cb} of production is given by Equation 1 (Gambhir, 2004).

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

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

Table 2 gives expressions for the modalities of using Equation 1 for the possibility of obtaining absolute concrete volume V_{ca} per 50 kg bag of Portland cement in m³. It also gives absolute concrete weight W_{ca} in kg per batch by giving consideration to specific gravities and bulk densities of the materials used. In the process, the mixture to be used was firstly assumed in the proportion of part of cement as α of which its value is normally considered as 1. Also, the assumed proportions of fine aggregate, coarse aggregate and water-cementitious material ratio (w/cm) are respectively β , ω , w/c that is always less than 1. The bulk densities of water, cement, fine aggregate and coarse aggregate are γ_w, γ_c, γ_{fa} and γ_{ca} respectively with their respective specific gravities as Sw, Sc, Sfa and Sca. It is worthy of note that the bulk density of water solution for containing CONPLAST SP430 superplastizer as admixture γw is 1. Likewise, in the determination of the concrete production respective weights of constituents of water with admixture, cement, fine and coarse aggregates are defined as w, c, f_a and c_a respectively.

A useful modelling template for the determination of absolute weight of concrete per batching using 50 kg bag of cement is in Table 3 while employing Microsoft Excel Spreadsheet. Table 4 is simulation of Table 3 showing the values of absolute concrete weight for batching of 0.222 m^3 in terms of each concrete material constituent for w/cm of 0.32 per each type of cement used.

Table 2: Expressions for the computation of the absolute volume and absolute weight of concrete per batch

	B	C	D	E	F	G
3	Label	water-cementitious material ratio (w/cm)	Cement	Fine Aggregate	Coarse Aggregate	Sum
4	Assumed Ratio	w/cm	α	β	ω	
5	Bulk Density	γ_w	γ_c	γ_{fa}	γ_{ca}	
6	Applied Ratio by Weight	w/cm	α	$\frac{\beta\times\gamma_{fa}}{\gamma_c}$	$\frac{\omega\times\gamma_{ca}}{\gamma_c}$	
7	Specific Gravity	S_w	S_c	S_{fa}	S_{ca}	
8	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
9	Applied Ratio by Volume	j/k	k/k	l/k	m/k	
10	Constituents proportioning for Volume of each concrete specimen per batch with entrainment air of 2 % and 7% wastage, Vcspb m^3	j/ Vca* Vcspb	k/ Vca*V	l/ Vca*V	m/ Vca* Vcspb	Vcspb
11	Absolute 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
12	Absolute concrete weight Wca for one bag of cement	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
13	Absolute concrete weight Wca for less than one bag of cement	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

Table 3: Modelling of absolute volume and absolute weight of concrete per batch of 0.32 water cement ratio

	B	C	D	E	F	G
3	Label	(w/cm)	Cement	Fine Aggregate	Coarse Aggregate	
4	Assumed Ratio	0.32	1	1.1025	2.28817	
5	Bulk Density	1000	1109	1509	1454	
6	Applied Ratio by Weight	=C4*D5/D5	=D4*D5/D5	=E4*E5/D5	=F4*F5/D5	
7	Specific Gravity	1	3.15	2.61	2.71	
8	Absolute concrete volume Vca, per 50 kg cement bag, m³	=C6*50/1000/C7	=D6*50/1000/D7	=E6*50/1000/E7	=F6*50/1000/F7	=SUM(C8:F8)
9	Applied Ratio by Volume	=C8/D8	=D8/D8	=E8/D8	=F8/D8	

10	Constituents proportioning for Volume of each concrete specimen per batch with entrainment air of 2 % and 7% wastage, Vcspb m^3	=C8/\$G\$8*\$G\$10	=D8/\$G\$8*\$G\$10	=E8/\$G\$8*\$G\$10	=F8/\$G\$8*\$G\$10	0.222
11	Absolute concrete weight Wca for a unique production batch	=D11*C6	=G10/G8*50	=D11*E6	=D11*F6	=SUM(C11:F11)
12	Absolute concrete weight Wca for one bag of cement	=D12*C6	=G8/G8*50	=D12*E6	=D12*F6	=SUM(C12:F12)
13	Absolute concrete weight Wca for less than one bag of cement	=D12*C6*(G10-G8)/G8	=(G10-G8)/G8*50	=D12*E6*(G10-G8)/G8	=D12*F6*(G10-G8)/G8	=SUM(C13:F13)

Table 4: Simulation of absolute volume and absolute weight of concrete per batch in relationship to Table 3 Applied Ratio by Weight

	B	**C**	**D**	**E**	**F**	**G**
3	Label	Water	Cement	Fine Aggregate	Coarse Aggregate	
4	Assumed Ratio	0.320	1.000	1.103	2.288	
5	Bulk Density	1000	1109	1509	1454	
6	Applied Ratio by Weight	0.320	1.000	1.500	3.000	
7	Specific Gravity	1	3.15	2.61	2.71	
8	Absolute concrete volume per 50 kg cement bag, m^3	0.016	0.016	0.029	0.055	0.116
9	Applied Ratio by Volume	1.008	1.000	1.811	3.487	
10	Constituents proportioning for absolute concrete volume of 0.222 m^3	0.031	0.030	0.055	0.106	0.222
11	Absolute concrete weight for 0.222 m^3 volume	30.631	95.721	143.596	287.163	557.110
12	Absolute concrete weight for 0.116 m^3 volume	16.000	50.000	75.008	150.000	291.008
13	Absolute concrete weight for 0.106 m^3 volume	14.631	45.721	68.588	137.163	266.103

2.3 Materials Batching and Concrete Specimens Production

Batching of the mixture started through measuring and pouring concrete constituents into the rotating mixer as proportioned in Table 5. The rotating mixer was charged with 10% of the required water solution followed by 50% of the coarse aggregate, then 100% of the fine aggregate and followed by 100% cement and then the remaining 50% of the coarse aggregate. 80% of water required was added to the rotating mixer for a minimum total mixing time of 4 minutes before the mixture was let out from the rotating drum. 10% of the water remaining was later pour into the rotating mixer and allowed to rotate for 30 seconds and the water together with the remaining constituent were poured out directly on top of the concrete mixture already on the platform. The use of the rotating mixer was based upon mixing required ingredients per one bag of Portland cement.

Thorough hand mixing was done for uniform concrete colour and there after it paved way for placing of the concrete finally into the required moulds to produce specific specimens. The moulds for concrete casting were duly primed with grease as a lubricator for easy removal of the concrete specimens. Batching of the mixture using the rotating mixer was carried out two times before the primed moulds that produced a set of the required specimens of 15 numbers of 150 mm x 150 mm x 550 mm beams, 6 numbers of 150 mm x 150 mm x 150 mm cubes and 6 numbers of 150 mm x 300 mm cylinders.

Demoulding of the specimens was carried out about 24 hours of casting and then cured. Curing of the specimens was done by placing them into clean water inside a tank having the average temperature of $23\pm1.7°C$ till the day of testing. The remaining 3 sets of specimens based on their concrete constituents were carried out similarly for batching, mixing, handling of the fresh concrete for making samples and curing but not on the same day because of the availability of specimen moulds and space inside the laboratory.

Table 5: Absolute weights of concrete constituents per batch of using one bag of cement

Cement Types	42.5Np	42.5Rd	32.5Rs	32.5Rt
Cement, kg	50	50	50	50
Water, kg	0.31 x 50 = 15.5	0.31 x 50 = 15.5	0.31 x 50 = 15.5	0.31 x 50 = 15.5
CONPLAST SP430 superplastizer, kg	0.01 x 50 = 0.5	0.01 x 50 = 0.5	0.01 x 50 = 0.5	0.01 x 50 = 0.5
River Sand, kg	75	75	75	75
Granite, kg	150	150	150	150

2.4 The Slump and the Compacting Factor Tests

The slump and the compacting factor tests were carried out 10 minutes of finishing concrete mixture. The slump test was carried out in accordance to AASHTO T 119 (2013). Sump test is useful in order to define the fresh concrete produced as to the choice of the state of production which consistency could be described as being high or of medium state.

The compacting factor test was also carried out according to BS 1881 (2011). The compacting factor test helps to define the fresh concrete of medium or of low workability. The compacting factor value was calculated by dividing the partially compacted concrete weight by that of the fully compacted concrete of which the value is always less than 1.

2.5 Compression Strength Test

The 150 mm x 150 mm x 150 mm concrete cubes were tested at 7 and 28 days after being removed from the clear water curing tank and dried for few hours in accordance to BS EN 12390 (2009). The cubes were tested using a calibrated compression machine inside the laboratory as in Figure 2 under the care of competent personnel. Each cube tested has the face perpendicular to the casting face and the machine exerts a constant compressive progressing force on the cube till it fails at a loading rate of 0.6 ± 0.2 N/mm²/s. The maximum compressive strength of the concrete is based upon the reading at failure.

Figure 2 *Compression strength test machine*

2.5. Flexural Strength Test

A sample of beam 550 mm by 150 mm by 150 mm was tested on a universal testing machine on two supporting pins of 400 mm distance with two loading pins of 200 mm at equal distance around the centre. The simply supported specimen has overhang distance of 75 mm as shown in Figure 2 to pave way for flexural strength test according to ASTM C 78 (2016).

Figure 3 *Flexural strength test machine*

The load was applied continuously and without shock at a rate of 200 m/s and the flexural strength, R or modulus of rupture was then calculated using the following formula Mamlouk and Zaniewski (2006).

$$T = \frac{3PL}{4bd^2} \qquad (2)$$

P = maximum load, N
L = span length, mm
b = specimen width, mm
d = specimen depth, mm

2.6 Tensile Splitting Strength Test

Each hardened concrete cylinder specimen of 150 mm diameter by 300 mm high was subjected to a compressive load for testing at a constant rate of 400 N/s along the vertical diameter until failure occurred in accordance to ASTM C 496 (2011) as shown in Figure 4.

Figure 4*Tensile splitting strength test*

Calculating the splitting tensile strength of the hardened specimen tested is as follows Mamlouk and Zaniewski (2006):

$$T = \frac{2P}{\pi ld} \quad (3)$$

Where:

T = splitting tensile strength, MPa

P = maximum applied load indicated by the testing machine, N

l = length, mm

d = diameter, mm

3. RESULTS AND DISCUSSIONS

The constituents of different types of individual concrete produced in this study are based upon four different types of cement but same fine aggregate, coarse aggregates, water and CONPLAST SP 430 superplastizer admixture. Comparisons are discussed of the four types of cement used along with their individual concrete production including fresh and hardened concrete tests in relationship to the standard specification requirements for highway pavement material properties for design and construction.

3.1 Properties of the Cements Examined

Table 6 shows the results of the compressive strength test on cement pastes of which at day 3 curing the compressive strength of cement brand 32.5Rt has the highest value while that of 32.5Rs has the lowest amount. At day 7 curing test compressive strength of cement brand 32.5Rs has the highest value while that of 42.5Rp has the lowest amount.

At day 14 curing test compressive strength of cement brand 32.5Rs and 32.5Rt both have the lowest value while 42.5Rp has the highest amount. Also at day 28 curing test compressive strength of cement brand 32.5Rs and 32.5Rt both have the lower value while both brands 42.5Np and 42.5Rd have the higher value.

The results upon research on the oxide compositions of the four brands of the Portland cement employed individually are presented in Table 7. CaO and SiO_2 in each of the four brands of cement used represent more than 80% of oxide composition and hence satisfied the standard specification requirements. The conditions at which each mineral in percentages at which each cement oxide composition satisfied standard specification requirements are elucidated in Table 7. It could be seen in Table 7 that all the four brands of cements satisfactorily complied with the standard specification requirements upon oxide composition of ordinary Portland cement. However, it is obviously shown in Table 7 that the values of Aluminium Oxide Al_2O_3 and Ferric Oxide Fe_2O_3 of normal Portland cement tagged 42.5Np are higher than those of the other cements that are of rapid-hardened cement. Also, the cement brand 32.5Rt values of Na_2O and K_2O that are close to the maximum specification required value is an indication that the alkalis can react with certain aggregates and affect its rate of concrete strength development and as well cause its disintegration.

As shown in Table 8, since the values of C_3S and C_2S of cement brand 42.5Np are within the specification requirements range, this is a confirmation that it is a normal Portland cement while the other three brands 42.5Rd, 42.5Rd and 32.5Rt are rapid Portland cement. Although for cement brand 42.5Np has the value of C_3A high for being at the maximum of specification requirement this can lead to an immediate stiffening of concrete paste and a rapid setting but it could be retarded by the presence of gypsum. Also, the value of C_4AF in each of the four cements is very low compared to the minimum standard specification requirement although it will not contribute much to the rapid hydration of the cement.

As seen in Table 9, Portland cement brand type tagged 32.5Rt has the lowest value of initial setting time while 42.5Rd has the highest of it and they all individually satisfied standard specification requirements for same. Also, considering the final setting time for each of the cement used, 42.5Rd has the highest value while 32.5Rt is of the lowest whilst they all satisfied standard specification requirements for same. On the issue of fineness, 42.5Np has the lowest value of cement in percentage that passed through 45 μm while 32.5Rt has the highest. Value obtained for each of the employed cement upon specific gravity and bulk density satisfied standard specification requirements.

However, value obtained for each of the cement used upon insoluble residue did not satisfy standard specification requirements. It could be seen in Table 9 that cement tagged 42.5Np and that of 32.5Rt could not satisfy the standard requirement for loss of cement ignition whereas those of 42.5Rd and 32.5Rs did.

Table 6: Compressive strength test on cement pastes (N/mm²)

Cement Brands	Curing Ages in Days				Cement Brands	Curing Ages in Days			
	3	7	14	28		3	7	14	28
42.5Np	11.70	11.82	12.37	13.03	32.5Rs	11.22	12.16	12.30	12.57
42.5Rd	11.70	11.96	12.57	13.03	32.5Rt	11.77	11.83	12.30	12.57

Table 7: Oxide composition in % for the four cements

Mineral (%)	Cement Types				Specification Requirements	Remarks in relationship to specification requirements
	42.5Np	42.5Rd	32.5Rs	32.5Rt		
Calcium CaO	63.82	64.25	63.74	66.07	60.66 - 66.30	All the four brands of cement complied
Silica SiO_2	22.21	19.16	20.35	21.23	18.70 - 22.00	Cement brand 42.5Np has value higher than standard while other brands complied
Aluminium Oxide Al_2O_3	6.08	4.92	4.48	4.75	4.70 - 6.30	Cement brand 32.5Rs has value lower than standard while other brands complied
Ferric Oxide Fe_2O_3	1.24	0.75	0.91	0.98	1.60 - 4.40	None of the four brands of cement complied
Magnesium Oxide MgO	2.75	2.17	2.04	3.65	0.50 - 40	All the four brands of cement complied
Sulphite SO_3	1.23	1.02	1.14	1.32	1.80 - 4.6	None of the four brands of cement complied
Sodium Oxide Na_2O	0.50	0.40	0.64	1.14	0.11 - 1.20	All the four brands of cement complied
Potassium Oxide K_2O	0.30	0.35	0.39	0.81	0.11 - 1.20	All the four brands of cement complied

Table 8: Portland cements and their corresponding calculated chemical composition

Compound Composition	42.5Np	42.5Rd	32.5Rs	32.5Rt	Specification Requirements	Remarks in relationship to specification requirements
Tricalcium Silicate, C_3S	44.82	78.83	70.11	70.19	40 - 63	Only cement brand 42.5Np complied of the four cements
Dicalcium Silicate, C_2S	29.95	4.45	5.54	8.01	9 - 31	Only cement brand 42.5Np complied of the four cements
Tricalcium Aluminate, C_3A	14.00	11.77	10.33	10.93	6 - 14	All the four brands of cement complied
Tetracalcium Aluminoferrite, C_4AF	3.77	2.28	2.77	2.98	5 - 13	None of the four brands of cement complied

Table 9: Other parameters of the four brands of the Nigerian produced cements

Parameters	**42.5Np**	**42.5Rd**	**32.5Rs**	**32.5Rt**	**Specification Requirements**
Initial Setting Time, minutes	2hrs. 32 mins	2hrs. 37 mins	2hrs. 6 mins	1hr. 45 mins	45 minimum
Final Setting Time, minutes	4hrs. 11 mins	4hrs 40 mins	3hrs. 30 mins	3hrs. 10 mins	375 maximum
Fineness, % retained on 45 μm	8	8	13	15	10 maximum
Fibre	0.00	0.00	0.00	0.00	
Specific Gravity γ_G	3.15	3.15	3.15	3.15	3.13-3.15
Bulk Density, γ_b kg/m3	1109	1110	1108	1011	1000-1300
Insoluble Residue, IR	99.40	99.56	99.38	99.60	99.95-99.97
Loss of Ignition , LOI	0.03	0.05	0.05	0.03	0.04-0.05
Standard consistency time	3 mins	3 mins	3 mins	3 mins	
Standard consistency	31.3%	32.5%	33.8%	32.5 %	

3.2 Properties of the aggregates examined

Table 10 shows both fine and coarse aggregates characteristics used in the course of laboratory concrete production for this study. The values of the river sand fine aggregate in relationship to particle percentages and fineness modulus show that it is of coarser material. Also, based on the values of coefficient of uniformity and coefficient of curvature, both the river sand and the 25 mm granite used is of uniformly graded aggregates. It could also be seen in Table 10 that the bulk density value of the river sand is higher than that of the 25 mm granite whilst specific gravity value of the former is lower than that of the later material. The water absorption of the fine aggregate used is greater than that of the 25 mm granite. The water absorption of the fine aggregate used is higher than that of the coarse aggregate thus the total surface area of the former material is more than that of the later. The values in percentages of aggregate crushing, impact and Los Angeles abrasion resistance are quite acceptable quality for concrete production. Also, Figures 4 and 5 show grain size distribution curves for the employed fine aggregate river sand and the coarse aggregate 25 mm granite for the purposes of defining the level at which they satisfied standard specifications.

Table 10: Properties of aggregates used in this study

S/No	Physical Properties	Fine Aggregate River Sand	Coarse Aggregate 25 mm Granite
1	Percent of particles retained on the 4.75 mm sieve	1	100
2	Percent of particles passing the 4.75 mm sieve	98.47	0
3	Percent of particles passing the 0.075 mm sieve	0.53	0
4	Fineness modulus	3.000	-
5	Coefficient of uniformity (Cu)	2.900	1.840
6	Coefficient of curvature (Cc)	1.060	1.256
7	Bulk density	1509.000	1454.000
8	Specific gravity	2.610	2.710
9	Moisture (water) absorption (%)	1.167	0.476
10	Aggregate crushing value (%)	-	18.137
11	Aggregate impact value (%)	-	10.009
12	Los Angeles abrasion value (%)	-	14.016

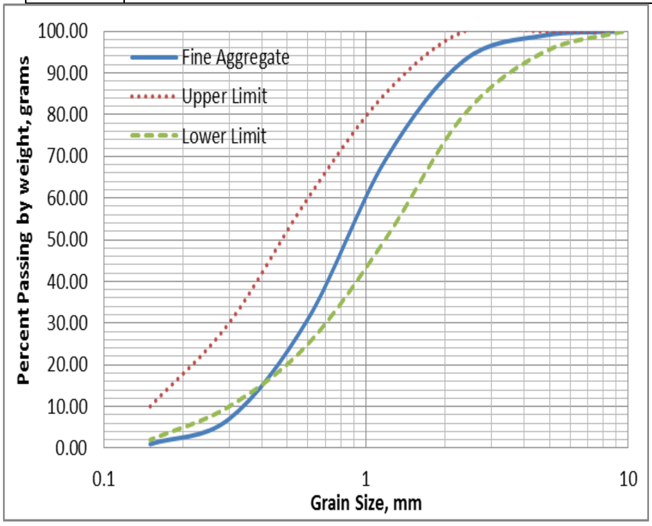

Figure 4: The fine aggregate river sand grain size distribution curve

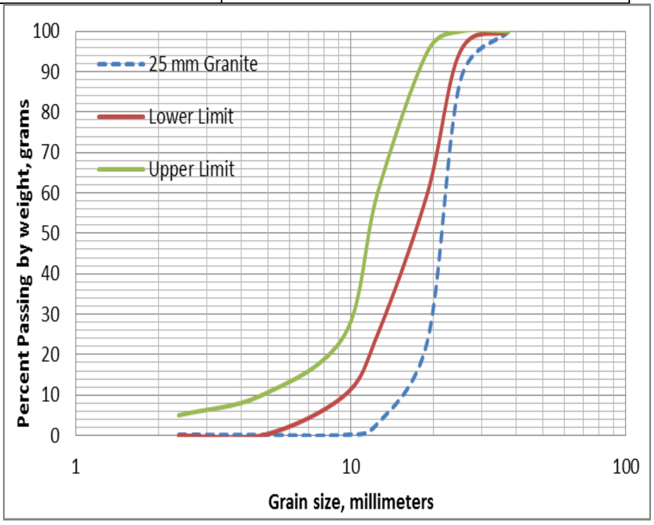

Figure 5: The coarse aggregate 25 mm granite grain size distribution curve

3.3 Properties of the fresh concrete produced

Fresh concrete production per batch was based upon using one bag of cement and w/cm of 0.32 (0.31 water cement ratio and 0.1 CONPLAST SP 430 superplastizer admixture cement ratio) by 1:1.5:3 concrete mix ratio. The slump test results in Table 8 showed that individual cement attained very low (stiff) degree of workability. On the other hand as shown in the Table, the compacting factor test gave results upon degree of workability as very low (stiff) while using cement tagged 42.5Np but Low (Stiff Plastic) for employing 42.5Rd, 32.5Rs and 32.5Rt.

Table 8: Slump and compacting factor values obtained upon examined fresh concrete

Cement Brands	Slump Test Results		Compacting Factor Test Results	
	Slump Value (mm)	Degree of Workability	Compacting Factor	Degree of Workability
42.5Np	10	Very Low (stiff)	0.79	Very Low (stiff)
42.5Rd	12	Very Low (stiff)	0.81	Low (Stiff Plastic)
32.5Rs	15	Very Low (stiff)	0.82	Low (Stiff Plastic)
32.5Rt	17	Very Low (stiff)	0.83	Low (Stiff Plastic)

3.4 Properties of the Cast Hardened Concrete Specimens

Flexural strength values obtained on testing hardened beam concrete specimens produced in the course of this research are shown in Table 9. It is only concrete produced with 42.5Np that attained value higher than the minimum standard specification that is 4.5 N/mm² at 28 day water curing.

Table 10 is showing percentages of flexural strength using 28 days curing as the base upon the ability of the concrete development in relationship to ages. While comparing 28 days strength to that of 120 days of curing, specimens of cement 42.5Np has flexural strength increment of less than 20% but cements 42.5Rd, 32.5Rs and 32.5Rt have increment range of 40% to 45%. This is an indication that concrete made of the cement tagged 42.5Np attained reliable higher strength faster than those of other three cements whilst also making best useful for highway pavements based upon this research.

The results of concrete cube specimens for compressive strength tests produced using 42.5Np, 42.5Rd, 32.5Rs and 32.5Rt cement brand upon 7 days cure are 71%, 69%, 68% and 69% respectively in relationship to 28 days of curing of which none is up to the required 75% as showing in Table 11.

Also as showing in Table 11, the results of concrete cylinder specimens for tensile strength tests produced using 42.5Np, 42.5Rd, 32.5Rs and 32.5Rt cement brand upon 7 days cure are 68%, 68%, 68% and 73% respectively in relationship to 28 days of curing of which none is up to the required 75%.

Table 9: Flexural strength values obtained upon hardened concrete tests

Cement Brands	Flexural Strength N/mm²				
	Curing ages				
	7 days	28 days	56 days	91 days	120 days
42.5Np	4.800	5.274	5.917	5.926	6.163
42.5Rd	3.674	4.208	5.067	5.570	6.104
32.5Rs	3.526	3.733	4.533	4.889	5.215
32.5Rt	3.378	3.496	3.881	4.415	4.918

Table 10: Relative flexural strength of concrete produced by the different types of cements employed individually

Cement Brands	Percent of flexural strength using 28 days curing as the base			
	28 days curing	56 days curing	91 days curing	120 days curing
42.5Np	100	112	115	117
42.5Rd	100	120	132	145
32.5Rs	100	121	131	140
32.5Rt	100	111	126	141

Table 11: Compressive strength and tensile strength values obtained upon hardened concrete tests of mix ratio (1:1.5:3)

Cement Brands	Compressive Strength N/mm²		Tensile Strength N/mm²	
	Curing ages		Curing ages	
	7 days	28 days	7 days	28 days
42.5Np	18.888	26.67	1.899	2.78
42.5Rd	17.628	25.63	1.687	2.48
32.5Rs	17.479	25.56	1.435	2.10
32.5Rt	17.387	25.11	1.398	1.89

4. CONCLUSIONS AND RECOMMENDATIONS

Four different types of Portland cement concrete specimens were tested individually for flexural, compressive and tensile strengths. The four different types of Portland cement used are Nigerian made kinds and are tagged 42.5Np, 42.5R, 32.5Rs and 32.5Rt. River sand, 25 mm granite, drinkable water and CONPLAST SP 430 superplastizer admixture were added proportionately in the course of the production of each type of the four different cement concrete. Flexural strength tests were carried out on each of the 60 numbers of 150 mm by 150 mm by 550 mm beam. Also, each of the 24 number of the 150 mm by 150 mm and 150 mm cube concrete specimens produced was tested for compressive strength. In addition, tensile strength tests were carried out on each of the produced 24 numbers of the 150 mm by 300 mm cylinder concrete specimens.

4.1 Conclusions

The following are the conclusions proffered based on laboratory experiments in this study.

1. The four different types of Portland cement produced in Nigeria tagged 42.5Np, 42.5R, 32.5Rs and 32.5Rt that were examined in the course of this research compared satisfactorily at very good level with ASTM, AASHTO and British relevant standard specification requirements upon its chemical and potential compound compositions. Parameters defined out from each of the Portland cement used including initial and final setting times, fineness, specific gravity, bulk density, insoluble residue and loss of ignition also compared favourably well with the relevant specification standards.
2. Since the percent of particles of the river sand that retained on the 4.75 mm sieve is 1% whilst percent of particles passing the 4.75 mm and 0.075 mm individual sieve sizes are respectively 98.47% and 0.53% confirmed the material as a useful fine aggregate. Also, for the fineness modulus value of the fine aggregate used to be 3 concludes that it is a coarser material. The coefficient of uniformity and that of curvature are respectively 3.0 and 2.9 which concludes that the material is uniformly graded fine aggregate.
3. In as much as the granite with the maximum size of 25 mm used has percent of particles retained on the 4.75 mm sieve to be 100% is an indication that the material is a coarse aggregate. Also as the coefficient of uniformity and that of curvature are respectively 1.84 and 1.256 is a conclusion that the material is a uniformly graded coarse aggregate. Aggregate crushing, impact and Los Angeles abrasion values that are respectively 18.137%, 10.009% and 14.016% are indications that the coarse aggregate employed has ability to resist damaging effect of traffic loads based upon satisfactorily toughness and hardness it exhibited.
4. The degree of workability defined by slump test results of the concretes made by the four cement brands tagged 42.5Np, 42.5R, 32.5Rs and 32.5Rt is of very low with intent that they are all worthy of providing satisfactory highway pavement materials. However, only concrete made using 42.5Np cement brand of the four brands met the worth of very low degree of workability that is worthy of appropriate highway pavement design and construction.
5. The flexural strength values obtained at 28 days curing for the concretes made by the four cement brands tagged 42.5Np, 42.5R, 32.5Rs and 32.5Rt individually are respectively 5.274 N/mm², 4.208 N/mm², 3.733 N/mm² and 3.496 N/mm². It is pertinent to note that only concrete made of the cement tagged 42.5N satisfied the required minimum standard flexural strength specification value of 4.5 N/mm² at 28 days of curing.
6. Also, considering the concrete produced upon the compressive strength in this study, the values obtained only satisfied the minimum specified standard specification value of 21 N/mm² at 28 days of curing

but they could not satisfy the required minimum standard specification value of 28 N/mm².

7. Considering the concrete tensile strength obtained in this research, specified minimum standard specification amount of 2.1 N/mm² was satisfied in the use of cement brands tagged 42.5Np, 42.5R and 32.5Rs only. However, each of the tensile strength value could not satisfy the required minimum standard specification amount of 2.95 N/mm².

4.2 Recommendation

The laboratory experiments carried out in this research have allowed submitting the following recommendations based upon.

1. Table 2 is a useful paradigm of using expressions for the computations of the absolute volume and weight of a batch for concrete production involving the use of CONPLAST SP 430 superplastizer admixture. 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.

2. 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.

3. Table 4 is showing the simulation of Table 3 of which it is important to identify the difference between the applied ratios by weight that is useful in the laboratory for research work or manufacturing yards for construction sites and whilst by volume which is beneficial at the construction site labour work.

4. Only the use of 1:1.5:3 of cement tagged 42.5Np, river sand used in this research and 25 mm granite with water-cementitious material ratio 0.32 (water 0.31 and CONPLAST SP 430 superplastizer 0.1) is recommended satisfactorily for highway rigid pavement construction.
5. This research work has shown that the result of workability by compacting factor test is related at a higher degree than that of slump test in relationship to strength tests.

REFERENCES

1. AASHTO M 85 (2009): *"Standard Specification for Portland cement (Chemical and Physical)",* American Association of State Highway and Transportation Officials, Washington, D.C

2. AASHTO T 119 (2013): *"Standard Method of Test for Slump of Hydraulic Cement Concrete",* American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

3. AASHTO T 19 (2014): *"Standard Method of Test for Bulk Density ('Unit Weight') and Voids in Aggregate",* American Association of State Highway and Transportation Officials, Washington, D.C

4. AASHTO T 27 (2014): *"Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates",* American Association of State Highway and Transportation Officials, Washington, D.C

5. AASHTO T 84 (2013): *"Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate",* American Association of State Highway and Transportation Officials, Washington, D.C

6. Akiije, I. (2016): *"Effects of Using 0.5, 0.55 and 0.6 Water Cement Ratio Separately with a Nigerian Grade 42.5R Portland Cement,"* International Journal of Science, Technology and Society; Vol. 4, No. 6, 2016, pp. 80-88.

7. ASTM C 188 (2015): *"Standard Test Method for Density of Hydraulic Cement, density, hydraulic cement, specific gravity",* American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

8. ASTM C 191 (2013): *"Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle",* American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

9. ASTM C 430 (2008): *"Standard Test Method for Fineness of Hydraulic Cement by the 45-µm (No. 325) Sieve",* American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

10. ASTM C 496 (2011): *"Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, cylindrical concrete specimens, splitting tension, tensile strength",* American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

11. ASTM C 78 (2016): *"Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)",* American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

12. BS 1881 (2011): *"Testing concrete",* British Standards Institution, London

13. BS EN 12390 (2009): *"Testing Hardened Concrete - Making & Curing Specimens for Strength Tests",* British Standards Institution, London

14. Falade, F. (1999): *"Effects of separation of grain sizes of fine aggregate on properties of concrete containing granite fines",* Journal of the University of Science and Technology, Kumasi, Volume 19 Nos. 1, 2 & 3

15. Fosroc (2016): *"Conplast SP430",* http://www.fosroc.com/product/show/conplast-sp430-accessed February 26, 2016

16. King, D. (2007): *"Supporting a Sustainable Future with Microsilica Concrete",* Proceedings of the 32nd Conference on Our World of Concrete & Structures, Conference Theme: Ready-mixed Concrete Technology, Singapore, 28-29 August, 2009, Conference documentation XXVI, pp 33-42.

17. Mamlouk, M. M and Zaniewski, J. P. (2006): *"Materials for Civil and Construction Engineers"*, Pearson Education, Inc., Upper Saddle River, New Jersey

18. Wright, P. H and Dixon, K. H. (2004) "*Highway Engineering*", John Wiley and Son, New York, NY, USA, 7th edition