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STRENGTH VARIABILITY OF SOME COMMON PORTLAND CEMENT USED IN FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

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Abstract : This paper reports an experimental investigation into the strength variability of six common brands of ordinary Portland cement (Burham, Ashaka, Dangote, Elephant, Sokoto and Lion) used in and around Federal Capital Territory, Abuja, Nigeria. Test was also conducted on properties such as fineness, standard consistency, soundness, and setting time of these cements. The result of the experiment shows that the properties were within the specified range and for mix proportions of cement, fine and coarse aggregate in the ratio 1:2:4 and water cement ratio of 0.5, at 7-day and 28-day compressive strength of concrete made from the six brands of cement varies in the range of 16.97 – 30.68 and 22.76 – 40.19 N/mm^2 and characteristic strength of 14.28 – 26.99 and 19.88 – 37.03 N/mm^2 respectively. The results were compared with acceptable minimum British Standard (BS) specification, which stipulated that at 7-day curing period, compressive strength should not be less than 14.0 N/mm^2; and at 28-day compressive strength should not be less than 26.0 N/mm^2. At 28-day curing period, the result of the experiment shows that Burham cement concrete has the highest compressive strength of 40.19 N/mm^2, followed by Ashaka cement concrete with 28.81 N/mm^2 and Lion cement concrete has the lowest with 22.76 N/mm^2. Codes also specified characteristic strength of OPC concrete at 7-day to be 16. 5 and at 28-day strength should not be less than 25N/mm^2 respectively. At 28-day it is only Burham, Ashaka and Dangote cement concrete that have their strength value within this range with characteristic strength values of 37.03, 26.29 and 25.42 N/mm^2 respectively. Concrete of inadequate strength will not protect reinforcement bars against severe weather and will be less fire resistant, thus the durability of such reinforced concrete structures will be severely impaired.

Introduction

The term cement is restricted to the bonding material used with stones, sand, bricks, blocks and so on for construction purposes. [1,2,3,12]. The importance of the study into the strength of ordinary Portland cement cannot be over emphasized, because cement is the most popular construction material used extensively in the construction industry in Nigeria and of course globally. Ordinary Portland cement is the cement best suited to general concreting and building purposes [1]. The chemical reaction will not occur until cement comes in contact with water. This result is what is generally referred to as the cement paste which forms a medium of cohesion and bondage in the preparation of concrete and other building materials. Cement is most widely used construction material, and it is difficult to point at another construction material which is as versatile as cement. This has made concrete and other building materials produced from cement to be choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required [15, 16]. Cement and the product made from it are so closely associated with every human activity that it touches every human being in his day-to-day living [16].

The cement of interest in the making of concrete,, bricks, blocks and other building materials have the property of setting and hardening under water by virtue of a chemical reaction with it and are, therefore called hydraulic cement [9]. Physical properties of cement such as fineness,

Keywords : Cement, fineness, consistency, soundness, setting time, properties, strength.

soundness, consistency and setting time contribute to the strength of the building materials made out of it [5, 7, 17].

In construction works, some brands of cement are often neglected in preference to others. The complaint has been that when certain brands are used, cracks often appear and that some brands do set on time. In block moulding industries, the complaint also has been that blocks made with some brands are often of very weak strength. The fineness to which the raw materials are grounded affects the soundness of the cement [5, 6, 7]. Cement is said to be unsound if excessive expansion of some of the constituents occurs after the cement has set and such expansion causes cracking, destruction and disintegration of the mass (4,19,20).

According to [4,17,19,20,22], the initial setting time is defined as the interval between the time when water is added to the cement and the time when the paste will just withstand a prescribed pressure. Similarly, the final setting time is defined as the interval between the time when water is first added and that when the paste has further stiffened to be able to withstand a higher prescribed pressure.

In view of the problems associated with the usage of some brands of ordinary Portland cement, a clear understanding of properties of various brands of Portland cement is necessary in order to determine the factors that affect the attainable strength of cement and compares it with the relevant standard [16]. Therefore the objectives of this study were to determine the factors that affect the attainable strength of OPC commonly used in construction works in Federal Capital territory, Abuja, Nigeria with a view to finding any deficiency or otherwise and compare it with the relevant standards and specifications. Concrete of prescribed proportions, made with specified materials under strictly controlled conditions were used for the purpose of determining the compressive and characteristic strengths respectively. Crushing strengths of between 20 and 50 N/mm^2 at 28 days are normally obtained on site with reasonably good supervision, for mixes roughly equivalent to 1:2:4 of cement, sand and coarse aggregate [3, 8,14].

Materials and Methods

The fineness, consistency soundness, setting time, compressive and characteristic strength of some brands of OPC which are found in FCT, Abuja and its environs were determined, and these brands of OPC are. Durham, Ashaka, Dangote, Elephant, Sokoto and Lion cement.

Materials

The materials (cement, fine and coarse aggregates, and water) used for the purpose of this research were selected and tested according to British Standard (BS) and American Society for Testing Materials (ASTM) recommended standards and procedures.

Cement : The principal focus of this research work is cement. The cement sample used in the process of the research is the ordinary Portland cement of six different brands (Burham, Dangote, Ashaka, Elephant, Lion and Sokoto). They were obtained from local distributors in and around FCT, Abuja, Nigeria, but care was taken to ensure that they were of recent supply and free of adulteration. The five brands of cement used are to BS 12:1991 specifications.

Fine aggregate : Fine aggregate are those that pass through 4.75mm BS sieve. The fine aggregate used is the upstream river bed fine sand, obtained from river Chanchaga, Minna, Niger State, Nigeria. It was found to be under standard F-classification and the sample falls under the grading limit of zone 2 of BS 882: 1972 after sieve analysis using the method of sieve analysis in accordance to BS 812: Part 3: 1975, BS 812: Part 103-1:1985 respectively.

Coarse aggregate : Coarse aggregate are those retained on 4.75mm BS sieve. The coarse aggregate used was made of crushed granite. The maximum size of the aggregate used falls within 25mm and 20mm using the method of sieve analysis in accordance to BS 812: Part 3: 1975, BS 882: 1972 recommendations and specifications.

Water : Water helps in rinsing, diluting of sample and also for mixing and curing of concrete. The water used for mixing and curing of the concrete was potable water, free from impurities such as silt, alkaline salt, clay, acid and organic matter.

The fineness, consistency, soundness, setting time, compressive and characteristic strengths of the various brands of OPC were determined.

Methods

The fineness test was conducted in accordance with BS 812: Part 103-1:1985 and BS 4550: Part 3: 1978 and ASTM C respectively using 45, 90 and 300 micro meters, weighing balance, weighing pan, sieve machine (mechanical shaker), spatula, brush, pestle and mortar. The residue retained was obtained by deducting the weight of the sieve from the measured weight of the sieve and then the percentage of residue was calculated. This was done y. Twenty test samples were conducted for each brand of cement.

$$\text{Fineness} = \frac{M_4 \quad M_1}{M_2} \quad 100 \tag{1}$$

Where M_1-Mass of sieve, M_2 - Mass of cement, M_3 - Mass of receiver, M_4 - mass of sieve + sample retained, M_5 -Mass of receiver + sample retained, M_4 - M_1 - mass of cement retained on sieve.

The consistency is a measure of water of wetness of fluidicity. The normal consistency of given cement is defined as the water content of cement paste giving a penetration of 5-7mm above the bottom of 10mm diameter plunger using vicat apparatus. Consistency of cement was conducted to determine the percentage of water required for preparing cement pastes of standard consistency for other tests. The consistency test was carried out using vicat apparatus, stop watch, plunger, spatula, electronic weighing balance, non-porous plate, vicat mould and measuring ruler. The test was carried out in accordance to BS 12: 1978, BS 4550: Part 3:1978 and ASTMC respectively. Standard consistency (y) is expressed as :

$$y \quad \frac{M_2}{M_1} \quad 100 \tag{2}$$

Where M_1-Mass of cement. M_2- Mass of water.

The soundness test was carried out using the Le-Chatelier apparatus, glass plate, heating appliance, mixing board plate, spatula, dish in carrying moulds, small weight of 100g, burette, thermometer water bath and lubricant. The test also was carried out in accordance to BS 4550: Part 3: Section 3.7: 1978 and ASTM C recommendations and specifications. Empirically soundness is expressed as :

$$\text{Soundness} = D_3 - D_2 \tag{3}$$

Where D_1 - Diameter of empty mould = 40mm, D_2 - Diameter of mould and sample before boiling, D_3 -Diameter of mould and sample after boiling,

The setting time was carried out using vicat apparatus, ring mould, gauging trowel, weighing pan, weighing balance, spatulas, stop watch, non-porous plate and 1mm square needle in accordance to BS12: 1991 and BS 4550: 1979 respectively. The setting is divided into two parts namely, the initial and final setting times. The time at which the cement paste loses its plasticity is termed initial setting time and time taken to reach the stage when the paste becomes a hard mass is known as final setting time Initial and final setting times were expressed as :

$$\text{Initial and Final setting times} = T - 1. \tag{4}$$

Where t - Initial time, T - Stopping time.

The crushing test for the compressive strength was carried out in accordance to BS 1881: Part 116:1983. A mix ratio of 1:2:4 and water cement ratio of 0.5 and 0.7 were used to cast the

cube of size 150mm for 7, 14 and 28-day curing periods. Seven concrete cubes were cast from each brand for each curing day crushing. The average compressive strength was then taken. The modes of failure of concrete cubes are normal, that is there are non-explosive failures.

The absolute volume equation was used in the calculation of nominal mix proportion. The mix ratio of 1:2:4 for concrete formulae were applied with 0.5 and 0.7 water cement ratio respectively. The standard aggregate 25mm size was used which eliminate the aggregate effect on the test. Absolute Volume Equation :

$$\text{Absolute Volume} = \left(\frac{W}{1000}\right)\ \left(\frac{C}{1000P_c}\right)\ \left(\frac{A_1}{1000P_1}\right)\ \left(\frac{A_2}{1000P_2}\right)\ 1 \qquad (5)$$

Where, W - weight of water; C - weight of cement; A_1, A_2 – weight of fine and coarse aggregates; P_c -specific gravity of cement; P_1, P_2 - specific gravity of fine and coarse aggregate respectively. $1000 = 1000\ \frac{kg}{m^3}$; $P_c = 3.15$; $P_1 = 2.65$; $P_2 = 2.64$; $\frac{W}{C} = 0.5$ (water cement ratio.

RESULTS AND DISCUSSION

Fineness

The percentage of cement sample retained on 45, 90 band 300 micro meters sieve should not exceed 10% as specified by BS 4550: Part 3: 1978 and as a measure of fineness of cement. Fineness of Durham cement –0.75%, Dangote cement –1.32%, Elephant cement –2.80%, Ashaka cement –4.65%, Sokoto cement –2.01% and Lion cement –5.70% respectively. All the cement samples have their fineness within the limit specified and sine hydration starts at the surface of the particles, it is the total surface are of the cement that represent the material available for hydration. Thus, the rate of hydration depends on the fineness of the cement particles and for a rapid development of strength, high fineness is necessary.

Consistency

The standard consistency percentage of ordinary Portland cement value as specified by the BS 4550: Part 3: 1978 is between 26 to 32%. From the result obtained Burham cement –32%, Dangote cement –28%, Ashaka cement –30%, elephant cement –27.7%, Sokoto cement –31% and Lion cement –26% respectively. These values are within the specified values.

Soundness

The soundness (expansion) of the brands of cements considered are in the range of 0.3 – 0.7mm, which comply with the BS 4550 : Part: 3: Section 3.7:1978 specification of not more than 10mm for the cement to be regarded as being sound. Soundness values obtained from the result shows that Burham – 0.58, Ashaka cement – 0.70, Dangote cement – 0.50, Elephant cement – 0.30, Sokoto cement – 0.55 and Lion cement –0.60mm respectively. These expansion values are within the values specified by the codes, which indicate that the cements are very sound.

Setting-time

BS 12: Part 1: 1991 and BS 4550 Part 3: Section 3.7: 1978 specified that initial setting time of ordinary Portland cement should not be more than 30minuets and not less than 45 minutes, and it's final setting time should not exceed 600minutes. The summary results of these physical and mechanical properties of various brands of ordinary Portland cement are reported in Table 1. From the result Burham cement has the highest initial setting time while Dangote cement recorded the highest final setting time respectively. These values are within the stipulated values which indicate that the concrete made from these cements can be mixed properly, transported, placed and compacted before stiffening process begins.

Table-1 : Summary of Physical and Mechanical Properties of various brands of OPC used.

Cement brand	Percentage consistency	Setting time (min)		Soundness (mm)	Percentage fineness/ percentage retained (%)
		Initial	Final		
Burhan	32	148	215	0.58	0.75
Ashaka	30	72	278	0.50	1.35
Dangote	28	80	134	0.70	4.65
Elephant	27.7	100	163	0.30	2.80
Sokoto	31	125	210	0.55	2.01
Lion	26	63	87	0.60	5.70

Compressive strength

Compressive strength of concrete is empirically a function of water-cement ratio, cement type, aggregate-cement ratio, and aggregate type, degree of compaction and duration of curing [16]. The result of the average compressive strength of various cement concrete (mix ratio 1:2:4) cube of size 150mm for 7-, 14-, 21- and 28-day curing period with water cement ratio of 0.5 and 0.7 are reported in Table-2. The relationship between the compressive strength and curing periods are also presented in Figure-2 and 3 respectively. The compressive strength with water-cement ratio of 0.5 is higher compared to that of 0.7. The British Standard (BS) specification stipulated that at 7- day curing period the strength should not be less than 14.0 N/mm^2; and 28- day curing strength should not be less than 26.0 N/mm^2.

Table-2 : Compressive strength of the various brands of OPC at water cement ratio of 0.5 and 0.7

Cement brand	Compressive strength (N/mm^2) at W/C = 0.5				Compressive strength (N/mm^2) at W/C = 0.7			
	7 Days	14 Days	21 Days	28 Days	7 Days	14 Days	21 Days	28 Days
Burham	30.68	36.87	38.63	40.19	20.34	22.02	24.85	26.29
Ashaka	21.30	22.78	26.37	28.81	14.99	18.87	20.47	22.81
Dangote	18.03	21.12	23.79	25.90	12.03	18.21	19.18	21.44
Elephant	18.00	21.32	23.22	24.28	12.12	16.89	18.41	19.26
Sokoto	17.76	21.27	22.86	24.13	11.05	15.87	17.06	18.64
Lion	16.97	20.48	21.72	22.76	10.80	14.36	16.11	17.09

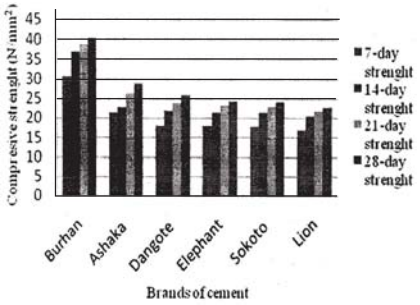

Fig-1 : Relationship between compresive str enght and curing periods with water cement ratio of 0.5

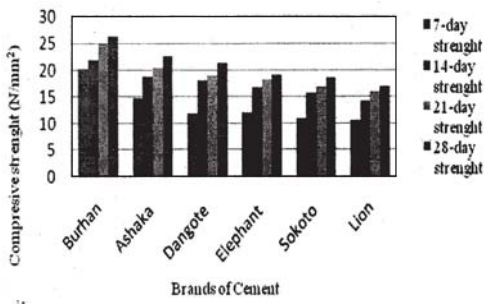

Fig-2 : Relationship between compresive strenght and curing periods with water cement ratio of 0.7

Burham , Ashaka and Dangote cement concrete strengths are higher than the value specified by the codes which shows that higher strength can be achieved at 28-day. Elephant, Sokoto, and Lion cement concrete have slightly lower strength compared with the standard specification.

According to [5, 9] the average compressive strength gives no indication of extent of variation of strength. This was ascertained by relating the individual strength to the average strength and determining variation from the average. However, in order to arrive at the meaningful result, which gives indication of extent of variation in strength, characteristic strength was deter-

mined. Characteristic strength is that value below which it is unlikely that more than 5 per cent of the test result will fall [11,16].

[18, 25] specify that, the characteristic strength of ordinary Portland cement concrete at 7-day to be 16.5 N/mm^2 and 28-day should not be less than 25 N/mm^2 respectively. The characteristic cube strength for 7-, 14-, 21- and 28-day curing period are reported in Table-3. The relationship between the characteristic strength and curing periods are also presented in Figure 3 and 4 respectively. It is only Burham, Ashaka and Dangote cement that have their strength values within this range. Strength developments largely depend t>n the degree of hydration of cement, its chemical and physical properties. Concrete of inadequate strength will not protect reinforcement bars against severe weather and will be less fire resistant, thus, the durability of such reinforced concrete structures will be severely impaired.

Table-3 : Characteristic strength of the various brands of OPC at water cement ratio of 0.5 and 0.7

Cement brand	**Compressive strength (N/mm^2) at W/C = 0.5**				**Compressive strength (N/mm^2) at W/C=0.7**			
	7 Days	**14 Days**	**21 Days**	**28 Days**	**7 Days**	**14 Days**	**21 Days**	**28 Days**
Burham	26.99	30.97	36.46	37.03	18.99	21.98	24.46	25.03
Ashaka	17.95	19.48	23.14	26.29	17.15	18.59	20.48	22.26
Dangote	15.80	19.52	22.38	25.42	12.95	14.74	16.36	18.84
Elephant	15.74	18.41	19.53	21.55	11.74	12.12	15.21	17.66
Sokoto	14.74	19.37	18.55	20.21	10.74	11.58	13.55	15.45
Lion	14.28	17.05	18.80	19.88.	9.58	10.77	13.71	15.69

Characteristic strength (f_c) = f_a – 1.6σ

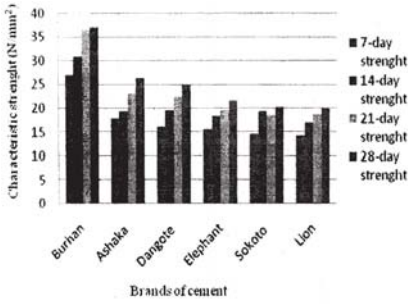

Fig-3 : Rdatioiislup between characteristic strength and curing periods with water cement ratio of 0.5

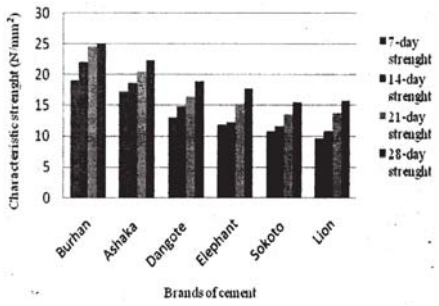

Fig-4 : Relationship between charactetistic strength and curing periods with water cemait ratio of 0.7

Conclusion and Recommendation

Results show that all the brands of OPC considered in this research met the standard specifications for fineness, consistency, soundness, and setting times. For the compressive strength, the water-cement ratio of 0.5 has higher strength compared to the 0.7. Not all the various brands of cement used for this research purpose satisfy the BS specification of compressive and characteristic strengths, which stipulates that at: 7-day strength should not be less than 14.0 N/mm^2; 28- day strength should not be less than 26 N/mm^2, and characteristic strength at 7-day to be 16.5 N/mm^{2}and at 28-day should not be less than 25 N/mm respectively. From the tests carried out, there are variations in the compressive and characteristic strengths of concrete produced from the various brands of cement which is due to the variability in the degree of hydration and properties of the cement brands used. Sequel to the results obtained, not all the brands'of cement used for this research can be used for specialized construction works as only Burham, Ashaka and Dangote cement that have their strength values within the range of codes specifications for all construction works.

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