STRENGTH DEVELOPMENT OF ORDINARY PORTLAND CEMENT BRANDS USED IN NIGERIA

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ABSTRACT

This paper presents the findings of an investigation into the strength development of some brands of ordinary Portland cement (OPC) used in Nigeria. The OPC brands considered are Dangote cement, Eagle cement, Burham cement, Ashaka cement, and Sokoto cement. These were represented not in any particular order, as A, B, C, D and E respectively. The strength of cement was determined by compressive strength tests of grade 20 concrete produced with the brands.

The results from the study show that all the brands of OPC tested displayed varying degree of responses to the provision of the BS 4550(1978) and NIS (1974) Standards; as they satisfy the minimum compressive strength requirements at 3, 7, 14, 21, and 28 days periods within normal laboratory condition of curing, drying & testing.

The results showed average compressive strength of brand 'A' as 30.37, 35.26, 37.41, and 39.28, 39.53N/mm^2 for 3, 7, 14, 21 and 28 days respectively. Whereas brand 'B' results are 24.74, 31.40, 34.4, 36.4, 37.47N/mm^2: for 3, 7, 14, 21 and 28 days respectively.

Similarly brand 'C' results are 22.67, 27.55, 30.3, 32.5, 33.03 N/mm^2 and 'D' attained strength of 25.63, 29.92, 31.41, 33.05, 35.11 N/mm^2 for 3, 7, 14, 21 and 28 days respectively. While Brand 'E' results are 22.37 27.11, 31.11, 32.03, 32.89N/mm^2 for 3,7,14,21, and 28 days periods respectively. These results displayed varying degree of strength development characteristics of the OPC brands used in construction work in the country.

It also showed that brands of OPC manufactured in Nigeria performed creditably well when compared to the imported ones.

SIGNIFICANCE: As a result of incessant failures of building structures in our urban and rural dwellings, a study on quality of the major construction materials, which cement is among, becomes necessary and significant.

KEYWORDS: Cement, OPC Brands, Compressive Strength and Ages of Development.

1. INTRODUCTION:

From the earliest time, naturally occurring materials such as timber, stone and fibres were used in construction work. Then followed the modern building materials of masonry, concrete (mass, reinforced and prestressed), structural steel in rolled, and fabricated sections and engineered wood.

Concrete, which is one of the most used structural materials, is described as a composite material made principally of cement, water, fine and coarse aggregate. At times admixtures are added to improve some deficient properties.

Cement, which is a principal constituent of concrete, is also widely used material in construction work from the time of its discovery. Right from the building of shelter needed by mankind for his protection down to the construction of roads, water works, factories, educational and health institutions, cement is an essential constituent in terms of structural system used for these physical development process.

The cement of interest here is restricted to the bonding materials used with stones, sands, bricks, building block, etc to form a composite mass.

For it to satisfactorily act as adhesive and binding material, its hydration property must produce a very hard and strong binding medium for the aggregates particles. The fresh mixture when hardens with sufficient gain in strength must be able to carry the expected loads, without failure deformation including deflection, etc.

The development of hydraulic cement by James Parker (Neville, 2003) by calcining nodules of argillaceous limestone, led to what later become the most common type of hydraulic cement named Portland cement as patented

by Joseph Aspdin in 1824. Various types of Portland cement exist due to various chemical compositions but the ordinary Portland cement (OPC) is the most widely and commonly used in Nigeria and beyond (CMAN, 1988). Neville, (2003) reported that about 90 percent of all cement used in United States (about 75 million tonnes in 1995) and a like percentage in United Kingdom (11 million tonnes in 1995) is the ordinary Portland type.

The manufacture of cement requires stringent control, and a number of tests are performed in the cement laboratory to ensure that the cement is of the desired quality and that it conforms to the requirements of the relevant National Standards.

The ordinary Portland cement (OPC) is manufactured to confirm to the requirements of quality standards specifying physical and chemical parameters such as Fineness, Soundness, Setting time and Compressive strength. All these tests attesting to the quality as specified by various standards such as NIS 11 (1974); BS4550 (1978); BS 12 (1991), DIN 1164, ASTM (C150-156), and EN 196-6:1989.

The compressive strength of hardened cement is considered the most important property, as other properties like, durability; permeability and resistance to abrasion are directly related to it, (Jackson and Dhir, 1988).

The pioneer work done by Walker and Bloem (1958) has contributed to development of a test method for the evaluation of cement strength uniformity from a single source. According to Neville (2003), the variation in the strength of cement from different plants is obviously large than when a single plant is the supplier.

Other works by Poole (1986), Gaynor (1993) reported variability in cement strength produced from various plants in United States of American.

The British Standards, BS4550 (1978), BS12 (1991) and Nigeria NIS 11 (1974) require that the cement shall be tested for strength in either mortar or concrete cubes.

In this paper concrete cube test is preferred since Neville (2003) reported that vibrated mortar gives a fairly reliable results due to greater scatter of strength value than would be obtained with concrete made of similar conditions. It can also be argued that the interest is in the performance of cement in concrete and not in mortar, for this reasons concrete test is preferred in this study.

Ordinary Portland cement either manufactured in Nigeria (Brands', D & E) or imported (Brands, A, B, & C) come by various brands names. Some of the mostly used brands include Ashaka, Sokoto, Dangote, Eagle, and Burham cement.

The problem of cement users competing for a particular brand at the expense of others not on sound engineering judgment is an issue of concern to manufacturers and dealers. More often a particular brand of cement is in high demand for use on site and this often leads to its scarcity and high cost where available. The scarcity and high cost of this particular brand often lead to temporary stoppage of work, and even extension in the project completion schedule.

Most literatures are available on the types and properties of cements produced and used in Nigeria, however comparison on strength variation of ordinary Portland cement manufactured or imported into Nigeria has not been fully investigated.

In this study further investigations were carried out to determine the variability in strength of some brands of ordinary Portland cement used in construction work in Nigeria.

2. CEMENT PRODUCTION IN NIGERIA

Before 1954, the cement need of Nigeria was imported form Europe until the pioneer work done by a British company named Associated Portland Cement Manufacturers (APCM). The work led to the establishment of Nigeria Cement Company, makers of Nigercem, a brand of OPC, at Nkalagu near Enugu, Niger CEM (1989).

The company, which started production in 1957 using basic raw materials of limestone (96%) and gypsum (4%) were producing only ordinary Portland brand of cement.

The success recorded by the cement company at Nkalagu coupled with ever increasing demand for the product led to establishment of more cement companies in this order; West African Portland cement (Elephant brand of OPC, 1960) at Ewekoro and Shagamu; The Bendel Cement Company (Rhino Brand of OPC, 1964) in Ukpilla; Calabar Cement Company (Calcemco Brand of OPC, 1965) in Cross River State; Cement Company of Northern Nigeria (Sokoto Cement, 1967) at Sokoto; Ashaka Cement Company (Ashaka Cement Brand of OPC,1979) in Bauchi; and Benue Cement Company (Lion Brand of OPC, 1989) at Makurdi;. These cement companies were either using the dry or wet processes in the production and were all producing only the ordinary Portland cement brands, CMAN, (1988); NCC, (1989).

The inconsistencies in management, lack of plant maintenance, inadequate power generation, financial incapacitation, lack of human resources development and political will, led to liquidation and / or below capacity production of most of the established cement companies.

These unfortunate variables combined with ever increasing construction work in the country led to several importations of different types of ordinary Portland cement brands in Nigeria. The newer brands of OPC, which are imported from Europe, come in ground form and are re-bagged in Nigeria. Among these brands of ordinary Portland cement include the popular Dangote cement, Eagle cement and others.
This study would also compare strength variability test on the ordinary Portland cement brands produced in Nigeria plants and those imported in ground form and re-bagged in Nigeria with a view of assessing the suitability in construction work.

3. EXPERIMENTATION:

3.1 Materials:

Cement: Ordinary Portland cement brands used include Dangote, Eagle, Burham, Ashaka and, Sokoto brands of OPC. They were purchased from a local dealer and care was taken to ensure that they were of recent supplies and free from adulteration.
Samples obtained were labeled A, B, C, D and E for identification purposes. The labeling of the samples has no relationship with the factory concerned or has it any thing to do with the quality of the product. It should be noted that while brands D and E are produced in Nigeria, brands A, B, C are imported in granular forms before re-bagging.

3.1.1 Aggregates:

The fine aggregate used in this experiment was naturally occurring clean sand, which was found to be zone 3 fine aggregates after the sieve analysis was carried out on the sample.
The coarse aggregate was crushed granite of density 2650 Kg/m^3 and maximum size of 20mm. All the supplies were obtained from a local supplier of these materials to the department for experimental purposes.

3.1.2 Water:

Pure and clean tap water, fit for drinking was used in making the concrete and it was assumed to be free of materials that can adversely affect the quality of concrete.

3.2 Experimental Procedure:

Concrete mix design was carried out based on D.o.E (1975) and the mix was limited to grade 20 concrete for all cement brands.
Water cement ratio of 0.55 was designed for with assumed true slump of 10-30mm.
The materials batched for each brand were mixed manually in the workshop. The mix was then cast into 150x150x150mm cube moulds and compacted manually with a tapping rod to the design density of 2429.38 kg/m^3.
A total of 45cubes were cast, each cement brand has a total of 9cubes. Each cube was identified with a mark to indicate its grade, date of casting, and brand of the cement, to avoid brand mix-up. The cubes were left for 24hours before de-moulding. The concrete cubes were immersed in a curing tank.
After 3, 7, 14, 21, and 28days of curing the cubes were air-dried in the laboratory for a day and the density of each of the cubes was determined before the cubes were tested for compressive strength.
The crushing test was performed using Avery Denison Universal testing machine with maximum capacity of 2000KN. The machine applied load axially on the cube specimen at a constant rate until a maximum load, which correspond to the ultimate compressive load, is reached at failure point.
The compressive strengths were calculated and tabulated as presented in tables 1, 2, 3, 4and 5 for cement brands A-E respectively.

4. RESULTS AND DISCUSSIONS:

The test results for cement brands A, B, C, D, and E are as presented in tables 1, 2, 3, 4, and 5 respectively. The relationship between compressive strength and age of concrete cubes cured in clean water for brands A, B, C, D, and E is presented in figure 1.
The results of the test generally indicate a gradual increase in strength from 3 days to 28 days for all the brands considered.
For cement brand 'A', the average strengths at 3, 7, 14, 21, and 28 days of grade 20 concrete cured normally in clean water are 30.37, 35.26, 37.41, 39.28 and 39.55N/mm^2respectively (table1 and fig.1)

Cement brand 'B' attained average strengths of 24.74, 31.40, 34.4, 36.4, and 37.47N/mm^2 at 3, 7, 14, 21, and 28 days respectively. Similarly for cement brand 'C' the average strength at 3, 7, 14, 21, and 28 days are 22.67, 27.55, 30.3, 32.5, and 33.03 N/mm^2 respectively. Also brand 'D' average strengths are 25.63, 29.92, 31.41, 33.05, and 35.11N/mm^2 at 3, 7, 14, 21, and 28 days respectively.

The average strengths for cement brand 'E' ages of 3, 7, 14, 21, and 28 days are 22.307, 27.11,31.11, 32.05, and 32.89 N/mm^2 respectively.

These results showed that all the brands of ordinary Portland cement tested displayed a varying degree of response to the provision of the BS 4550 (1978) and NIS (1974) standards as they satisfied their minimum compressive strength specifications of at least 13 and 29N/mm^2 at 3 and 28days respectively.

Among the five cement brands used in the experiment, brand 'A', was found to have the highest strength developed at all the ages; about 134% above 13N/mm^2 minimum strength at 3days and 36% above 29N/mm^2 minimum strength at 28days as recommended by BS4550 and NIS 11 standards. The strength developed by brands B, D, C and E followed in decreasing order as shown in tables 1– 5 and Figure1.

Though the 28-day strength of all the studied cement brands are above the BS 4550 (1978) and NIS 11 (1974) specified minimum, brands C, D, E present cases of concern. That the 28-day strength values of cement brands C, D, and E are only 14%, 21% and13% respectively, above the BS 4550 (1978) and NIS 11(1974) specified minimum suggest that the major advantage of prescribing a target mean strength far above the concrete grade, which is to check the unsafe reduction in the concrete strength during construction may not be had.

The results also show that the imported ordinary Portland cement brands bagged in Nigeria showed a remarkably high early strength development when compared to cement brands produced in Nigeria plants.

This can be seen from the results for brands A (30.37N/mm^2), B (24.74N/mm^2), C (22.67N/mm^2) at 3 days as represented in figure 1.

It should also be noted that the cement brand 'D', from Nigeria plant showed a high strength development comparable to the imported brands even as its early strength development of 97% above minimum specification at 3 days is better than some imported ones.

5. CONCLUSIONS AND RECOMMENDATION:

The ordinary Portland cement brands produced in Nigeria plants are safe structurally.

The variation in strength of cement brands may be attributed to the lack of uniformity in the raw materials used in its manufacture.

The imported cement brands have shown greater early strength development when compared to the brands from local plants.

The cement manufacturing plants in Nigeria should be rehabilitated to ensure cement is produced with the abundant locally sourced raw materials.

There is the need for Nigerian Industrial Standard (NIS) to expedite action on periodical quality test of cement produced and imported into the country.

Table1: RESULTS OF COMPRESSIVE STRENGTH TEST ON CEMENT BRAND 'A' (F)

Concrete Grade	Age (Days)	Compressive Strength (N/mm^2) Cs	BS4550 (1978): Minimum Requirement (N/mm^2) Mr)	Difference in Strength (Cs – Mr)	(%) Difference in strength
20	3	30.37	13	17.37	134
20	7	35.26	16	19.26	12
20	14	37.41	NS	-	-
20	21	39.28	NS	-	-
20	28	39.55	29	10.55	36

Table 2: RESULTS OF COMPRESSIVE STRENGTH TEST ON CEMENT BRAND 'B' (F)

Concrete Grade	Age (Days)	Compressive Strength (N/mm^2) Cs	BS4550 (1978) Minimum Requirement (N/mm^2) Mr	Difference in Strength (N/mm^2) (Cs – Mr)	(%) Difference in Strength
20	3	24.74	13	11.74	90
20	7	31.40	16	15.40	96
20	14	34.41	NS	-	-
20	21	36.4	NS	-	-
20	28	37.47	29	8.47	29

Table 3: RESULTS OF COMPRESSIVE STRENGTH TEST ON CEMENT BRAND 'C' (F)

Concrete Grade	Age (Days)	Compressive strength (N/mm^2) Cs	BS4550 (1978): Minimum Requirement (N/mm^2) Mr	Difference in Strength (N/mm^2) (Cs – Mr)	(%) Difference in strength
20	3	22.67	13	9.67	74
20	7	27.55	16	11.67	72
20	14	30.30	NS	-	-
20	21	32.50	NS	-	-
20	28	33.03	29	4.03	14

Table 4: RESULTS OF COMPRESSIVE STRENGTH TEST ON CEMENT BRAND 'D' (L)

Concrete Grade	Age (Days)	Compressive strength (N/mm^2) Cs	BS4550 (1978) Minimum Requirement (N/mm^2) Mr	Difference In strength (N/mm^2) (Cs – Mr)	(%) Difference in strength
20	3	25.63	13	12.63	97
20	7	29.92	16	13.92	87
20	14	31.41	NS	-	-
20	21	33.05	NS	-	-
20	28	35.11	29	6.11	21

Table 5: RESULTS OF COMPRESSIVE STRENGTH TEST ON CEMENT BRAND 'E' (L)

Concrete Grade	Age (Days)	Compressive strength (N/mm^2) Cs	BS4550 (1978) Minimum Requirement (N/mm^2) Mr	Difference in Strength (N/mm^2) (Cs –Mr)	(%) Difference in strength
20	3	22.37	13	9.37	72
20	7	27.11	16	11.11	69
20	14	31.11	NS	-	-
20	21	32.03	NS	-	-
20	28	32.89	29	3.89	13

Notes: NS = Not specify
F = Foreign
L = Local

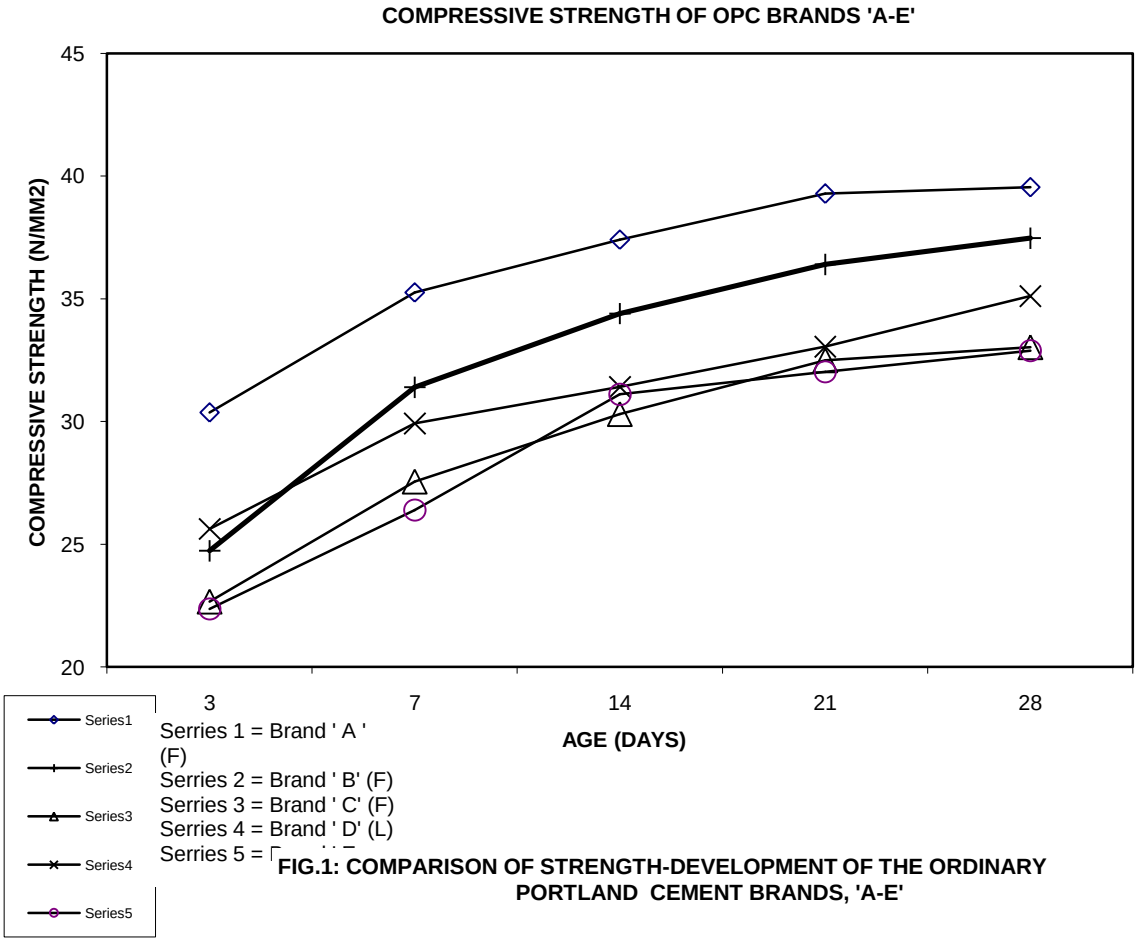

FIG.1: COMPARISON OF STRENGTH-DEVELOPMENT OF THE ORDINARY PORTLAND CEMENT BRANDS, 'A-E'

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