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Comparative Study of the Physical Properties of Some Selected Cement Brands in Nigeria

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Abstract:- Cement is a core component of concrete; its properties affect the properties of concrete made using the particular type of cement. Unsuitable choice of cement in construction work involving use of concrete can affect the integrity of the construction work. This work was aimed at studying some selected physical properties of some cement brands produced in Nigeria. The selected brands are Ashaka, Sokoto, Dangote, Rhino and Elephant. The properties studied are fineness, consistency, soundness and compressive strength. The study was carried out by laboratory investigation and the tests were as prescribed in BS 4550. All the brands tested exhibited properties that meet the requirements of the appropriate BS and ASTM standards. All the brands tested were able to develop a minimum compressive strength of 33.5N/mm^2 which means they meet the grade 32.5 rating. Elephant cement on the other hand was able to attain strength of 23.5N/mm^2 at 28 days which means that it is not suitable structural concrete works.

Keywords:- Cement brands, compressive strength, physical properties, standard consistency.

I. INTRODUCTION

Cements, in broad sense, are adhesive and cohesive materials that are capable of binding particles of solid matter into durable mass of adequate strength (Duggal 2009, Nilson et al 2004 and Ghosh 1983). Cement is classified into hydraulic and non-hydraulic types. The non-hydraulic types do not need water to increase its strength an example of which is Plaster of Paris (POP). The hydraulic cement sets and hardens in water, and results into a stable product. The most common example of this is the Ordinary Portland Cement (OPC).

Cement is a core component of concrete; its properties affect the properties of concrete made using the particular type of cement. The integrity of construction work that involves the use of concrete can therefore be affected if the choice of cement is not suitable for the construction method and the service condition of the resulting structure.There have been many cases of building collapse in Nigeria in recent times. Some of these collapses have been attributed to the use of sub-standard materials (Oyewande, 1992). It is therefore important to know the characteristics of the materials used in construction. The main properties expected of cement in construction, according to Duggal (2009), are permanency of structure, strength and rate of setting suitable to demand of the work at hand. Being this important there is the need to investigate the properties of some of the brands of cement available in the Nigerian market. Some researchers have done some work on some properties of cement. Yahaya (2009) did some classification of Nigerian cement on the basis of their physical and chemical properties. The author reported that some work needs to be done to improve on the properties of the locally manufactured brands of cement to meet some of the international standards. Sam et al (2013) also analysed the chemical properties of cement brands in Ghana among which was Dangote cement. The results showed that two out the cement brands investigated conform to international standards. The aim of this work was to investigate the physical properties of some selected brands of cement available in the Nigerian market; compare the results with established standards to determine conformity and to compare the results among the brands. This waswith the view to determining the most suitable cement brand available in the Nigerian market for use in construction under given environmental conditions and construction method.

II. MATERIALS AND METHOD

2.1 Materials Cement

Five brands of cements were selected namely; Dangote cement, Sokoto cement, Ashaka cement, Rhino cement(Edo cement) and Elephant cement.The cement brands were chosen because they are the ones readily available in the market in the research location. They also contribute more than 70% combined of the cement brands used in the Nigerian construction industry. They were obtained from the open market in Kaduna in North West Nigeria. Effort was made to ensure that the brands of cement bought were not re-bagged outside the factory.

Fine Aggregates

The quality of concrete produced using any brand of cement depends on the quality of sand used. The fine aggregate used was natural sharp river sand obtained from river Kaduna.It was free of silt or any deleterious materials and did not contain particles exceeding 5mm in size.

Coarse Aggregate

The most common type of coarse aggregate used for construction work is the 20mm size. Crushed, angular, graded granite having maximum size of 20 mm was therefore used as coarse aggregate. The supply was free of dust and other impurities.

Water

The water used for the test was obtained directly from the tap in the laboratory. It was used both for producing and curing the concrete.

III. METHODOLOGY

The following tests were carried out on each of the selected brands of cement namely: fineness test, consistency test, soundness test, setting time test, and strength test. All the tests were carried out on the basis of the guidelines given in BS 4550:1978 in the material laboratory of the Department of Building of Kaduna Polytechnic.Three (3) specimens prepared for each brand of cement for each of tests to be carried out on them.The average of the results from the three specimens will be recorded as the value for the given property.The results obtained were compared with the values given in the appropriate standard and also compared among the selected brands of cement.The results have been presented in tabular form for ease of comparison.This is with the view to determining which brand of cement is most suitable for use in construction in a specified situation in compliance with established standards.

Fineness Test

Using a weighing balance, 10g of cement was weighed approximately to the nearest 0.01g and then placed on 90μm BS sieve. The sieve was agitated by swirling in both planetary and linear movements until no more fine material passes through it. The residue was weighed and its mass was expressed as a percentage R1 of the quantity first placed on the sieve to the nearest 0.1%. The particles on the sieve were gently brushed off from the base of the sieve and the whole procedure was repeated using a fresh 10g cement sample in order to obtain R2. The value of R was derived from the mean of R1 and R2 as a percentage expressed to the nearest 0.1%.
The above procedure was repeated for each of the cement brands. The results obtained are shown in Table 1.

Table 1: Fineness test results for the tested brands of cement

Cement brands	Total weight of cement (g)	Total residue (%)	Average residue (%)
Ashaka	10 10	R_1-7 R_2-6	6.5
Sokoto	10 10	R_1-6 R_2-7	6.5
Dangote	10 10	R_1-5 R_2-6	5.5
Elephant	10 10	R_1-7 R_2-6	6.5
Rhino	10 10	R_1-6 R_2-5	5.5

Source: Laboratory investigation

Consistency Test

400g of cement sample was weighed and mixed with a weighed quantity of water and then properly mixed to produce a homogenous paste of cement. The time of gauging was between 3-5 minutes. The Vicat mould was filled with the cement paste and properly levelled with a trowel. The plunger of the Vicat's apparatus was gently lowered till it touched the surface of the cement paste.

The plunger was then released allowing it to sink into the paste. The reading on the gauge was noted after releasing the plunger into the paste. The above procedure was repeated using fresh samples of cement and different quantities of water until the reading on the gauge was 5-7mm.The amount of water was expressed as a percentage of the weight of dry cement to the first place of decimal.The above procedure was repeated for every brands of cement. The results for all the brands of cement are shown in Tables 2(a) –(e)

Table 2: Standard Consistency Test Results

(a) Ashaka Cement

Sample No	Weight of Cement (g)	Volume of Water (ml)	Depth of Penetration(mm)	W/C Ratio (%)	Remarks
1	400	125	13	31.25	Not satisfactory
2	400	120	8	30.00	Not satisfactory
3	400	115	5	28.75	satisfactory

(b) Sokoto cement

Sample No	Weight of Cement (g)	Volume of Water (ml)	Depth of Penetration(mm)	W/C Ratio (%)	Remarks
1	400	125	12	31.25	Not satisfactory
2	400	120	9	30.00	Not satisfactory
3	400	115	5	28.75	Satisfactory

(c) Dangote Cement

Sample No	Weight of Cement (g)	Volume of Water (ml)	Depth of Penetration (mm)	W/C Ratio (%)	Remarks
1	400	125	11	31.25	Not satisfactory
2	400	120	8	30.00	Not satisfactory
3	400	115	6	28.75	Satisfactory

(d) Elephant cement

Sample No	Weight of Cement (g)	Volume of Water (ml)	Depth of Penetration(mm)	W/C Ratio (%)	Remarks
1	400	125	14	31.25	Not satisfactory
2	400	120	9	30.00	Not satisfactory
3	400	115	7	28.75	satisfactory

(e) Rhino Cement

Sample No	Weight of Cement (g)	Volume of Water (ml)	Depth of Penetration(mm)	W/C Ratio (%)	Remarks
1	400	125	13	31.25	Not satisfactory
2	400	120	10	30.00	Not satisfactory
3	400	115	5	28.75	satisfactory

Source: Laboratory investigation

Observations

It was observed that, with all the specimens experimented on and with water content been reduced at interval of 5ml in decreasing order, all the brands of cement failed to achieve result with volume of water at 125ml and 120ml. However, all samples achieved the desired depth of penetration at the volume of water of 115ml given a standard consistency of 28.75% each.

Conclusively, all the brands of cement tested were found to be normal as they all have their depth of plunger penetrations within the range of 5mm-7mm as specified in the by the relevant British Standard.

Soundness Test

A cement paste of standard consistency was prepared. The le Chartlier's moulds were placed on a glass plate and then filled with the cement paste keeping the slit of the moulds gently closed by tying the moulds with a piece of thread before covering the top of the mould with glass plate. The whole set up was totally immersed in water of temperature 20°C for about 24hours. The moulds were removed after 24hours with their

contents and the initial gap or slit of the moulds measured as D1. The moulds were re-immersed in a water bath and heated for 30 minutes to boiling point and the water kept boiling for about an hour. The moulds were then removed from the boiling water and allowed to cool. After cooling, the distances between the indicators were again measured as D2. The value of the differences between D1 and D2 represents the expansion of cement. The above procedure was repeated for all brands of cement.

Table 3: Comparative results for soundness test on cement samples

Cement Type	Weight of Cement(g)	Volume of Water(ml)	Distance b/w Pointers before Heating(mm)	Distance b/w Pointers after Heating(mm)	Expansion $l_2 - l_1$(mm)
Ashaka	400	115	13	17	4
Sokoto	400	115	12	16	5
Dangote	400	115	13	18	5
Elephant	400	115	10	13	3
Rhino	400	115	13	17	4

Source: Laboratory investigation

Observations:

From the tests conducted on the cement samples, individual expansion of the various samples were found to be within the range of 3mm-5mm. Dangote cement and Sokoto cement both have the highest expansion rate of 5mm. Elephant cement on the other hand, was tested to be the brand of cement with the least expansion rate of 3mm while Ashaka cement and Rhino (Edo cement) were both found to have 4mm expansion rate each. The cement samples tested all adhere to the required standards as it specifies that the individual expansion of any cement should not be more than 10mm. however, Elephant cement with the least expansion rate has the ability to control its rate of expansion thereby reducing the rate of cracking in concrete.

Setting Time

A cement paste of standard consistency was prepared with 400g of cement mixed properly with 115ml of water to form a homogenous paste. The timing was monitored the movement water was added to the cement. The vicat mould was filled with the cement paste and properly gauged and levelled with the top of the mould. The cement block prepared in the mould serves as the test block.

a. Initial Setting Time

The test block was placed under the rod bearing the needle and the needle was lowered gently in order to make contact with the surface of the cement paste, and then quickly released allowing it to penetrate the test block. This action was repeated till the needle failed to pierce the test block to a point 5.0+/-0.5mm measured from the bottom of the mould which was achieved after 45 minutes was recorded as the initial setting time.

b. Final Setting Time

The needle used above was replaced by the one with an annular attachment and just as the previous process, the annular attachment was allowed to fall gently on the surface of the test paste. It was noticed that the needle made an impression on the surface of the paste, while the annular attachment failed to do so. The period elapsing between the time water was added to the cement and the time, the needle made an impression on the surface of the test paste, while the annular attachment failed to do so was noticed and recorded as the final setting time of the cement sample.The above procedure was carried out for all brands of cement.

Table 4. Setting times of the selected brands of cement

Cement Brands	Weight of Cement(g)	Volume of Water(ml)	Depth of Penetration(mm)	W/C Ratio (%)	Initial Setting Time(hr.)	Final Setting Time(hr.)
Ashaka	400	115	5	28.75	1h:20mins	8h:15mins
Sokoto	400	115	5	28.75	1h:14mins	9h:00mins
Dangote	400	115	6	28.75	1h:32mins	8h:22mins
Rhino	400	115	5	28.75	1h:14mins	8h:05mins
Elephant	400	115	7	28.75	1h:43mins	9h:33mins

Source: Laboratory investigation

Observations

From the result obtained for all the cement samples on their initial and final setting time of paste, it was observed that Elephant cement and Rhino (Edo cement) took longer time to finally set completely as they all elapsed 9hours above compared to other samples such as Dangote and Ashaka cement as their final set time were noted to be below 9hours.

However, all the cement brands tested adequately meets the standard requirements when compared to the acceptable standards as specified by BS 12, 1991 which specifics that the initial setting time of 2 standard concrete pastes should not be less than 45 minutes and that the final set time should not exceed 10hours.

Compressive Strength Test

a. Preparation of Test Specimen

The moulds were properly cleaned and oiled with the thin coat of mould oil. The moulds were further greased with petroleum jelly along the two halves of the moulds and also the contact surfaces of the bottom of the moulds and its base plate to avoid water from escaping during vibration. The mix proportion used was 1:6 (one part by weight of cement to six parts by weight of standard aggregates) with a W/C ratio of 0.4. The quantities of materials for the test cubes were weighed as follows cement, 1110g; standard sand, 3330g; crushed stone, 3330g; water 4440g.

b. Mixing and Aggregates

Dry cement, sand and stone were mixed in a mixing tray using a trowel for one minute and then with water a further 4 minutes, thereby producing a concrete of homogenous consistency.

c. Compaction

The moulds were assembled, filled with each concrete and then placed on the vibrating table. The moulds were properly vibrated at about 1200 vibrations / minutes for two minutes.

d. Curing

The cubes were covered with impervious sheet immediately for 24hrs at room temperature and relative humidity. The cubes were removed from their moulds after 24hrs and marked for identification (i.e. date of cast and group number). The cubes were then immersed in clean water at room temperature until just prior to testing.

e. Testing

Three of the prepared cubes were tested at 1day, another three cubes for 4days, followed by 7days, 14days, 21days and the remaining three cubes for 28days.The mean compressive strength was recorded in N/mm^2 to the nearest $0.5N/mm^2$.

The results are shown for all the compressive test results in Table 5.

Table 5 Compressive strength test results of the selected brands of cement

Age of Concrete (days)	Brands of Cement				
	Ashaka	Sokoto	Dangote	Rhino	Elephant
	Compressive strength (N/mm^2)				
1	8.0	9.0	8.5	8.5	9.0
4	10.5	10.0	9.48	9.5	9.5
7	15.5	15.0	15.63	16.0	13.0
14	22.0	21.0	23.63	23.5	15.0
21	29.0	27.0	29.19	29.0	19.0
28	33.5	33.5	33.5	34.0	23.5

Observations

From the tests conducted on the three samples of concrete cubes made with all five selected brands of Portland cement, the average compressive strength for the three samples of concrete cubes made with Ashaka, Sokoto and Dangotebrands cured in portable drinking water for 28days all have their maximum strength of $33.5N/mm^2$ each. Rhino cement was tested after curing for 28days with an average strength of $34.0N/mm^2$ as the highest in terms strength compared to other brands of cement. Elephant cement was tested after 28days with an average strength of $23.5N/mm^2$ which is the least compared to other samples tested.

IV. DISCUSSION

From the results obtained from the fineness tests, three of the brands, Ashaka, Sokoto and Elephant have fineness values of 6.5% while Dangote and Rhino brands have values of 5.5%. Thisis an indication that the Dangote and Rhino brands will develop strength at higher rates than the other brands. This is because fineness controls the rate and completeness of hydration in cement, with the rates increasing with higher values. The values of 5.5% and 6.5% are however below the value of 10% specified in the standards for Ordinary Portland Cement (OPC).

All the brands tested have a standard consistency of 28.75%. This value falls within the range of between 22% and 30% specified in ASTM. This shows that all the brands of cement tested have normal and acceptable consistencies.

The soundness values for all the brands tested fell between 3mm and 5mm with Dangote and Sokoto having the highest value of 5mm. Elephant cement has the least value and the remaining two brands have common value of 4mm. All the values fall below the maximum allowable value of 10mm. elephant cement which has the least value will therefore have the least tendency to crack if used during construction.

The initial setting time for the samples tested fell between one hour fourteen minutes and one hour forty three minutes which are the above the forty five minutes set as the minimum in BS 12, 1991. The final setting time on the other hand ranged between eight hours five minutes and nine hours thirty three minutes which all fell below maximum accepted value of ten hours.

Ashaka, Sokoto and Dangote brands were able to attain a common compressive strength value of 33.5N/mm^2 at 28 days; Rhino cement attained a strength value of 34N/mm^2 while Elephant cement attained the least value of 23.5N/mm^2 at 28 days. The rate of strength development in each case was adequate to allow for normal speed of construction using any one of the brands.

V. CONCLUSION

All the cement brands tested exhibited physical properties that met the requirements of the appropriate British Standards. These are in terms of fineness, consistency, soundness and setting times. The rates at which strengths were developed for each brand also are adequate to allow for good rate of construction. All the brands tested except Elephant cement were also able to achieve a minimum compressive strength of 33.5N/mm^2 which means that they meet the grade 32.5 rating. Elephant was able to achieve strength of 23.5N/mm^2 at 28 days. For this reason it is not suitable for constructing elements which will function to carry loads in a structure. From all the tests carried out and the findings, all the brands meet the basic requirements that make them suitable for use in construction based on the specifications of relevant BS and ASTM relevant standards.

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