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RESEARCH ARTICLE

THE EFFECTIVENESS OF QUALITY CONTROL IN DANGOTE PLC IBESE OGUN STATE NIGERIA

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ABSTRACT

The project evaluates the effectiveness of quality control in Dangote Cement PLC, Ibese Ogun State, Nigeria. Limestone, shale and laterite samples were from the mines to determine their right grade as well as their mixing proportion. Also samples were taken from kiln feed and the final stage of cement production. The compressive strength of the cubes is determined according to the ages of the cubes which is 2 days, 7 days and 28 days while the degree of lime content in raw materials, clinker, cement, limestone in relation to other oxides were determined using XRF and setting time and residue determination values were also estimated. The results show that the compressive strength for 2 days is between 16 – 33, for 7 days is between 28 – 47 and for 28 days is between 33 – 53. Meanwhile, percentages of CaO, C₃S, C₂S and MgO in clinker are 53.57 %, 56 %, 16.47 %, 2.14 % and 62 %, 58 %, 19 %, 0 % in cement. The amounts of residue retained by different sieves were within the standard specification of 10 – 22gm. The study therefore concluded that the quality control in Dangote Cement Company is effective and cement produce meets international standard requirements and characteristics which dependable and satisfacto.

INTRODUCTION

The development of Portland cement materials and processes used in the manufacture of cement were comprehensively described by [Lea, 2003] and that in several respect, there has since been little advanced with [Pollit, 1964] further noted that Portland cement consist principally of four components:

- Tricalcium silicate (C₃S)
- Dicalcium silicate (C₂S)
- Tricalcium Aluminum (C₃A) and a phase
- Tetra calcium aluminoferrite (C₄AIF)NF

These compounds have temperatures in the region of 1300^oC - 1500^oC between lime on one hand and silica, alumina and iron oxide on the other. Lime is obtained by decarbonating calcareous materials such as chalk or limestone and the alumina, silica, and iron oxide obtained by heating argillaceous material such as clay, shale or schist. In relationship with this, he stated that the optimum cement company quality is obtained when the proportions of the four oxides are consistent throughout the cement. When the principal cement compounds are formed in the resulting clinker as it is termed, is cooled and grounded with gypsum to produce a fine powder, which is the final product of the Portland cement (Rodson, 1969).

Explained that the predominant cementations compounds present in alumina cement is a monocalcium aluminates or CAL, it has been known since 1856 that some calcium aluminates composition posses good cementation properties. He further stated that little practical used as made of this fact for many for many years and the aluminates instead of calcium silicate for research, for a cement which would be much more resistant to sea water, sulphate solution or alkali soils than any other cement available at the time [Turrisan, 1964]. Limestone and gypsum, the major raw material for cement manufacturing are very essential for developing. The study of the mineralogy of the deposit shows that, there are two carbonate materials that are in abundance. They are calcite and aragonite. Calcite is in two types depending on the percentage of magnesium present in the composition, calcite with less than 4mil % magnesium is called magnesium carbonate and that with more than 4mil% is called calcite magnesium [Isarinade, 1997]. Limestone the chief ingredient in cement production is widely variable in appearance and in mode of formation, this is due to complexity of post depositional alteration, which these rocks undergo [Thomson, 1998]. Many limestones are made up of nearly pure calcite and sure mined as the raw materials of cement. They include calcite (CaCO₃) all these are mined for Portland cement. Furthermore prolong test have confirmed that aluminous cement is capable of giving concrete or mortars an exceptional resistance to attacked from sulphates and that it found at

an early stage. However this type of cement although showing a normal slow setting time is hardened more rapidly more than Portland cement. [Turrizan, 1964] defined pollozans as substances which thought not themselves cementations, contain substances which combine with lime at ordinary temperatures in aqueous media to form insoluble substances which possess cementing properties, they include various natural material most of which are of volcanic origin and artificial product such as burnt clay and pulverized fuel ash (phy-ash). He further explained that lime pollozans mortars are used by Romans in structures of any kinds, including ones exposed to sea. Condition of many these structures today agent evidence of the durability of the cementing agent and pollozans are used today in mortars. In direct addition to concrete and in the pollozanas cement. He noted that natural pollozans include volcanic incoherent and compact rock of volcanic origin, highly siliceous rock which are probably the residue of the mineral which have suffered considerably chemical attack and siliceous composed of skeleton of living organisms [Adu, 2016]. Portland masonry cement are hydraulic that can set and harden under water. The cement is made by controlled high temperature burning in a horizontal- mounted, rotating refractory-lined cylindrical steel vessel called a rotary kiln of a measured blend of calcerous rock (usually limestone) and as needed and lesser quantities of siliceous, aluminous and ferrous materials. Portland cement can be sold directly to concrete manufacturers or other customers, converted at the cement (or concrete) plant into blended Portland cement product of similar properties by adding other cementations or pozzolanic extenders (siliceous materials requiring added lime to become cementations) or can be mixed with plasticizing materials such as ground limestone or lime to make masonry type cements used in mortar [Robert, 1986].

Economics of cement production dictates that the cement plant should be located in proximity to the limestone deposit which is the main raw material; the other raw material is shale/clay. Approximate proportion of these two components for producing cement is about 75% limestone and 25% shale/clay. The other components such as iron ore, silica sand etc can be used in smaller proportions in case there is deficiency of any mineral in the main component. The limestone which generally exists in the form of rocks and boulders is fragmented by drilling holes and using high explosives for blasting the softer limestone rock is generally quarried by ripping. The smaller size stones are then loaded into dump trucks by shovels, excavators or loaders and unloaded into the crusher [Robert, 1986].

CEMENT: Cement can be defined as a mix of clinker and gypsum together into a powder. In another sense cement can be defined as an adhesive or bonding material produced by the grinding together quiet intimately calcareous materials or any other lime bearing compounds and argillaceous materials or any silica, alumina and iron oxide bearing compounds which have been mixed intimately and burnt at high temperature in a kiln to produce clinker to which is added small proportion of gypsy before grinding. Cement is also a finely ground, non-metallic inorganic powder when mixed with water forms a paste that sets and hardens. This hydraulic hardening is primarily due to the formation of calcium silicates hydrates as a result of the reaction between mixing water and the constituents of the cement. In the case of aluminous cements hydraulic hardening involves the formation of calcium aluminates hydrates. Many cement plant have adopted general primary measures such as fuel feed systems, optimized cooler connections and use of power management systems. These measures are usually taken to improve clinker quality and lower production costs but they also reduce the energy use and air emissions [Thomson, 1998].

TYPES OF CEMENT: The most common types of cement can be divided into three main groups

Portland cement: They are by far the most common types of cement produced around the world they are;

- **Ordinary Portland cement (O.P.C):** This is the most widely used type of cement and it is for general purposes. This produced by Dangote cement.
- **Sulphate resistant cement:** this is used where a higher resistance is required to sulphate bearing water. It has lower C3A content less than 8%
- **Rapid hardening Portland cement:** It is a Portland cement in that develops strength faster than OPC in the same sense that it is finer and has smaller quantity of gypsum added.
- **Low heat cement:** it is used where low heat development during hardening is required, for example in large concrete structures like dams it has strength slower than OPC although the final strength maybe higher.
- **White cement:** this is used where white colour is wanted for the face of.
- **Composite cement:** This is also known as blended cement. It starts with Portland cement clinker and gypsum but also have the addition of another material such as:
- **Masonry cement:** it is a combination of OPC clinker, limestone and
- granulated blast furnace slag in the proper proportions.
- **Pozzolanic cement:** it is produced by mixing together OPC and a pozzolona which is a material that is capable of reacting with lime in the presence of water at ordinary temperature to produce cementitious compounds.
- **Blast furnace slag cement:** this cement is produced grinding together OPC clinker and granulated blast furnace slag in the proper proportions.
- **Oil well cement:** Oil well cement is used for cementing the steel casing of gas and oil wells in the borehole and to seal porous formations. Usually Portland cement more coarsely ground than normal with the addition of special retarders to allow for slow setting conditions.

Portland Cement: This is the most common type of cement in general usage many parts of the world especially Nigeria, as it is a basic ingredient of concrete. It is a fine powder produced by grinding Portland cement clinker (more than 90%) a limited amount of calcium silicates which controls the set time and up to 5% minor constituents (as allowed by various standard). As defined by the European standard EN 197.1 "Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates ($3\text{CaO} \cdot \text{SiO}_2$). The remainder consists of aluminum and iron containing clinker phases and other compounds. The ratio of Cao to SiO_2 shall not be less than 2.0 while the magnesium content (MgO) shall not exceed 5.0% by mass. Portland cement clinker is made by heating in a kiln, a homogenous mixture of raw materials to a sintering temperature, which is about 1450°C for modern cements. The aluminum oxide and iron oxide are present as a flux and contribute little to the strength. For special cements such as low Heat (LH) and Sulphate Resistant (SR) types, it is necessary to limit the amount of Tricalcium Aluminate ($3\text{CaO} \cdot \text{Al}_2\text{O}_3$) formed. The major raw material for the clinker making is usually limestone (CaCO_3) mixed with a second materials containing clay as source of alumino-silicate. Normally an impure limestone which contains clay or SiO_2 is used. The CaCO_3 content of this limestone can be low as 80%. Second raw materials in the raw mix other than limestone depend on the purity of the limestone. Some of the second raw materials used are clay, shale, sand, Iron ore, bauxite, fly ash, and slag. The ash of the coal acts as a secondary raw material when a cement kiln is fired by heat. There are three fundamental stages in the production of Portland cement:

- Preparation of the raw mixture
- Production of the clinker
- Preparation of the cement

The chemistry is very complex so cement chemist notation was invented to simply the formula of common oxides found in cement. This reflects the fact that most of the elements are present in their

highest oxidation state and chemical analyses of cement are expressed as mass percent of these notional oxides (Turrizan, 1964).

Raw Materials: The two main raw materials required in cement production are calcareous, argillaceous materials.

- **Calcerous Materials:** This supply the major portion of lime required in some part of the world, this occurs as chalk or coal. In Nigeria these occur in form of limestone. All these materials have different form of the chemical compound called calcium carbonate (CaCO₃)
- **Argillaceous Material:** This occurs as shale. They are two varieties: grey shale which has laminated structures and red shale which is referred to as alluvium. The main constituents of shale or any other argillaceous materials are silica, aluminum and iron oxide.

Properties of the Major Cement Minerals: About 90-95% of a Portland cement is comprised of the four main cement minerals, which are C₃S, C₂S, C₃A, and C₄AF, with the remainder consisting of calcium sulfate, alkali sulfates, unreacted limestone (free CaO), MgO, and other minor constituents left over from the clinkering and grinding steps. The four cement minerals play very different roles in the hydration process that converts the dry cement into hardened cement paste. The C₃S and the C₂S contribute virtually all of the beneficial properties by generating the main hydration product, C-S-H gel. However, the C₃S hydrates much more quickly than the C₂S and thus is responsible for the early strength development. The C₃A and C₄AF minerals also hydrate, but the products that are formed contribute little to the properties of the cement paste. As was discussed in the previous section, these minerals are present because pure calcium silicate cements would be virtually impossible to produce economically (Walter, 2002). The crystal structures of the cement minerals are quite complex, and since these structures do not play an important role in the properties of cement paste and concrete we will only present the most important features here. (Taylor, 2003).

Tricalcium Silicate (C₃S): C₃S is the most abundant mineral in Portland cement, occupying 40–70 wt% of the cement, and it is also the most important. The hydration of C₃S gives cement pastes most of its strength, particularly at early times. Pure C₃S can form with three different crystal structures. At temperatures below 980°C the equilibrium structure is triclinic. At temperatures between 980°C – 1070°C the structure is monoclinic, and above 1070°C it is rhombohedra. In addition, the triclinic and monoclinic structures each have three polymorphs, so there are a total of seven possible structures. However, all of these structures are rather similar and there are no significant differences in the reactivity. The most important feature of the structure is an awkward and asymmetric packing of the calcium and oxygen ions that leaves large “holes” in the crystal lattice. Essentially, the ions do not fit together very well, causing the crystal structure to have a high internal energy. As a result, C₃S is highly reactive. The C₃S that forms in a cement clinker contains about 3-4% of oxides other than CaO and SiO₂. Strictly speaking, this mineral should therefore be called alite rather than C₃S. In a typical clinker the C₃S would contain about 1 wt% each of MgO, Al₂O₃, and Fe₂O₃, along with much smaller amounts of Na₂O, K₂O, P₂O₅, and SO₃. These amounts can vary considerably with the composition of the raw materials used to make the cement, however. Of the three major impurities, Mg and Fe replace Ca, while Al replaces Si. One effect of the impurities is to “stabilize” the monoclinic structure, meaning that the structural transformation from monoclinic to triclinic that would normally occur on cooling is prevented. Most cements thus contain one of the monoclinic polymorphs of C₃S.

Dicalcium Silicate (C₂S): As with C₃S, C₂S can form with a variety of different structures. There is a high temperature a structure with three polymorphs, a b structure in that is in equilibrium at intermediate temperatures, and a low temperature g

structure. An important aspect of C₂S is that g-C₂S has a very stable crystal structure that is completely unreactive in water. Fortunately, the b structure is easily stabilized by the other oxide components of the clinker and thus the g form is never present in Portland cement. The crystal structure of b-C₂S is irregular, but considerably less so than that of C₃S, and this accounts for the lower reactivity of C₂S. The C₂S in cement contains slightly higher levels of impurities than C₃S. According to Taylor (2003), the overall substitution of oxides is 4-6%, with significant amounts of Al₂O₃, Fe₂O₃, and K₂O.

Tricalcium Aluminate (C₃A): Tricalcium Aluminate (C₃A) comprises anywhere from zero to 14% of a Portland Cement. Like C₃S, it is highly reactive, releasing a significant amount of exothermic heat during the early hydration period. Unfortunately, the hydration products of formed from C₃A contribute little to the strength or other engineering properties of cement paste. In certain environmental conditions (i.e., the presence of sulfate ions), C₃A and its products can actually harm the concrete by participating in expansive reactions that lead to stress and cracking. Pure C₃A forms only with a cubic crystal structure. The structure is characterized by Ca⁺² atoms and rings of six AlO₄ tetrahedra. As with C₃S, the bonds are distorted from their equilibrium positions, leading to a high internal energy and thus a high reactivity. Significant amounts of CaO and the Al₂O₃ in the C₃A structure can be replaced by other oxides, and at high levels of substitution this can lead to other crystal structures. The C₃A in Portland cement clinker, which typically contains about 13% oxide substitution, is primarily cubic, with smaller amounts of orthorhombic C₃A. The C₃A and C₄AF by simultaneously as the liquid phase formed during the clinkering process cools, and thus they are closely intermixed. This makes it difficult to ascertain the exact compositions of the two phases. The cubic form generally contains 4% substitution of SiO₂, 5% substitution of Fe₂O₃, and about 1% each of Na₂O, K₂O, and MgO. The orthorhombic form has similar levels, but with a greater (5%) substitution of K₂O.

Tetracalcium Aluminoferrite (C₄AF): A stable compound with any composition between C₂A and C₂F can be formed, and the cement mineral termed C₄AF is an approximation that simply the represents the midpoint of this compositional series. The crystal structure is complex, and is believed to be related to that of the mineral perovskite. The actual composition of C₄AF in cement clinker is generally higher in aluminum than in iron, and there is considerable substitution of SiO₂ and MgO. Taylor reports a typical composition (in normal chemical notation) to be Ca₂AlFe_{0.6}Mg_{0.2}Si_{0.15}Ti_{0.5}O₅. However, the composition will vary somewhat depending on the overall composition of the cement clinker. The various constituents and their percentage mass is shown in table 1.1

CONTROL RATIOS: There are some factors used for the controlling of the properties of cement. The main strength giving compounds in cement are C₃S and C₂S. C₃S being the most important for early strength. The company’s aim is to produce clinker with as much possible in form of C₂S. The factors are lime saturation factor, silica ratio and alumina ratio. The three principal ratios used in the cement industry are;

Lime Saturation Factor: This tells the degree of lime content in the raw materials, cement, clinker, limestone in relation to other oxides. This means of describing the capacity of other three major elements that total use up the lime calcium in the mixture. Increasing the LSF at constant free time increases the quantity of C₃S, while decreasing the quantity C₂S.

Calculation of lime saturated factor

LSF =

CAO 1.1
(2.8 × SiO₂ + 1.18 × Al₂O₃ + 0.64 × Fe₂O₃)

Silica Ratio:- the higher the silica ratio, the higher the production in form of the silicate

C3 S and C2 S as silica ratio increases combination and burning becomes more difficult Silica ratio of 2.5 is often desirable

$$SR = \frac{S}{A+F} \quad 1.2$$

Alumina Ratio:- determines the proportion of C3A to C4AF present in the cement. As alumina ratio increases, so does the proportion of C3A, the proportion of C3 S decreases. About 1.5s alumina ratio combinational becomes easy. Too low or too high alumina ratio makes burning difficult.

$$AR = \frac{A}{F} \quad 1.3$$

Where SR is silica ratio; AR is alumina ratio; S is silica oxide; A is alumina oxide and F is iron oxide.

Mineral and Oxide Composition of Portland Cement: When considering the composition of a Portland cement, the most important factors are the relative amounts of each of the cement minerals, the amount of calcium sulfate, and the total amount of alkalis (Na and K). However, when performing a direct chemical analysis of the cement, what is actually determined is the relative concentrations of each of the elements in the cement. These values are then normally converted to the weight fraction of each element in oxide form, since the cement always contains an amount of oxygen sufficient to charge balance the other elements. This, along with a few other measurements, is then reported as the oxide composition of the cement. It should be noted that only a very small fraction of a cement consists of independent oxides of the form shown in Table 1.2 below.

Table 1.2. Oxide Composition of a Portland Cement.

Oxide	Range (wt%)	Cement #135 (wt%)
CaO	60.2 – 66.3	63.81
SiO ₂	18.6 – 23.4	21.45
Al ₂ O ₃	2.4 – 6.3	4.45
Fe ₂ O ₃	1.3 – 6.1	3.07
MgO	0.6 – 4.8	2.42
P ₂ O ₅	--	0.11
TiO ₂	--	0.22
Na ₂ O	0.05 – 1.20	0.20
	Na ₂ O equiv)	
K ₂ O		0.83
SO ₃	1.7 – 4.6	2.46
Loss on Ignition	--	0.81
Insoluble residue	--	0.16
Free CaO	--	0.64

The loss on ignition reported in Table 2.3 is the weight lost when the cement was heated to 1000 °C. At this temperature any water or CO₂ present in the cement specimen is driven off. The insoluble residue is the mass of material that is not dissolved by acid. This material generally consists of mineral crystals such as quartz, and a rule of thumb used by cement chemists is that the insoluble residue is 2/3 SiO₂ and 1/3 Al₂O₃. The free CaO (often called the "free lime") is the amount of calcium oxide present as CaO that is, not bound into the cement minerals. The free CaO is already counted in the weight fraction of CaO, so the total amount of cement mass accounted for in Table 2.3 is the sum of all the rows except for the last, which is 99.9%. The remaining 0.1% is likely in the form of other trace elements that were not tested for. The mineral composition of the cement is more useful than the oxide composition. However, the mineral composition is more difficult to determine accurately. It can be measured directly using techniques such as light microscopy, powder X-ray diffraction, or SEM X-ray analysis, or it can be

calculated from the oxide composition. According to a summary by Taylor (2003) powder XRD analysis is difficult because of the dominance of the C3 S peaks and the extensive amount of peak overlap, and accurate results are obtained only when very careful procedures and analysis are followed. Microscopy, which involves a point-count method, tends to be operator dependent and unreliable for separating the C3A and C4AF phases.

The Bogue Calculation of Cement Mineral Composition: A simple estimate of the phase composition of a Portland cement can be obtained from the oxide composition if one assumes that the four main cement minerals occur in their pure form. With this assumption, all of the Fe₂O₃ is assigned to C4AF and the remaining Al₂O₃ is assigned to C3A. This leaves a set of two linear equations to be solved for the amounts of C2 S and C3 S. This method is named after the cement chemist R.H. Bogue. A standardized version of this simple method is given in ASTM C 150 (2005).

There are two sets of equations, based on the ratio of A/F in the cement (both inputs and outputs are in weight percent):

If A/F > 0.64

$$C3 S = 4.071C - 7.600S - 6.718A - 1.430F - 2.852$$

$$C2 S = 2.867S - 0.7544C3S \quad 2.4$$

$$C3A = 2.650A - 1.692F$$

$$C4AF = 3.043F$$

If A/F < 0.64

$$C3 S = 4.071C - 7.600S - 4.479A - 2.859F - 2.852$$

$$C2 S = 2.867S - 0.7544C3S \quad 2.5$$

$$C3A = 0$$

$$C4AF = 2.100A + 1.702F$$

Applying Eqn. 2.5 to the oxide composition given in column 3 of Table 1.2 results in: 55.4% C3 S, 19.7% C2 S, 6.6% C3A, and 9.3% C4AF. While this method is simple, it is not very accurate. In particular, there is a tendency to overestimate the amount of C2 S and underestimate the amount of C3 S. One study found that the Bogue calculation gave C3 S contents that were on average 8% lower than of those obtained from light microscopy (a technique that is reasonably accurate for estimating C3 S). Also, the sum of the four minerals tends to be much less than 100%. While there are several sources of error in the Bogue calculation, the most significant is the assumption that the minerals occur in their pure form. In fact, the actual composition of each of the cement minerals differs rather significantly from its assumed formula. By taking into account the known tendency for other oxides to substitute into the cement minerals.

Research Method

Data Collection: The efficiency of a complete research work depends largely on the reliability and validity of the data used. The data used in this project were collected majorly from the quality control Centre of Dangote Cement and the mines department of the company. The purpose of data collection is to obtain information to keep record to make decisions about important issues, Primarily the data collected is to pass information regarding a specific topic.

Sample Collection and Preparation: Samples from the mines (limestone, shale and laterite) are tested to determine their right grade as well as their mixing proportion to achieve the required target; also during the production stage materials produced are regularly tested. Samples are gotten for the kiln feed and final cement produced. A sample collector stationed at junctions on the production process.

The sample collector is anti-corrosive and fire proof. The materials are well prepared for testing mainly done by the robot in the ROBO-lab (it mills and pelletize the samples).

Quality Control of Limestone and Additives: Tests are carried out at every hour from each mill to enhance the quality in accordance to the standard and target for the company. Sample collected from each mill is analyzed for calcite, sulphate (SO_3), alite, belite, magnesia, free lime, silica, alumina and so on. These parameters are examined to control the rate of grinding during processing.

Quality Control Processes / Laboratory Procedures: The quality control center of the company employs the latest technology of quality control in the world. There are various quality control measures set for effective production and effective cost effectiveness in the company. The quality control and laboratories processes include: ROBO lab/ QCX (quality control by x-ray) lab; compressive strength determination; cement fineness determination; moisture test and the setting time determination.

The ROBO/QCX Lab: This is the main quality control room of the company, the operations here are fully automated, in the lab certain constituents of the cement are checked and controlled; they include LSF, C3A, C4A, and the amount of free limestone (FCaO), $\text{Al}_2\text{O}_3\text{Fe}_2\text{O}_3$, SiO_2 . All these constituents of cements are regularly checked and controlled every 20 minutes so that they don't pass their already stipulated quantity or percentage. It comprises of the following: ROBO-lab; X-ray fluorescence Analyzer; and Online Analyzers (Thomson, 1998).

ROBO- Lab: In this laboratory there is a robot present in the lab that tests the materials gotten from the production process using a sample collector stationed at junctions on the production process. The sample collector is anti-corrosive and fire proof. The processes at ROBOT include:

- Receives materials from the sample collector.
- Takes it into the milling machine where the material is ground to fine particles.
- Takes the ground material to the cooling machine.
- Removes the material from the cooling machine and pelletize it into flat metal pellets.
- Sends the pellets to the XRF for analyzing.
- At the same cooling process it removes some of the fine materials into small containers which is sent to the fineness test lab for further testing.
- The robot also collects the pellets through a mini conveyor belt and returns it to its original position.
- It then waits for another 20 minutes to continue the sequential process.

XRF: In today's cement manufacturing process, to ensure continuous 24/7 high quality cost-effective quality control requires that results obtained from chemical analysis are available a few minutes after the sample is taken. X-ray Fluorescence (XRF) is a well-established analytical technique used at many stages of the cement manufacturing process, from raw materials, i.e. at the quarry, to intermediate products (clinker, gypsum) and the finished product (cement). In all cases robust, simple to use XRF instruments, operated by production staff can provide cost-effective analysis allowing the material to be continuously produced on a 24/7 basis with no delays, reworks, etc. The machine is the simplest multi-element analyzer typically measuring MgO , Al_2O_3 , SiO_3 , SO_3 , K_2O , CaO and Fe_2O_3 in cement materials. It is often used to measure sulphate addition in gypsum, measuring the powder sample directly with no additional sample preparation. The Lab is located on the production site, typically in a control room and operated by production staff. Samples can be loaded either as 40mm pressed pellets or if an automation system is used 51.5 mm diameter steel rings which has been carried out in the robolab (Morgan, 1983).

Online Analyzers: This is an online method of quality control method of quality control employed in the plant. Receivers are placed at strategic points of the production process. The online analyzing is carried out by gamma rays and it helps to check and control the constituents and also help to keep the production process intact. The process is fast but not as efficient as the XRF method.

Compressive Strength Test Lab: In this laboratory the test for the compressive strength produced is tested, this is basically done to know how much pressure it can withstand, the test is done for 2 days, 7 days, and 28 days, so has to know how well the strength of the cement produced can be after the stipulated amount of days. Apparatus needed includes; 450g cement, measuring cylinders, distilled water, jolting machine, 1350g of sand, mortar mixer. The procedures include:

- Clean and grease the mould (aets of moulds are shown as plate 2.4)
- Measure 225ml of water.
- Add the 225ml of water to the mortar mixer's container.(a mortar mixer is shown as plate 2.2)
- Add the 450g of cement and 1350g of sand.
- Switch the mortar mixer on and let it mix all the materials evenly.
- Leave the machine for 240seconds.(4 minutes).
- Pour the mixed product in the mould to give the bricked shape.
- Place the mould on the jolting machine and let it suck out the air, leave the machine to make it solid and leave for 24 hours, after 24 hours the samples are placed in water.(a jolting machine is shown as plate 2.3)
- The test is done for 2 days, 7 days and 28 days
- After the amount of days needed, the samples are placed on the compressive strength machine to measure the strength of the cement.



Plate 2.1. Compressive strength machine



Plate 2.2. Mortar mixer



Plate 2.3. Jolting machine



Plate 2.4. Moulds

Fineness Test: Fineness is also an important factor required in cement production, the cement produced must be as fine as possible so that it can react well in the kiln, if it is coarse it affects the smoothness of the kiln, the fineness also helps burning. The aim of this determines whether the cement is as fine as required. The procedures include:

- Measure 450g of cement.
- Pour measured cement in the 90mm sieve.
- Shake the 90mm sieve till the particles pass through.

The quantity of residue retained determines the degree of fineness.

Moisture Test: The aim of this test is to know the percentage of moisture present in the clinker before it goes to the kiln so as to know the actual tonnage left after heating, a reduction in the moisture content reduces the quantity of cement produced; this method also helps in cost effectiveness of cement production. The procedures involved include:

- Measure a volume of cement clinker and record its weight.
- Place the material in an oven and heat for 24hours.
- After 24hours remove the clinker from the oven and allow to cool.
- Measure the new weight of the clinker.
- The difference in weight shows the quantity and the percentage of the moisture present in the clinker.

The Setting Time Determination: The aim is to determine the setting time of cement. The materials used are cement, water, Vicat moulding mixing plate, set needle. The procedures involved are:

- The vicat plate and base plate were properly oiled and cleaned.
- 450g of sample was measured and spread on a steel bench plate for 30 minutes and allowed to cool to room temperature.
- 130ml of water (this depends on water intake capacity of the sample) was added to the cement) the time is noted down and mixed to form paste.

- Immediately the paste was transferred into mould, the excess smoothened of and labeled.
- The mould with paste was placed under the initial set needle. Lower gently to make contact with the surface of the paste, then quickly released and allowed to sink into the paste.
- The penetration test was repeated at regular 15minutes interval when setting began, the time interval was reduced to 5minutes and this was carried out at least on 10 positions of the pot. The initial setting is carried out at least on 10 positions of the pot. The initial setting is released when the needle sinks to 10mm mark. The time between the addition
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- n of water to the sample and initial setting is initial time in minutes.
- Immediately the initial set is reached, the final set started with initial. The final set is reached when the attachment on the needle failed to make any impression on the surface of the paste over 10 positions. The addition of the initial set time and the interval between the initial set and final set is added together to get final time.

RESULTS AND DISCUSSION

Compressive Strength Test Results: Compressive strength (N/mm^3) values obtained from different sample of slag water mixture after 2, 7 and 28 days as shown in Table 3.1

Table 3.1. Compressive Strength Test

Sample	Compressive Strength		
	2 days	7days	28days
1	21	40	53
2	19	28	50
3	19	37	49
4	16	32	43
5	17	33	45
6	19	31	-
7	22	40	53
8	18	36	50
9	33	47	33
10	17	31	41
11	19	34	45
12	18	33	46

Chemical Analysis in the ROBO-LAB: The result on chemical analysis of clinker and the final Portland cement is given in Table 3.2

Table 3.2. Percentage of Constituents in clinker and cement

Constituent	% in clinker	% in cement
LSF	101.21	115
CaO	53.57	62
C3 S	56	58
C2 S	16.47	19
Al ₂ O ₃	5.1	4.7
SiO ₃	20.34	19.1
MgO	2.14	-
Fe ₂ O ₃	3.34	3.1
Free lime	1.1	-

Setting Time and Residue Determination: The results gotten from the setting time and residue determination test is given in Table 3.3

Discussion of Result: The compressive strength of the cubes is determined according to the ages of the cubes which is 2 days, 7 days and 28 days. Table 4.1 presented that the higher the ages of the cubes, the higher the compressive strength of the cubes, therefore the number of days spent is directly proportional to the compressive strength. Therefore, the result shows that the cement can withstand much pressure according to the number of days.

Table 3.3. Setting Time and Residue test result

Sample	Initial	Final	Residue 90mic
1	193	240	10.0
2	165	234	10.4
3	170	236	11.1
4	161	234	14.5
5	191	261	13.1
6	165	234	10.4
7	196	255	16.6
8	195	260	16.2
9	193	260	16.3
10	198	263	19.6
11	195	260	16.2
12	205	264	13.4
13	196	255	16.0

Each cement company has its set target for every constituents of cement. The degree of lime content was estimated using Eqn. (4). It estimated the degree of lime content in raw materials, clinker, cement, limestone in relation to other oxides as shown in Table 3.2. The target set by the company is 96 %±2 while it is 130.0 % for crushed materials. Table 3.2 shows that the content of MgO in cement is less than 3.0 % which is within the recommended standard but if the content is more than 3.0 % it cause expansion in the cement and it need to be controlled in the clinker. Free lime is always present in the clinker if the combustion is not complete (that is when kiln do not burn very fast) there will be more of alite than belite and free lime. The presence of free lime causes low strength of the clinker, the company tries to reduce the content as soon as possible, the target is less than 1.5 %. Also, the values of C3S and C2 S are within the standard value of 55 – 60 % C3 S and 15 – 20 % for C2 S. The addition of belite and alite should not be more than 70 %. Table 3.3 shows the setting time and residue determination values. It was deduced from Table 3.3 that all the residue values were within the standard range of 10 – 22 gm. It helps to determine the particle size distribution of the cement which is used for monitoring the quality distribution of cement being produced. The amount of residue retained by different sieves must not be below or above the standard specification of 10 – 22 gm. Cement residue is a qualitative measurement used to determine material size distribution and mill performance/ efficiency. If residue obtained was not with the standard specification after the test the speed of the classifier has to be increased. The residue materials must not be too fine in order to overcome over burn problem but it must be appropriate so that it can react well in the kiln. Meanwhile, if the material is coarse it also affects the smoothness of the kiln as the kiln coating wears out. The setting time determination is important in determining the binding rate of cement if the setting time is too slow the binding rate will be too high when it is exposed to the sun it may cause cracking of walls after sometime. The setting time is a physical measurement that cannot be neglected because it is a function of the effectiveness of the added gypsum.

Conclusion and Recommendation

CONCLUSION

Quality control has made production of cement easier as every process is being monitored to avoid defects or errors during production.

As a result of this, effectiveness of quality control in Dangote Cement PLC, Ibeso Ogun State, Nigeria has been investigated. The results show that the compressive strength for 2 days is between 16 – 33, for 7 days is between 28 – 47 and for 28 days is between 33 – 53. Meanwhile, percentages of CaO, C3 S, C2 S and MgO in clinker are 53.57 %, 56 %, 16.47 %, 2.14 % and 62 %, 58 %, 19 %, 0 % in cement.

The amounts of residue retained by different sieves were within the standard specification of 10 – 22 gm. The study therefore concluded that the quality control in Dangote Cement Company is effective and cement produce meets international standard requirements and characteristics which dependable and satisfactory.

Recommendation

Based on the study and result obtained, the study makes the following recommendation.

- The company should provide more training and acquire latest modern equipment in order to be more competitive in international market.
- Not all the quality of cement required by the customers is adequately available, the company should increase their production in high grade cement used for special purposes.
- The company should make provision for training and re-training of their staff so as to update them with the quality control measures.
- The companies should collaborate with academician in-terms of research in solving their problem.

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