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Assessment of Portland Cement and Pozzolana Cement: Which Cement? Where? and How in Civil Engineering Construction Applications?

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ABSTRACT

A critical study in this paper is made into the chemistry and manufacture of ordinary Portland and pozzolana cements; so as to be able to understand that basics similarities and differences. It is true that both cements have their own noted benefits; they also have their own short comings. Which cement type to use for a particular civil Engineering Construction projects, where and how is fully assessed in this paper. It is also noted that the type of structure under a particular consideration, the environment under which the structure is build and the urgency and requirements of the works specified play a major role in cement selection. This study proffered adequate recommendation and conclusion which are of importance for this paper.

Keywords: Ordinary Portland Cement, Pozzolana Cement

INTRODUCTION

The early production and introduction of Portland cement in the nineteenth century was really a great leap forward the entire global construction industry. It is true that other hydraulic cements were known to mankind in the ancient times, the introduction of Portland cement had already transformed the construction industry from the wood and the stone based to concrete based construction. In 1824, a known British brick layer by name Joseph Aspid, registered a patent after producing a cementatious material by burning a powdered limestone and clay together in his kitchen stove. The name he gave to the product was Portland cement, simply because it looked like a stone mined in the isle of Portland England. After that period, in a relatively shorter period of time, cement then made its way throughout the world [1].

The Chemistry Background of Cement

Portland Cement: The production of cement involves a complex inorganic reaction of the various compounds. This is achieved by blending and heating the raw materials to obtain the appropriate properties and proportions of line (cao), silica (siO_2), alumina ($A/_2O$). The basic raw materials that generate these compounds are limestone ($caco_3$), dolomite (mg co_3), dry soil, silt, sand and other materials. The high quality cements require raw materials of proper chemical composition that is proportioned to precise quantities. The chemical constituents of these materials combined at the high temperatures of the kiln to from new compound phases.

The limestone, which consists majorly of calcium carbonate is the most common source of lime, although other raw materials such as dolomite, ckalk, shell deposits, and calcareous muds are usually used. Heating limestone to a temperature of about 90 ^{O}C drives off carbon dioxide [Co_2] to the atmosphere, and leaving the lime [Cao]. In the presence of moisture, Cao reacts with water to form slaked lime [$CaoH_2$].

Table 1: Major Compounds in cement

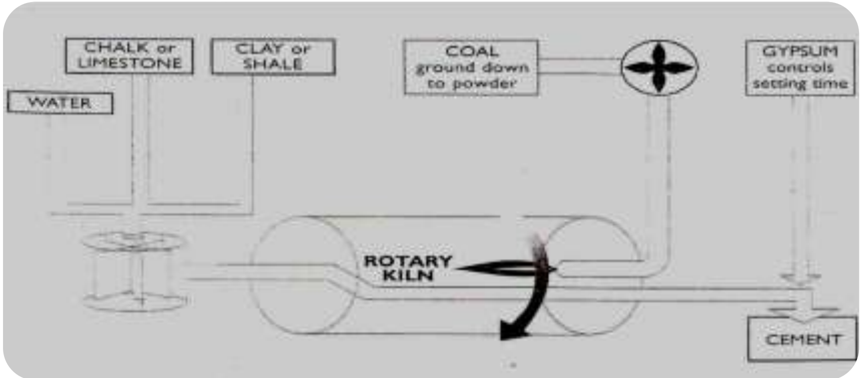
Name	Chemical Formula	Shorthand notation	Expected proportion %
Tricalcium silicate (alite)	$3CaO.SiO_2$	C_3S	37 to 60
Dicalcium silicate (belite)	$2CaO.SiO_2$	C_2S	15 to 37
Tricalcium aluminate	$3CaO.A1_2O_3$	C_3A	7 to 15
Tetracalcium aluminioferrite (ferrite phase)	$4CaO.A1_2O_3.Fe_2O_3$	C_4AF	10 to 18
Others (Free lime, MgO, alkalis, etc)	Nil	Nil	<10

Source: [EACE] Bulletin Vol 8, No 5, (2015)

Clay as Major Oxides of Silicon

Clay is the major source of oxides of silicon, aluminum. And iron (Cao(C), $Si^{O}2$ (S), $Al2^{O}3$ (A) and Fe_2 $^{O}3$ (F) are the major Oxides that usually interact with each other in the kiln to from minor compounds such as alkalis ($Na_2{}^{O}$, $k2^{O}$), magnesium Oxide (mgo) and ash.

Table 2: The raw materials Heated in a Rotary kiln



Source:- **ELE International:- Construction Materials Testing Equipment (10th Edition)**

The typical manufacturing process of cement involves heating of the raw materials in the kiln. A modern kiln may be of 6m in diameter and about 180m long that may be inclined against the horizontal and revolving at about 6 to 20 pm, which may be capable of producing 5,000 tons of clinker per day. Generally, the cement clinker production inside the biln involves three phases namely: evaporation of water from raw materials, calculations (formation) of calcium Oxide and expulsion of carbon dioxide) and sintering (clinkering) that enables the recombination of Oxides. Cement manufacturing is an energy intensive operation, requiring an average, Temperature of about 1450% at clinder formation. A sequence of Temperature ranges from evaporation to cooling of the chinder can be understood as shown below

Table 3: Temperature ranges in cement manufacturing [3]

Action	Temperature(ºC)	Outcome
	~100`	Free water coming from raw materials evaporation
	~ 150-350	Loosely bound water is lost from clay.
	~350-650	Clay decomposes to silicon and aluminum oxides(Sio_2&$A1_2O_3$)
	~600	Decomposition of dolomite (Mg_2O_3 to MgO and CO_2
Heating	~900	Decomposition of limestone (Ca^2O_3 to C_aO and CO_2
	~1250-1280	Liquid formation and start of compound recombination
	~1280	Clinkering begins.
	~1400-1500	Clinkering.
	~100	Clinker leaves the kiln & falls into cooler

Sources: EACE (2015) Vol 8,No5

Pozzolana Cement

Pozzolana cement is a volcanic ash like pumice, scoria and red ash. It's name is derived from a place called puzzuoli in Italy where such materials were mined for producing concrete.

According to ASTM C21907, a pozzolanic material is described as follows:-

"a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will in finely divide form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form cementitious hydrates"

With the above, a pozzolanic material is a material consisting of silicon and aluminous oxides with the potential to react with calcium hydroxide (Caott)

ASTM 61805 also subdivided pozzolana materials into three classes, namely:-

(i) Class N(raw or calcined natural pozzolana)
(ii) Class F (ash from the burning of anthracite or bituminous local and)
(iii) Class C (ash from lignite or subituminous local)

The above three stated classes have their own marked physical and chemical properties. The use of pozzolanic materials for cement is increasingly attracting attention. Pozzolana cements are a kind of blended cements whereby pozzolanic materials are added with cement cliker or are separately and blended with ordinary Portland cement. In the presence of moisture, pozzolanic materials react with free lime to form other cementitious products such as calcium hydroxide [$Ca(oH)_2$], silica (Sio_2) and alumina ($Al_2 O_3$)

Portland Cement and Pozzolana Cement

(i) They usually improves the properties of fresh concrete by extending the chemical reaction so that sufficient time for the mixing, transporting, placing and consolidation can be attained
(ii) They improves the strength and modulus of elasticity of concrete through the provision of higher compressive strength for equal amount of cement at later age
(iii) Permeability and corrosion of Reinforced concrete bars is usually reduced, mainly due to the reduction of micro pores in concrete, as a result of the formation of calcium silicate and

calcium aluminates hydrates from pozzolanic reactions.

(iv) Pozzoland cement is particularly useful in marine works and also in mass concrete structures.

Characteristics of Pozzolana Cement

(i) Pozzolana produces less heat of hydration and also offers greater resistance to the attack of aggressive water or sulphate.

(ii) It is slow in reaction and cannot serve for construction projects that require fast strength development

(iii) Bleeding and large shrinkage is a short comings in the pozzoland cement concrete

(iv) The rate of development of strength is lower than that of normal Portland cement, especially at low Temperature

(v) Ultimate strength of this cement is more than that of ordinary Portland cement

(vi) The reaction of pozzolanas with free lime usually avoids alkali aggregate reaction which otherwise would cause cracking and deterioration

(vii) Pozzolanic reaction takes up the free lime and mal-effects of the carbonation becomes minimized

(viii) Sulphate attack from sea water or sulphate bearing water or sulphate bearing soils is reduced due to reduction of tricalcium aluminate (C_3A) as a result of replacement with

(ix) Heat of hydration and subsequent cracking of mass concrete is reduced due to the reaction extension effect of pozzolands

(x) The concrete life- cycle cost is reduced consequently upon better durability and long life of concrete attribute to addition of pozzolanas and their subsequent reactions

(xi) The risk of global warming arising form cement production is actually reduced through replacement of high energy intensive clinker production with pozzolanas

(xii) The Thermal and electrical energy consumption is reduced as pozzlanas do not require intensive heating

Which Cement? Where? and How in Civil Engineering Construction Applications?

The selection of OPC and PPC Cements for a particular civil Engineering construction projects will usually depend on a number of parameters such as:-

(i) Environmental factors, such as weather either hotness or coldness
(ii) The location of a particular structure under construction either in water logged or dry condition
(iii) The type of structure
(iv) Expected suphate attack
(v) The maximum limit of heat of hydration
(vi) The urgency requirements of the project specified in the contract
(vii) The table below shows and compares the salient properties of OPC and PPC

Table 4

Major properties of OPC and based concrete Mixed for construction applications

Property	**OPC**	**PPC**
Setting and hardening	Fast	Slow
Early strength development	Fast	Slow, but large at later age
Heat of hydration	High	low
Frost resistance	Good	poor
Shrinkage	Little	Big
Corrosion resistance	Poor	Good
Heat resistance	Poor	Good
Impermeability	Poor	Good
Carbonation resistance	Poor	Good
Resistance to sulphate attack	Poor	good

Source: EACE (2015), vol 8,No 5

Based on the general properties shown in the table above, it is in order to suggest that OPC has a better frost resistance at early age, and is generally good for localities where cold weather is prevalent. In a project where the structure under consideration and construction is either water logged or soon to become concrete gains adequate strength, it is better or advisable to USC OPC than PPC, but however the use of OPC with high water to cement ratio allows the increase of potentially dangerous fluids inside the micro pores of concrete that would ultimately cause durability challenges.

Alternatively, on the other hand, in a hot weather condition and for any mass concrete construction where the low heat of hydration is required, using PPC is the most feasible choice. In addition, when long term durability is the essence and resistance to corrosion, carbonation and sulphate attack is seen, PPC comes to the fore. Unless and otherwise when little shrinkage, faster early strength development and early age frost resistance is primarily sought for; using PPC is much more practicable than OPC in most geographic locations in Nigeria

RECOMMENDATION

Design Engineering should always be conversant with the environmental conditions of any project site before putting up any design project. A detail environmental impact assessment should be carried out.

The relevant design codes of practice for structures should always be contacted and well apply during the design of any civil Engineering structure.

Contactors engaged in carrying out project contracts should always stick to material specifications, especially with the choice of cement for any construction project site.

Detailed market survey on construction materials should always be carried out in order to carry out as certain the proper origin or source of the materials for a particular project for construction.

CONCLUSION

The following conclusions are drawn from the above assessment:

(i) Ordinary Portland cement (OPC) is energy intensive and hence costly to produce. Its use is necessary in cold highland locations where frost attack on fresh concrete is expected. In humid localities, OPC can be used with low water to cement ratio, so that durability will be less affected

(ii) Portland pozzland cement (PPC) has numerous benefits from durability, long term strength, cost, energy and global warming perspectives. However, PPC concretes are slow in early strength development, has higher shrinkage, and also susceptible to frost attack, while fresh and slow in setting and hardening. When these shortcomings out weight the benefits, the use of PPC can therefore be avoided, otherwise PPC suits most geographical locations in Nigeria.

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