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CONSTRUCTION COST REDUCTION THROUGH PARTIAL REPLACEMENT FOR CEMENT USING CALCINED CLAY

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ABSTRACT

Overtime cost of construction have been on the rise several attempts have been made to reduce cost. It has been discovered that cement that occupy a paramount space in construction contribute largely to construction cost. Research has pointed to the fact that there are viable naturally existing materials that can take the

Introduction

Portland cement-based materials such as concrete are nowadays the most widely used construction materials. Due to a relative low production cost and versatile application of concrete, its main constituent Portland cement has become a desired material. The annual global production of cement has risen the last 10 years by more than 50% and in 2015 4.2Bt of cement was produced (Cement Industry, 2015). Moreover, the economic growth of developing countries will result in a further increase of the total global cement production. This further expansion of the cement industry is a cause of concern, since the production process is very energy-intensive and has a considerable environmental impact.

During the production process of Portland cement clinker, limestone ($CaCO_3$) is decomposed into calcium oxide and the green house gas carbon dioxide. The amount of CO_2 released upon the

place of cement there by leading to cost reduction. The Research looks into exploring a local cementitious building material in lateritic clay that has been in use since time immemorial in the indigenous building industry to partially replace cement to reduce the cost of construction. This research extends the investigation on calcined clay for partial replacement of cement. Samples of Calcined Clay (CC) were prepared from Natural Kaolinite clay and were blended with Portland Cement (PC) of 20%, 30% and 50% were replaced with Calcined Clay and compared to 100% Ordinary Portland Cement. Samples of lateritic clay were used and calcined (heated) to about 800°. Each specimen produced were cured, weighed and tested, an interval of 7, 14, 21 and 28days were adopted. The 28th day compressive strength test carried out on the samples shows that 20% and 30% calcined clay were better stabilizers; this translates to environmentally friendly alternative to cement. Of the three specimens produced, the effect of the blend of 20% and 30% replacement were more pronounced as they had higher crushing strength than 50% replacement. With this replacement it is envisaged that equal concrete strength is achieved and cost is reduced. The two samples made the gauge for the research and partial replacement of cement is recommended for high strength concrete and also a solution for cost reduction in concrete production.

Author keywords: *Add-mixtures, Calcination, Cement-based materials, Decarbonation of clay, Low-carbon economy proposal, Low-cost building materials, Supplementary cementitious material.*

decarbonation of calcium carbonate counts for 50 – 60% of the total amount of CO_2 emitted during the production process of cement. The other 40-50% can be attributed to the combustion of fossil fuels that are needed to heat the kiln to the desired temperature of 1450°C and to a minor extent to the grinding and transportation. On average for each ton of cement that is produced approximately 0.85 ton of CO_2 is emitted (Gartner, 2004). As a consequence, the cement industry accounts for around 4 % of the total global greenhouse gas emissions and up to 8 % of the total global anthropogenic CO_2 emissions (Barcelo et al., 2013; Damtoft et al., 2008).

In response to the environmental concerns about the high CO_2 emissions, political decisions resulted in the 2050 low-carbon economy proposal of the European union which stated that the industrial CO_2 emission should be reduced by 80% in 2050 compared to the 1990 levels (European Commission, 2011). As a result, the cement industry faces a huge challenge to decrease their CO_2 emission without diminishing the quality of the Portland cement produced. Different alternatives to reach this goal have already been suggested whereby both the applied process and the type of fuels have been optimized. However, the upper limit of the energy efficiency is nearly reached and the potential to advance becomes rather small.

However, blending cement with supplementary cementitious materials (SCMs) is considered to be one of the most effective ways of reducing the environmental impact of the cement industry (Gartner, 2004; Juenger and Siddique, 2015; Lothenbach et al., 2011). Conventional and high-quality SCMs like granulated blast furnace slag from iron production and fly ash from coal combustion of electricity production face complete utilization (Snellings et al., 2012). There is an interest to search for alternative SCM sources due to supply-and-demand concerns in the future. One of the most promising alternative sources are limestone calcined clays since they have not yet reached their full potential as cement replacement and clay is an abundant and widespread material which can lower transportation costs (Schneider et al., 2011). The production process of calcined clay is less energy intensive and more environment-friendly due to lower firing temperatures and the absence of a decarbonation reaction. The calcination of clays occurs in the temperature range of 600 and 850 °C, and results in the dehydroxylation of the clay whereby an amorphous phase is formed. The Si and Al in this phase can chemically react at ambient temperatures with $Ca(OH)_2$ (portlandite), which is formed during cement hydration, in the presence of water to form compounds that posses cementitious properties.

Many studies have already demonstrated the effectiveness of calcined clays, particularly for kaolinitic clays to produce metakaolin with increased pozzolanicity, i.e., reactivity with portlandite (Al-Rawas and Hago, 2006; Fernandez et al., 2011; He et al., 1994; Sabir et al., 2001; Tironi et al., 2012) However, calcined clays other than metakaolin are hardly used as SCMs due to the complexity of clay minerals and ignorance of the underlying reaction mechanisms.
Furthermore, only limited studies are conducted to examine pure calcined clays, like the highly reactive metakaolin. Most clays in nature, however, are mixtures of different clay minerals (kaolinite, illite, montmorillonite and mixed layers) and a large proportion of impurities of non-clay materials, such as quartz, calcite, feldspars and mica (Tironi et al., 2012). Consequently, the pure clays are not representative for the wide variety of clay deposits. Moreover, pure clays are not economical for cement industry (He et al. 1994; Lara et al. 2011). Pure calcined clays are more costly than other commonly used SCMs due to restricted, regional availability and an energy-intensive manufacturing process. Due to these limitations, there is increasing interest in implementing blended-kaolinite clay minerals that have a widespread availability, as a less expensive alternative to metakaolin (Fernandez et al., 2011). Hence the main aim of this study is to investigate the potential use of calcined clays from a mineralogical point of view by linking the characteristics of the untreated clays to the pozzolanic activity of the calcined clays. To achieve this goal several issues, discussed in the subsequent paragraph, have to be solved and examined in detail.

STATEMENT OF PROBLEM

The cement industry is one of the two largest producers of carbon dioxide (CO_2), creating up to 8% of worldwide man-made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. The CO_2 produced for the manufacture of structural concrete (using ~14% cement) is estimated at 410 kg/m3 (~180 kg/tone @ density of 2.3 g/cm3) (reduced to 290 kg/m3 with 30% fly ash replacement of cement). The CO_2 emission from the concrete production is directly proportional to the cement content used in the concrete mix; 900 kg of CO_2 are emitted for the fabrication of every ton of cement, accounting for 88% of the emissions associated with the average concrete mix. Cement manufacture contributes greenhouse gases both directly through the production of carbon dioxide when calcium carbonate is thermally decomposed, producing lime and carbon dioxide, and also through the use of energy, particularly from the combustion of fossil fuels.

One area of the concrete life cycle worth noting is the fact that concrete has a very low embodied energy per unit mass. This is primarily the result of the fact that the materials used in concrete construction, such as aggregates, pozzolans, and water, are relatively plentiful and can often be drawn from local sources. This means that transportation only accounts for 7% of the embodied energy of concrete, while the cement production accounts for 70%. With a total embodied energy of 1.69 GJ/tone concrete has a lower embodied energy per unit mass than most common building material besides wood. However, concrete structures have high mass, so this comparison is not always directly relevant to decision making. It is worth noting that this value is based on mix proportions for concrete of no more than 40% calcined clay. It is estimated that one percent replacement of cement with calcined clay represents a .7% reduction in energy consumption. With some proposed mixes containing as much as 80% fly ash, this would represent a considerable energy saving.

Cost Analysis

The cost of concrete with different levels of Calcined Clay replacement:

1. Cost of concrete with 100% cement in 1:2:4 – 19mm aggregate is ₦37,283.88/m^3.
   Assume a bill of 10m^3 concrete will therefore cost: 10m^3 at ₦37,283.88 = ₦372,838.80
2. Cost of concrete with 20% Calcined Clay replacement is ₦ 24,811.69
   Similarly, a bill of 10m^3 concrete will therefore cost: 10m^3 at ₦24,811.69 = ₦248,116.90, which is: 33.45%
3. Cost of concrete with 30% Calcined Clay replacement is ₦ 23,935.86

Also, a bill of 10m^3 concrete will therefore cost: 10m^3 at ₦23,935.86 = ₦239,358.60, which is: 35.80%

PURPOSE OF THE STUDY

This study is conducted to accomplish some predefined objectives. These objectives are:

i) To study the performance of concrete containing different percentages of calcined clay and to identify the optimum replacement percentage.

ii) To investigate the effect of calcination temperatures to the strength performance of calcined clay-concrete.

iii) To compare the performance of calcined clay with other cement replacement materials (CRMs).

SIGNIFICANT OF THE STUDY

The basic motivation is sustainability by finding new type of binder.

The sustainability also means;

I} Durability required

II} Resources [energy required to produce the cement

III} carbon dioxide [climate change]

IV} social acceptance

V} cost

The benefits of calcined clay for the production of cement are many, from reducing the emission of polluting gases to a higher final compressive strength (final age), depending on the case,

Every year, several cement industries produce billions of tons of concrete, reaching an average of 3.7 billion of these products produced annually, constituting one of the biggest bases of the world economy, both directly, employing several people in their factories, and indirectly, in sectors such as civil construction, where it is the main material in several countries. To produce them, the cement industry uses clinker, a material that generates high thermal and electrical consumption, which raises production costs.

With this, several companies, both national and international, have been looking for alternatives to reduce the costs of this production, replacing clinker by calcined clay, a clay material that can be found both naturally and artificially produced. This pozzolanic calcined clay, as it is also known in addition to helping to reduce CO_2 emissions in industries can also bring several economic advantages for cement production.

The production of pozzolanic cement, on the other hand, does not need a raw mill, as one of the greatest benefits of calcined clay is that it only needs to be reduced in size to be fed directly into the kiln. In addition, this material does not require clinkerization, it only needs to be dried and heated between 700°C and 900 ° C (but the temperature depends on the clay) and activated, to increase its porosity to increase the surface area and reactivity. However, the fuel consumption for the calcined clay to be activated is significantly lower than that of the clinker.

In cement production, in some countries, this material replaces clinker by up to 50% in the composition of the product, whether natural or artificial, and can bring a reduction of up to 25% in thermal consumption and up to 15% in electrical consumption compared to other material. In addition, cements made with this type of clay in their composition will have great advantages in relation to final compressive strength (final age) and corrosion.

SCOPE OF STUDY

This study focuses on the strength performance of concrete with limestone calcined clay Strength is the most important property of concrete since the first consideration in structural design is that the structural elements must be capable of carrying the imposed loads. Strength characteristic is also important because it is related to several other important properties which are more difficult to measure directly. With regard to this matter, the development of compression strength of calcined clay concrete is studied. Cement replacements by 5%, 10%, 15%, 20% and 30% with calcined clay are studied. Concrete tests are conducted on the concrete samples at the specific ages. All the strength tests are limited to the ages of 28 days. 5 In the study of the effect of calcination temperatures to the strength performance of calcined clay, the temperatures are set within the range of 600°C-800°C. The temperatures interval used is 50°C. For the performance comparison study, the cement replacement materials used are silica fume and ground granulated blast furnace slag. These two cement replacement materials are chosen as they are the most common replacement materials nowadays and will be good comparisons to calcined clay. The comparison is made on the compressive strength performance of calcined clay, silica fume and slag concrete.

RESEARCH QUESTIONS

I. To determine the compressive strength of Limestone Calcined Clay (LC3) and Ordinary Portland Cement (OPC).
II. To establish the percentage replacement of Limestone Calcined Clay (LC3) and Ordinary Portland Cement (OPC).
III. To determine if limestone calcined clay is a cheaper alternative.
IV. To lower carbon dioxide emissions been produced in cement industries by suggesting Supplementary Cementitious Materials (SCMs).

MATERIALS AND METHODS

CALCINATION

The optimal calcination temperature is influenced by the mineralogy and chemical composition of the clay. When the temperature is not sufficiently high, the dehydroxylation of the clay minerals is not completed and the structure remains partially intact. However, high calcination temperature > 900°C can lead to recrystallisation of high temperature phases and additional sintering resulting in a decrease in the pozzolanic reactivity of the material. To estimate the influence of the differences in decomposition on the pozzolanic reactivity, a temperature range between 500 and 900°C are used for the pure clays and the mixtures in order to obtain different stages of the degree of dehydroxylation for all studied clay types. For the natural clays only one optimal calcination temperature are chosen within this range depending on the clay type. Clays that predominantly consist of kaolinite were calcined at 750°C, while for more smectitic clays 800°C are applied.

Raw clays were thermally treated in a laboratory programmable fixed-bed furnace. The clay was spread out as a thin layer (<1.5 cm) in porcelain crucibles to insure homogenous firing of the samples. In this process, the heating rate are divided in three major steps, 20°C/min for the first step, 10°C/min for the second step and 5°C/min for the last 100°C The different steps were introduced to limit the overheating of the clay. The residence time at the desired temperature are set at 2 h.

After gradually cooling, the calcined clays were ground to achieve a more similar fine grain size distribution. This milling step is done to minimize the sintering effect of the calcination process and has a positive effect on the surface interaction when blended with lime or cement (Gamelas et al., 2014). Furthermore, the grain size might overshadow the effect of mineralogical parameters on the pozzolanic properties especially for smectitic clays which easily sinter. Some authors suggested that the pozzolanic reactivity can be influenced by the milling step as it can induce the formation of a thin amorphous layer that covers the surface of the mineral grains (Benezet and Benhassaine, 1999; Vdovic et al., 2010). This effect was however reduced by applying wet milling with a McCrone Micronizing mill for 5 min using ethanol as grinding agent instead of other more common grinding techniques (Środoo et al., 2001).

COMPRESSIVE STRENGTH TEST

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc.

Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.

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Procedure: Compressive Strength Test of Concrete Cubes

For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Following are the procedure for testing Compressive strength of Concrete Cubes

Apparatus for Concrete Cube Test

Compression testing machine

Preparation of Concrete Cube Specimen

The proportion and material for making these test specimens are from the same concrete used in the field.

Specimen

6 cubes of 15cm size Mix. M15 or above

Mixing of Concrete for Cube Test

Mix the concrete either by hand or in a laboratory batch mixer

Hand Mixing

(i) Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color
(ii) Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
(iii) Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

Sampling of Cubes for Test

(i) Clean the mounds and apply oil
(ii) Fill the concrete in the molds in layers approximately 5cm thick
(iii) Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end)
(iv) Level the top surface and smoothen it with a trowel

Curing of Cubes

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

Precautions for Tests

The water for curing should be tested every 7 days and the temperature of water must be at 27+-20C.

Procedure for Cube Test

(i) Remove the specimen from water after specified curing time and wipe out excess water from the surface.
(ii) Take the dimension of the specimen to the nearest 0.2m
(iii) Clean the bearing surface of the testing machine
(iv) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
(v) Align the specimen centrally on the base plate of the machine.
(vi) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
(vii) Apply the load gradually without shock and continuously at the rate of 140 kg/cm2/minute till the specimen fails
(viii) Record the maximum load and note any unusual features in the type of failure.

FINDINGS AND RESULTS

This chapter presents a discussion of the results obtained from 4 specimens tested at a laboratory.

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. Portland cement is the commonly used type of cement for production of concrete. In a building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements.

Various types of cements are used for concrete works which have different properties and applications. Some of the types of cement are

Portland Pozzolana Cement (PPC), rapid hardening cement, Sulphate resistant cement etc.
Materials are mixed in specific proportions to obtain the required strength. Strength of mix is specified as M5, M10, M15, M20, M25, M30 etc, where M signifies Mix and 5, 10, 15 etc. as their strength in kN/m.
Water cement ratio plays an important role which influences various properties such as workability, strength and durability. Adequate water cement ratio is required for production of workable concrete.
When water is mixed with materials, cement reacts with water and hydration reaction starts. This reaction helps ingredients to form a hard matrix that binds the materials together into a durable stone-like material.
Various structural members such as beams, slabs, footings, columns, lintels etc. are constructed with concrete.
ACI 318 Building code requirements for structural concrete and ACI 301 Specifications for Structural Concrete are used in United States as standard code of practice for concrete construction.
There are different types of admixtures which are used to provide certain properties. Admixtures or additives such as pozzolans or superplasticizers are included in the mixture to improve the physical properties of the wet mix or the finished material.
Various types of concrete are manufactured these days for construction of buildings and structures. These have special properties and features which improve quality of construction as per requirement.

Grade of Concrete

Grade of concrete denotes its strength required for construction. For example, M30 grade signifies that compressive strength required for construction is 30MPa. The first letter in grade "M" is the mix and 30 is the required strength in MPa.
The mix proportion can be 1:1:2, where 1 is the ratio of cement, 1 is the ratio of sand and 2 is the ratio of coarse aggregate based on volume or weight of materials.
Regular grades of concrete are M15, M20, M25 etc. For plain cement concrete works, generally M15 is used. For reinforced concrete construction minimum M20 grade of concrete are used.

Concrete is manufactured or mixed in proportions with reference to cement quantity. There are two types of concrete mixes, i.e., nominal mix and design mix. Nominal mix is used for normal construction works such as small residential buildings. Most popular nominal mix are in the proportion of 1:2:4.

Design mixed concrete are those for which mix proportions are finalized based on various lab tests on cylinder or cube for its compressive strength. This process is also called as mix design. These tests are conducted to find suitable mix based on locally available material to obtain strength required as per structural design. A design mixed offers economy on use of ingredients.

Once suitable mix proportions are known, then its ingredients are mixed in the ratio as selected. Two methods are used for mixing, i.e., Hand Mixing or Machine Mixing.

Based on quantity and quality required, the suitable method of mixing is selected. In the hand mixing, each ingredient is placed on a flat surface and water is added and mixed with hand tools. In machine mixing, different types of machines are used. In this case, the ingredients are added in required quantity to mix and produce fresh concrete.

The primary objective of the study was to study the performance of concrete containing different percentages of calcined clay and to identify the optimum replacement percentage as stated in chapter 1.

Complete description of specimen and testing procedure are presented in chapter 3.

For the purpose of this research; mix design concrete was adopted for the following compressive test as 2 samples of each specimen was produced and tested at interval of7 and 14 days respectively.

Materials selected in producing the specimen used for compressive test.

Laterite soil were source from Karji Kaduna South, Nigeria.

Dangote Ordinary Portland cement (3x) was used as a sample cement to be compared to and to also partially replaced with Calcined clay.

River Sand were source from Sokoto Road 2 Zaria Kaduna State, Nigeria.

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And tap water source from borehole in College of Environmental Studies Barnawa Kaduna, Nigeria.

Tests Result and Discussions

The following tables' presets data for mix proportions of various specimens used in compressive strength test

Table 3.1 presents the mix proportion of sample 1 specimen with 20% calcined clay and 80% ordinary Portland cement with mix ration of 1:3:4.

S. NO	MATERIAL	QUANTITY (kg)
1	Ordinary Portland cement	0.8
2	Calcined clay	0.2
3	Fine aggregate (sand)	3
4	Coarse aggregate (gravel)	4
5	Water	0.7

Table 3.2 presents the mix proportion of sample 2 specimen with 30% calcined clay and 70% ordinary Portland cement with mix ration of 1:3:4.

S. NO	MATERIAL	QUANTITY (kg)
1	Ordinary Portland cement	0.7
2	Calcined clay	0.3
3	Fine aggregate (sand)	3
4	Coarse aggregate (gravel)	4
5	Water	0.7

Table 3.3 presents the mix proportion of sample 3 specimen with 50% calcined clay and 50% ordinary Portland cement with mix ration of 1:3:4.

S. NO	MATERIAL	QUANTITY (kg)
1	Ordinary Portland cement	0.5
2	Calcined clay	0.5
3	Fine aggregate (sand)	3
4	Coarse aggregate (gravel)	4
5	Water	0.7

Table 3.4 presents the mix proportion of sample 4 specimen with 100% ordinary Portland cement with mix ration of 1:3:4.

S. NO	MATERIAL	QUANTITY (kg)
1	Ordinary Portland cement	1
2	Fine aggregate (sand)	3
3	Coarse aggregate (gravel)	4
4	Water	0.7

Compressive Strength of Concrete Cubes

$$\text{Compressive strength} = \frac{\text{Load at failure (N)}}{\text{Area of the cube (mm)}}$$

As stated earlier, the above table presents the mix proportions of 4 specimens with different percentage replacement of ordinary Portland cement with calcined clay of 20%, 30% and 50% respectively.

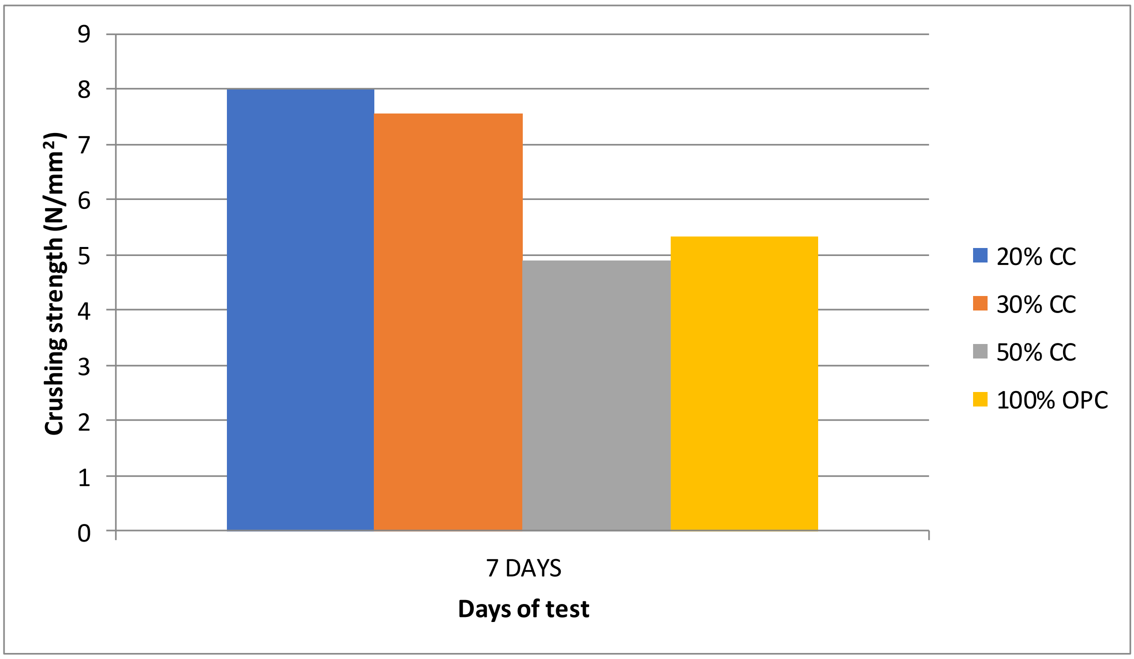
Table 3.5 Summarizes the results of all the 4 specimens used in concrete compressive strength, the table gives the main characteristics of each specimen that include; the crushing strength of each specimen after some ages.

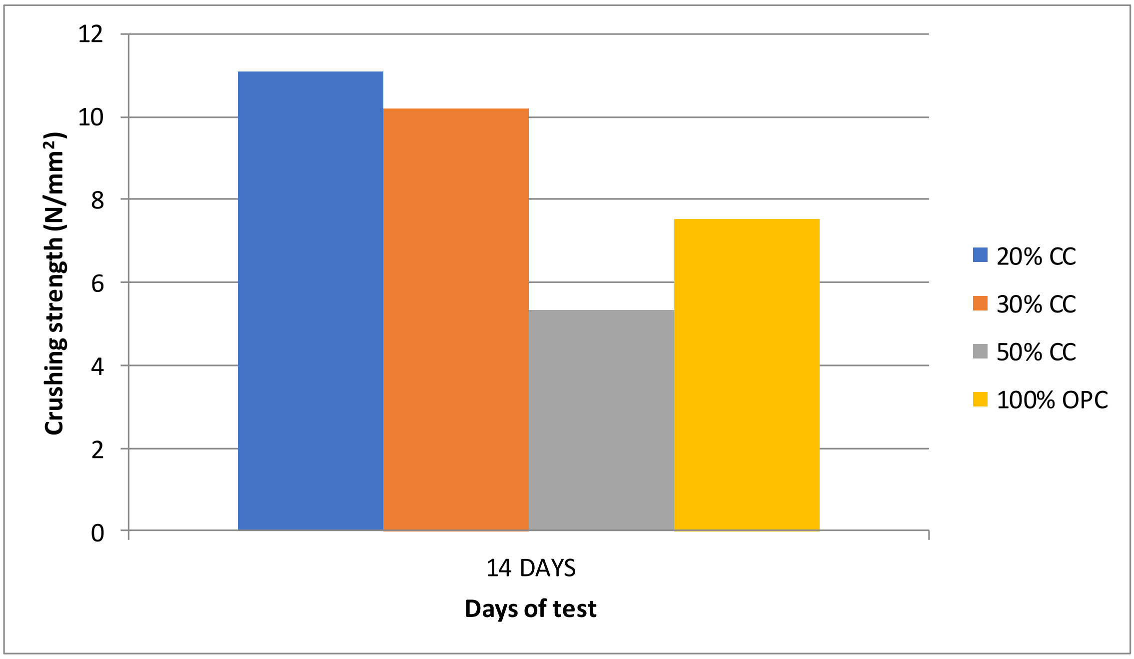
cubes No.	Sizes of cubes (mm)	Date cast	Age for testing (days)	Date tested	Curing condition	Weight of cube (kg)	Mix proportion	Crushing Load KN	Crushing strength (N/mm²)	Percentage of cement replacement
1a	150×150	30/9/21	7	6/9/21	Water	8.12	1:3:4	180	8.00	20%CC
2a	150×150	30/9/21	7	6/9/21	Water	7.65	1:3:4	170	7.56	30%CC
3a	150×150	30/9/21	7	6/9/21	Water	7.75	1:3:4	110	4.89	50%CC
4a	150×150	30/9/21	7	6/9/21	Water	7.70	1:3:4	120	5.33	100%OPC
1b	150×150	30/9/21	14	13/9/21	Water	8.27	1:3:4	250	11.11	20%CC
2b	150×150	30/9/21	14	13/9/21	Water	7.73	1:3:4	230	10.12	30%CC
3b	150×150	30/9/21	14	13/9/21	Water	7.86	1:3:4	170	5.33	50%CC
4b	150×150	30/9/21	14	13/9/21	Water	7.91	1:3:4	170	7.55	100%OPC

Note: the above specimen 20%, 30%, 50% partially replaced Calcined Clay (CC) are compared 100% Ordinary Portland Cement (OPC)

The above table answers research question one which says;

To establish the percentage replacement of cement with calcined clay





The above graph answers research one which says;

To determine the compressive strength of concrete using Ordinary Portland Cement and Calcined Clay.

The graph shows the strength development of each specimen with time, it also shows the greater and less strong some of the specimen has.

50% replacement of ordinary Portland cement with calcined clay has less strength development of 9%as its recorded 4.89N/mm^2 after 7 days and 5.33N/mm^{2}after 14 days.

100% Ordinary Portland Cement has highest strength development 42% it recorded 5.33N/mm^2 of it 7 days and 7.55N/mm^2 after 14 days.

30% partial replacement of ordinary Portland cement with calcined clay recorded 7.73N/mm2 after seven days and 10.12N/mm2 after 14days as its crushing strength which means it has 34% strength increase in 14 days.

20% partial replacement of ordinary Portland cement with calcined clay also recorded a higher crushing strength as it has 39% increase in strength as it is 8.00N/mm^2 after 7 days and 11.11N/mm^2 after 14 days.

With the above result obtained from various compressive tests it is concluded that 20% partial replacement of ordinary Portland cement with calcined clay has the highest crushing strength as such it's the best partial replacement of ordinary Portland cement with calcined clay followed by 30% partial replacement of ordinary Portland cement with calcined clay 50% partial replacement of ordinary Portland cement with calcined clay was weak and as such cannot work.

To determine if Calcined Clay is a cheaper alternative.

The following statement explains the above question

Production process

The manufacturing process of calcined clay includes calcinations and grinding. For calcination, a normal rotary kiln is needed similar in operating principle to rotary kilns for clinkerization. In Cuba, the old wet process cement kilns are being adapted to calcinekaolinitic clays. These kilns are especially interesting because at the chain section the clay dries, while the chains destroy the clumps, so no previous treatment for the clay is necessary. And the method of calcination does not have much impact on the reactivity for similar temperatures and residence time.

However, the calcination method will have a big impact on cost. The advantages of rotary kilns are the possibility to use low grade fuels such as pet coke or even biomass, which mean the cost of calcination can be less than that of clinker production. Grinding can also be carried out with conventional equipment.

Raw materials

Clays together with limestone are the most abundant materials in the earth's crust. There is a large demand for pure kaolinite clays for the production of the cement with calcined clay. There are however abundant amounts of clays which are not suitable for such applications. Clays containing kaolinite also occur in many tailings from mines and quarries. Thus, the quality and availability of kaolinitic clays is an issue in the production of calcined clay cement.

Investment and cost of production

As outlined above, calcined clays can be produced in similar equipment to Portland cement with similar investment costs. Calcination temperatures are much lower (750–850 °C) than clinker (1450 °C) leading to lower energy costs. However, the major cost reduction is due to the high clinker substitution rates and the possibility to incorporate high quantities of limestone. Nevertheless, the issue of scale is also important. The cost of producing clinker drops dramatically when it is done in large plants and with the use of cheap fuel sources or use of waste materials as part of the fuel. Ideally, clay calcination needs to be done on the same scale and with the same fuels to realize savings. Furthermore, there may be issues if the clay is very wet and needs energy for drying.

The viability of any technology is dependent on four important factors:

i) Technical viability
ii) Economic feasibility
iii) Low capital investment
iv) Easy availability of raw materials

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The calcined clay technology developed fulfils all the above criteria. It has been technologically proven to produce a comparable quality to general purpose cement with comparable economic feasibility. It does not require any high investment in equipment and can easily be integrated into the existing cement production system. Moreover, all the required raw materials are available widely at comparable costs. Thus, the potential sustainability of the technology is well established compared to the existing cement types.

Simplified environmental assessment

It is interesting to note that whatever the technological level, the calcined clay cement always produces around 30% savings in CO_2 emissions. Furthermore, it is known that the worse calcined clay cement made in the industrial trial is better (in terms of CO_2 emissions) than the best OPC that are be produced. Major emission reductions were related to energy savings and clinker substitution, although there is reported a significant decrease in electricity consumption during the grinding process due to calcined clay softness in comparison with OPC. Hence it will lower tax paid by cement producers since the higher of effect of industry has on environment, the more tax paid. And it will as well reduce the cost of the product drastically.

CONCLUSIONS

Initial strength develops at a lower rate until seven days for most mixes containing calcined strength of the companion pure cement mixes. This holds especially for mixes containing calcined clays where in some cases even a replacement of 50 % led to same strength values beyond 14 days. The inclusion of calcined clay increases it crushing strength. Besides the positive impact on strength the replacement of cement by calcined clay will yield ecological benefits. Considering global warming, it will help saving non-renewable primary energy and reduce the average CO_2 release during cement production process and will as well reduce the cost of the cement by utilizing this calcined clay.

RECOMMENDATION

With the various results obtained from concrete compressive test using 20%, 30% and 50% as partial replacement of cement

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Cement producers should adopt the use of calcined clay as a partial replacement of cement to reduce the cost of cement production which will as well reduce the negative impact the cement production has on the environment.

It is recommended that the maximum cement replacement is 30% which gives more crushing strength than 100% cement and 50% replacement gives below average crushing strength, hence cement can only be replaced by 30% and above.

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