

Study on the Effects of Kaolinite and Laterite Admixtures on Physiochemical Properties of OPC Mortar

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Abstract: *The high cost of Portland cement makes cement building very expensive and most people cannot afford to own a house more so carbondioxide emission into the atmosphere due to cement production which has negative impact on the environment.*

Consequent upon this therefore, this study seek to find alternative solution to these problems using kaolinite and laterite with cementitious properties which is abundant in nature.

This research evaluated the effect of kaolinite and laterite admixtures on the physiochemical properties of ordinary Portland cement mortar at 0%,2% 5% 10% 15% and 20% concentration..

Kaolin substitution indicated good consistency up to 10%, beyond which the percentage of water added was greater than 30%. However substitution in laterite up to 20% maintained good consistency.

Setting time decreased with increase in substitution for both kaolinite and laterite. The rate of decrease is faster for laterite than kaolin, however 20% kaolin substitution. The initial setting time falls below recommended range.

The compressive strength for the substitute kaolin showed virtually the same strength for control and 20%.

More so the strength for control, 2%, 5%,10% and 20% showed strength with in the same range within the first 2days.

With a drastic decrease in the strength in 20% substitute of kaolin.

In the case of laterite there is a drastic decrease in compressive strength between control and other percentages.

Kaolin and laterite soundness did not exceed standard. Laterite showed a minimal expansion at 2% whereas in the case of kaolin 2%, 5%and 10% were of same range except for 20% which was between 5mm and 6mm range.

Introduction

The immediate needs of a man are food and shelter, hence man's creativity and technology comes to him on his struggle to acquire these vital needs. For shelter, man used cave and thick forest. The ancient Egyptians used calcined limestone. Later, the Romans discovered that better mortars were obtained when lime and volcanic ashes were grounded; called it pozzolonic cement (Dabalet *al.*, 2005).

Chemical Composition of Portland cement

During the firing or heating in the kiln of the materials, CaO, SiO₂, Al₂O₃ and Fe₂O₃ react to produce alite (C₃S: 28% to 55%), belite (C₂S: 19% to 49%), celite (C₃A: 4% to 10%), and teracalcium-alumino-ferrite (C₄AF:7% to 12%) that collectively make up the clinker minerals.

Laterites are commonly referred to as a soil type as well as being rock type. This and further variation in modes of conceptualization about laterites (e.g. also as a complete weathering) has led to calls for the term to be abandoned altogether. At least there is no likelihood, however that the name will ever be abandoned for materials that looks like highly similar to the Indian laterite occurs abundantly worldwide and it reasonable to call such material laterites. Historically laterite was cut into brick like shape and used in monument building. Laterites are a source of aluminium ore, the ore exists largely in clay material and the hydroxide, gibbsite, boehmite and diaspor, which resembles the composition of bauxite.

Kaolinite is a clay material, part of the group of industrial materials within the chemical composition Al₂Si₂O₅(OH)₄, it is a layered silicate mineral with one tetrahedral sheet of silicate (SiO₄) inked through oxygen atoms to one octahedral sheet of alumina (AlO₆) octahedra. Rocks that are rich in kaolinite are known as kaolin as shown in plate 2.

Properties of Concrete

Workability, strength and durability are the tree basic properties of concrete. Amount of useful internal work necessary to overcome the internal friction to produce full compaction is termed as Workability. Size, shape, surface texture and grading of aggregates, water-cement ratio, use of mixture and mix proportion are important factors affecting workability. Strength is to bear the desired stresses within the permissible factors of safety in expected exposure condition. The factors influencing the strength are: of water/ cement ratio, grading of aggregate, degree of compaction, and efficiency of curing, curing temperature, age at the time of testing, impact and fatigue. Durability is sustenance of shape, size and strength: resistance to exposure conditions, disintegration and wearing under advance conditions. Variation in concrete production, loading conditions in service life and subsequent attack by the environment factors are main deteriorating factor of

concrete. Properly compacted and cured concrete used in rice husk ash on cement mortar and concrete (RCC) continues to be substantially water tight and durable till capillary pores and micro-cracks in the interior are interconnected to form pathways up to surface. Durability is mainly influenced by environmental exposure condition, freezing-thawing, contact to aggressive chemicals, type and quality of constituent material, water-cement ratio, workability, shape and size of the member, degree of compaction, efficiency of curing, effectiveness of cover concrete, porosity and permeability. During service life of structure, penetration of water and aggressive chemicals, carbonation, chloride ingress, leaching, sulphate attack, alkali-silica reaction and freezing-thawing are resulting deterioration. Loading and weathering inner link voids and micro-cracks present in transition zone and network of same micro cracks gets connected to cracks on concrete surface which provides primary mechanism of the fluid transport to interior of concrete. Subsequent increase of penetrability leads to easy ingress of water, oxygen, carbon dioxide and acidic ions etc. into concrete resulting cracking, spalling, loss at mass, strength and stiffness Oyetola et al (2006).

Literature Review

Thomas et al (2010) reported that the production of Portland cement clinker results in significant carbon (iv) oxide (CO₂) emission, associated with the calcinations or decarbonation of limestone.



and the combustion of fossil fuels to achieve the high clinkering temperature of about 1500°C approximately 1 kilogram (1kg) CO₂ is produced for each 1 kg of clinker, although the precise amount varies depending on the fuel efficiency of the manufacturing plant. It was also reported that cement product accounts for approximately 5% of the CO₂ produced gradually. Reducing the clinker content of cement by 10% will effectively reduce CO₂ emission associated with its production.

Effects of kaolin on the engineering properties of Portland Cement Concrete (PCC) is a research study carried out to determine the feasibility of using kaolin, a very small particle clay, as partial replacement of fine aggregates in Portland cement concrete (PCC). Kaolin clay is a locally available and inexpensive clay mineral. The slump, air void content and compressive strength were examined on samples of PCC with different content of Kaolin. The research indicated the maximum kaolin substitution of fine aggregate for workability of optimal dosage range for PCC compressive strength was also found to be 33% greater than the control group. It was also noted that Kaolin

engenders a soft and cohesive concrete mix that prevents segregation. A brief cost of analyses was performed and determined the economic feasibility of kaolin PCC Mazloom et al., (2004).

Cement manufacturing factories produce greenhouse gases in two ways; one, directly through the production the production of carbon dioxide when calcium carbonate is thermally decomposed, producing lime and carbon dioxide second, burning huge amount of fuel to heat up rotary furnace up to 1200 C°. overall, the top 10 cement producing countries in 1994 accounted for 63% of global carbon emissions from cement production. Canadell P. (2014).

Another research work opined that metakaolin (calcined kaolin clay) was widely applied as supplementary cementitious materials for Portland cement. Due to their scarcity and high cost, calcined abundant polymineral clays are actively studied as alternative to metakaolin. This research presented the study results of influence of calcined ground loamy clay on the properties of Portland cement paste. About 5-15% of loamy clay calcined at 400-600°C and ground to 250-500m²/kg were found to be more effective compared to metakaolin of specific surface area of 1200m²/kg for improvement of compressive strength, water resistance, and increase in density of hardened Portland cement paste (Rakhimov et al., 2017).

Metakaolin is usually added to concrete in amount of 5-15% by weight of cement. Addition of metakaolin causes an increase in mechanical strength, enhancement of long term strengths, decrease of permeability, porosity, reduction of efflorescence, increase of resistance to soluble chemicals like sulphate, chlorides and acids (Ambroise et al., 1994; Kostuch et al., 1993; Sabir et al., 1996). The addition of metakaolin decreases workability of fresh concrete mix. This disadvantage can be reduced by super plasticizers (SP) or increasing water to binder (W/B) ratio. However, rheological properties of fresh concrete mix depend on the type of (SP) Okan et al., 2012. The replacement with 30% of Metakaolin leads to a substantial improvement in strength and transport properties of blended concrete when compared to that of unblended concrete, Shata (2014).

Cement soil reinforcement technique has been accepted worldwide in the areas of foundation engineering, slope reinforcement, road construction, and rammed earth wall engineering for many years. It has been proved as an effective reinforcement technique with many advantages, such as high usage rate of origin soil, low cost, and convenient construction S kolias, V et al., (2005), J.M Ortega et al., (2017). However, in the cement production process, about 900kg CO₂ will be emitted into the atmosphere per tonner of cement which contributed to global

warming and climate change F. Pacheco – Torgal et al., (2010), AM Rashard et al., (2011), E. Benhalal et al., (2013). Therefore, some supplementary cementitious materials (e.g. Metakaolin, fly ash, slag and nanosilica) have been used for replacing part of cement to reduce CO₂ emission associated with cement production A.M Rashard (2013), A. Alswaidini et al., (2016), H. Mola-Abasi et al., (2016).

As a typical pozzolanic material, metakaolin (MK) is an amorphous aluminosilicate compound produced by calcinations of pure kaolinite at 500°C to 550°C ZL. Wu et al., (2016), which has high activity and has attracted increasing attention in recent years that could partly replace Ordinary Portland Cement (OPC) T.W Zhang et al., (2014). Compared with other supplementary cementitious materials, MK has many advantages, including higher activity, larger specific surface, and finer particle size K.G Kolovou et al., (2013). Studies have emerged that offer contradictory findings about the effects of MK content on physical and mechanical properties of cement soil and concrete materials and acquired abundant accomplishment Wu et al., (2016) studied the effect of MK contents on the strength performance of cement modified soil, and test results reveal that both the unconfined compression and splitting tensile strengths are improved, and the suitable ration of MK to cement ranges from 1/3 to 1/2. Moreover, the addition of MK led to a higher quantity of hydration products and denser microporosity distribution according to X-ray diffraction (XRD), scanning electronic microscopy (SEM), thermogravimetric analysis (TGA) and mercury intrusion porosimetry (MIP) test results, and a similar series of experiment results are also found. Wang et al., investigated the effects of curing time and coal-metakaolin content on the properties of cemented sandy soils, and test results indicate that the unconfined compression strength at 28 days was improved by 1.68-2.18 times by incorporating coal-metakaolin.

Ordinary Portland Cement(OPC)

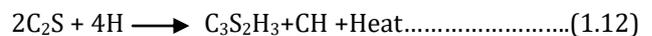
In response to growing pressures to reduce the production, a new classification of cement called Ordinary Portland Cement (OPC) was introduced and allowed by the British and European Standards BS/EN/197-1 since the year 2000, (Thomas *et al.*, 2010). It contains a controlled level of high purity limestone, between 6-29% (Lafarge, 2012). Although a number of European countries allowed the use of such cement through national standards for a decade or more prior to the year 2000 (Thomas *et al.*, 2010).

Ordinary portland cement is produced by blending Portland cement and limestone, or preferably, inter grinding Portland cement clinker, limestone and gypsum (Thomas *et al.*, 2010).

Chemistry of Hydration of Ordinary Portland Cement

When water is added to Portland cement, a cement paste which stiffens gradually is formed. This is achieved through an exothermic chemical reaction called hydration. It is responsible for the chemical transformation of the cement from an initial scattered suspension to a final connected and strengthened system of particles which gives the paste its hardness and therefore binds the aggregates in concrete (Khan and Ullah, 2004).

According to Birnin-Yauri (1998), the hydration reaction involves the two most vital silicate minerals in the cement, tricalcium silicate-alite, (C₃S) and dicalcium silicate-belite (C₂S) which totally released calcium ions (Ca²⁺) and hydroxide ions (OH⁻) that, in the presence of the alkali oxides (Na₂O and K₂O), raise the pH of the paste to about 13±1 on formation of Ca(OH)₂; with an evolution of heat; as follows:



Arum and Olotuah (2006), reported that the reaction continues slowly until the system is saturated, at that stage, the crystallization of the calcium hydroxide commences and calcium silicate hydrates form simultaneously, with an increase in evolution of heat. The crystals of the calcium silicate hydrates (CSH) grow thicker which slows the rate at which water molecules reach the unhydrated alite and belite, hence controls the reaction speed.

Materials and Methods

The materials used in this work are categorized into two: chemicals and reagents, as well as apparatus and instruments.

Chemical and Reagents

The chemicals and reagents used in this work are listed in Table 2.1 with their percentage purity, grade and manufacturers. Some were available at the quality control laboratory of the CCNN and the research laboratory of the Usmanu Danfodiyo University, Sokoto, while others were purchased from a reputable chemicals dealer in Sokoto State. They were used without further treatment except drying in some ca

Instruments

The list of the instruments and major apparatus used in this study is given in table 2.2 below, which indicates both the model and manufacturers. They were used in accordance with the manufacturer’s specifications.

Procedure

The methods employed for the various investigations conducted in this study are broken into samples and samples collection, samples treatment as well as preparations and procedures.

Samples and Samples Collection

The main sample for this research is ordinary Portland cement from Cement Company of Northern Nigerian Sokoto. Kaolinite from Kankara Local Government Area Katsina State and laterite from Kalambaina area of Sokoto state.

Samples Treatment

Preparations of Solutions, Reagents and Admixtures Samples

The preparation of solutions, reagents and admixture samples used in this work is described as follows:

- i. **Sodium hydroxide solution (1.0M):** 40g of NaOH was weighed and dissolved in 250cm³ of distilled water, transferred into a 1L flask and diluted to the mark.
- ii. **Consistency and Setting times Tests:** Five portion (392g, 380g, 360g, 340g and 320g) of Ordinary Portland Cement (OPC) were mixed with 8.0g, 20g, 40g, 60g and 80g of Kaolin and obtained 2%, 5%, 10%, 15% and 20% respectively of OPC and Kaolin admixture samples. A 400g of pure OPC was also used as the sixth portion to represent 0.0%, it served as the control.
- iii. **Admixture for Soundness (Expansion) Test:** Five portions (196g, 190g, 180g, 170g and 160g) of Ordinary Portland Cement (OPC) were mixed with 4g, 10g, 20g, 30g and 40g of Kaolin and obtained 2%, 5%, 10%, 15% and 20% respectively of OPC and Kaolin admixture samples. A 200g pure OPC was also used as the sixth portion to represent 0.0% - it served as the control.
- iv. **Test for Compressive Strengths Tests:** Three portions (441g, 427.50g, 405g, 382.50g and 360g) of Ordinary Portland Cement (OPC) were each combined with 1350g of standard laboratory sand (SS) and mixed with 9g, 22.5g, 45g, 67.5g and 90g of kaolin and obtained 2%, 5%, 10%, 15% and 20% respectively of OPC and kaolin admixture samples. A 450g of pure OPC was also mixed with 1350g of SS to represent 0.0% and served as the control.

Procedures

About 41kg of OPC was randomly sampled and collected from the dispatch chamber of the Cement Company of Northern Nigeria (CCNN) and thoroughly mixed (Muhammad, 2011).

Determination of Specific Surface Area (Blaine)

2.850g of the cement sample was poured into a Blaine cell containing a perforated disc and filter paper (after cleaning) and covered with another filter paper. A plunger was used to gently push it down until the colar touched the cell. The cell and its content were then mounted in right arm of a manometer that contained paraffin oil. The manometer is graded with three marks. The oil was raised above the three marks and then allowed to fall back, the time in seconds required for the meniscus level of the oil to fall from the first mark to the second mark was recorded as (T). The time (T) was used to calculate the Blaine value of the cement sample; using the expression below (CCNN Manual, 2010).

$$B = F\sqrt{T} \dots\dots\dots(2.1)$$

Where:

T = time (s) and F = Blaine factor

Determination of Loss on Ignition (LOI)

An empty platinum crucible was immersed into a 1:1 HCl solution for some minutes. The crucible was removed and ignited for 5 minutes in a muffle furnace at about 950°C temperature. It was then removed and cooled in a dessicator and weighed (M₁).

4.6020g (M_s) of the OPC sample was transferred into crucible and both were weighed (M₂ = M₁ + M_s). The crucible and its contents were placed into the furnace and ignited for 30 minutes at about 950°C temperature. The crucible was removed and cooled to room temperature in a dessicator and weighed again (M₃). The percentage loss on ignition was calculated using the relation below: (CCNN Manual, 2010).

$$LOI (\%) = \frac{M_2 - M_3}{M_s} \times 100 \dots\dots\dots (2.2)$$

Determination of Free Lime

Exactly 1.0g of the OPC sample was transferred into a conical flask and 1.20g of standard sand added and mixed thoroughly. 40ml of glycol solution was then added and the flask was covered with a stopper and vigorously shaken. The flask was then placed into a water bath at 71°C for 30 minutes. The solution was shaken after every 5 minutes. The solution was then filtered under suction through a dry filter paper marked 'free lime' and the residual precipitate was washed with methanol. The filtrate was then titrated with 0.1M HCl using 2-3 drops of bromophenol blue as indicator until a yellow end point was reached. The free lime content was calculated using: (CCNN Manual, 2010).

$$[FL = FLF \times VA] \dots\dots\dots (2.3)$$

Where:

FL = Free lime, FLF = Free lime factor and VA = Volume of acid

X-ray Fluorescence Spectrometry

This was carried out on the sampled OPC to determine its minerals concentration (concentration analysis) as follows:

The final mass of the OPC sample from 3.2.4.3 (i.e. M₃) was used. Claissen blocks (8.6g lithium bromide and 1.2g lithium borates) were added into the sample and gently re-grinded into a mortar and transferred into a platinum crucible. The crucible was taken into a Claissen machine which converted the sample to a small circular glass prism within 13 minutes. The prism was removed, wiped with a clean tissue and then placed into the XRF machine (CCNN Manual, 2010).

Determination of Consistency

Exactly 400g of OPC was weighed and transferred into a mixing bowl. Clean water was also measured using a measuring and gradually added into the cement and thoroughly mixed for 4 minutes to obtain a paste.

The paste was immediately transferred into a Vicat’s mould and the top of the mould smoothed off as quickly as possible. The mould and the paste were placed under the plunger and the plunger was lowered freely and allowed to penetrate the paste. The scale reading was noted and recorded when the plunger stopped. When the plunger penetrated to a point 5mm, 6mm or 7mm above the bottom of the mould, a standard consistency was obtained and calculated using the water/cement ratio (w/c).

The same procedure was followed for the 2%, 5%, 10%, 15% and 20% of kaolin admixtures respectively.

$$\%Consistency = \frac{\text{quantity of water consume d}}{\text{weight of sample}} \times 100 \dots\dots(2.4)$$

Determination of Initial Setting Time

A standard consistency paste was prepared for each of 2%, 5%, 10%, 15% and 20% of the kaolin and laterite admixtures respectively as well as the control (0%).

The time at which water was initially added to the current for the mixing was recorded. The plunger was replaced with the initial setting time needle on the Vicat’s apparatus and allowed to penetrate the paste at 5-10 minutes interval, and at different positions, until the paste has stiffened sufficiently for the needle not penetrate deeper than 5mm above the bottom of the mould. The time from when the mixing water was added to the time when the needle stopped at 5mm was recorded in minutes as the initial setting time (CCNN Manual, 2010).

Determination of Final Setting Time

After the attainment of the initial setting time of 0%, 2%, 5%, 10%, 15% and 20% for each of the ‘kaolin and laterite admixture samples respectively, the needle for

the initial setting time was replaced with the needle for final setting time, which has an annular attachment. The needle was allowed at an interval of 10 minutes to rest gently on the paste. A circular mark and a dot were formed. The final setting time was reached when the circular mark could not appear, but only the dot. It was calculated as the time from the instance of adding water for mixing to the time when the circular mark disappeared in minutes (CCNN Manual, 2010).

Determination of Expansion (Soundness)

A standard consistency paste was prepared at 0%, 2%, 5%, 10%, 15% and 20% for each of the ‘KAOLIN’ and ‘LATERITE’ admixture samples respectively. The paste was transferred into the LeChatelier’s apparatus and covered with glass sheets at both ends, using a stretchable rubber to tie the two. The distance between the two tails of the LeChatelier’s apparatus was measured and recorded as (L₁) in millimeters. The paste was cured inside the water for 24 hours at 20°C ±1 temperature and a humidity of <90%. It was then removed and boiled for one hour inside water bath, and then removed and allowed to cool. The distance between the two tails of the apparatus was measured again in millimeters (L₂) mm. The expansion was calculated thus: (CCNN Manual, 2010).

$$\text{Expansion} = L_2 - L_1(\text{mm}) \dots\dots\dots(2.5)$$

Test for Compressive Strengths

The OPC sample, standard sand and admixtures, each for the 0%, 2%, 5%, 10%, 15% and 20% kaolin and laterite respectively, was mixed by using an automatic mixer and a calculated volume of water. The mixture was then transferred into the three compartments of a prism mould and mounted on a jolting machine that compacted the mould for 2 minutes. The mould was removed, covered and cured in the curing chamber for 24 hours at 20±1 temperature and a humidity of <90%. The prism was then removed, de-moulded and cured in water under the same conditions. Three moulds each of the above percentage admixtures were removed and crushed using a digital compressive strength testing machine at the curing interval of 1-day, 7-day, 21-days and 28-days. The compressive strengths were averagely recorded in Nmm⁻²(CCNN Manual, 2010).

Results and Discussions

The results for all the test and analysis carried out in this work are presented in this chapter in table, graphs, and charts. The presentation follows the following sequence:

- a) Physical performance tests
- b) Chemical analysis results

Physical Performance Tests

Consistency

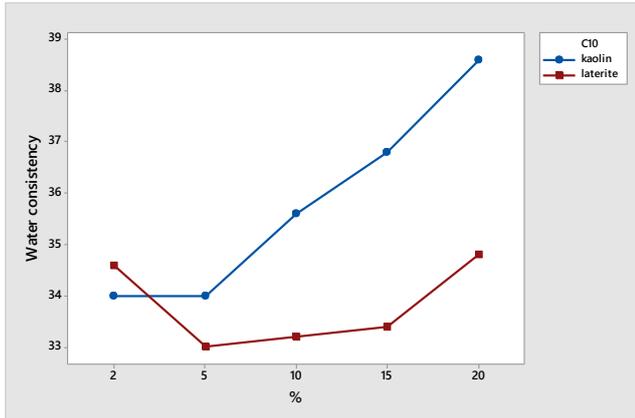


Figure 1: Kaolin and Laterite Substitution Consistencies at Various Concentrations

Standard consistency = 25-35%

Setting Times

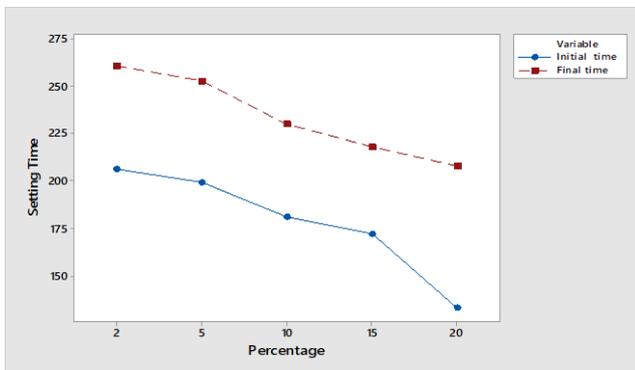


Figure 2: Setting Time of OPC in the presence of Kaolin

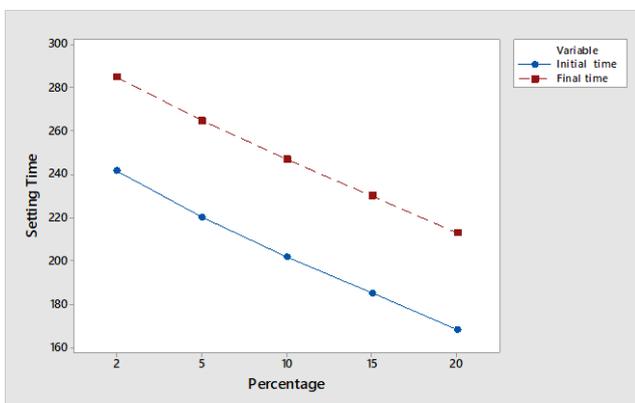


Figure 3: Setting Time of OPC in the presence of Laterite

Compressive Strengths

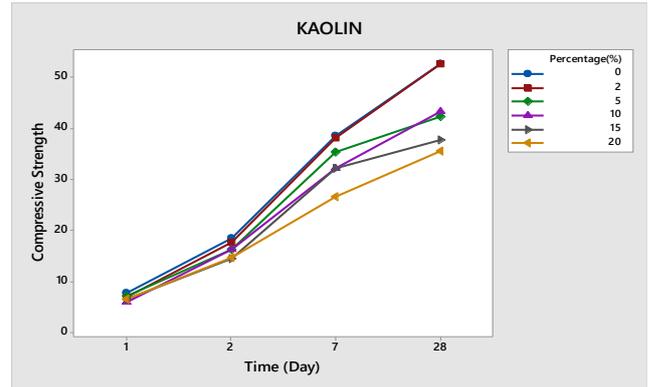


Figure 4: Variation of Compressive strength with age and Kaolin contents.

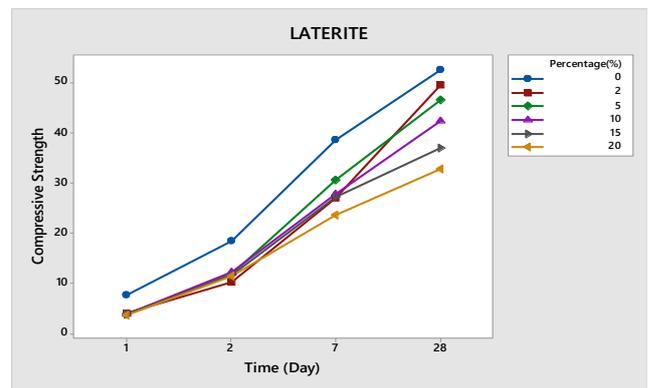


Figure 5: Variation of Compressive strength with age and with laterite contents.

Flexural Strength

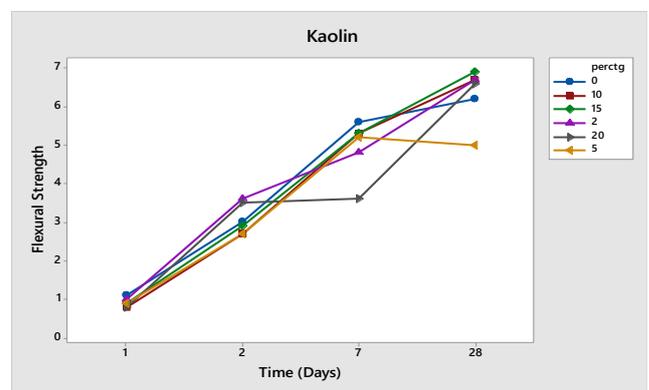


Figure 6: Variation of flexural strength with age and with kaolin contents

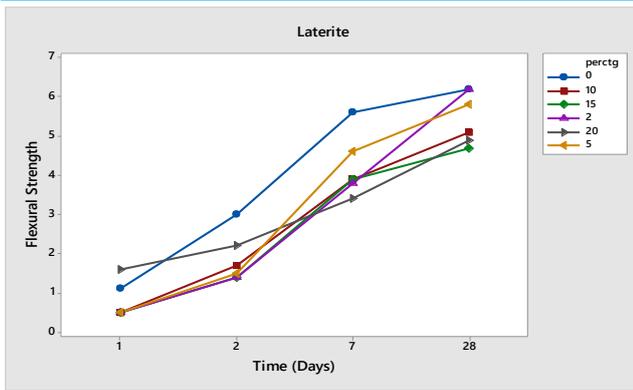


Figure 7: Variation of flexural strength with age and with laterite contents

Soundness

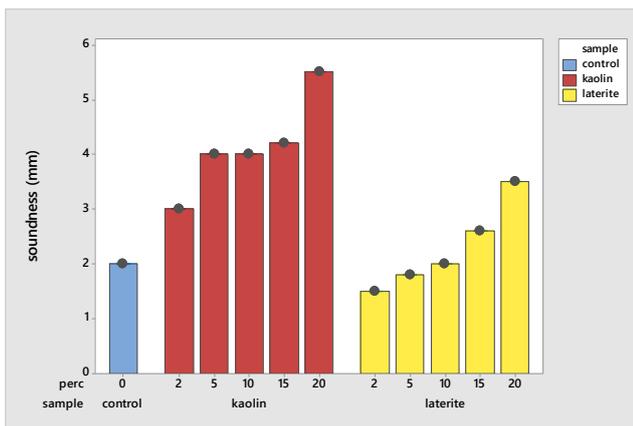


Figure 8 Variation of soundness with kaolin and laterite contents

Discussions

Consistency

Consistency is the measure of how much water need to be added to cement powder in order to produce a paste that can allow penetration by Vicat's needle up to 6 ± 1cm from the bottom of the mould. The water content of the standard paste is expressed as a percentage by mass of dry cement. The usual range of values is between 25% and 35% Neville (1995).

In this work, kaolin substitution indicated good consistency up to 10%, beyond which the % percentage water added for consistency was greater than 36%. However, substitution in the laterite up to 20% maintained good consistency.

Setting time

The initial setting time of cement is prescribed by British standard BS915: 1972 (1993) as between 2 and 6 hours. There is no fixed final setting time period, however the final setting time in minute is estimate =d as 90 + (1.2 x initial setting time (Neville 1995).

In this work the initial setting time decreased with increase in substitution for both kaolin and laterite. The rate of decrease is faster for laterite than kaolin.

The initial setting time falls within the recommended value of 2-6 hour in both Kaolin and laterite substitution. However with 20% kaolin substitution, the initial setting time falls below recommended range. There is similar pattern of decrease in final setting time with increase in substitution for both kaolin and laterite.

Compressive test

Compressive test is the mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The strength of mortar or concrete depends on the cohesion of the cement paste, on its adhesion to aggregate particles and to a certain extent the strength of the aggregate itself. The compressive strengths for both kaolin and laterite are shown in figures 4.4 and 4.5 respectively.

The compressive strength for the substitute Kaolin showed virtually the same strength for control and 2%, more so the strength for control, 2%, 5%, 10%, 15% and 20% showed strength within same range within the first 2 days with a more drastic decrease in strength in 20% substitute of kaolin.

In the case of the laterite additive there is a considerable decrease in compressive strength between the control and other percentages.

Flexural strength

Flexural strength is also known as modules of rupture or bend strength, or transverse rupture strength.

Flexural strength is the ability to resist breaking when pressure is applied. The result helps to ascertain the products application suitability and longevity as well as the end users safety.

Soundness

Soundness of cement refers to the stability of the volume change in the process of setting or hardening of cement. If the volume change is unstable after setting or hardening the concrete structure will crack, which can affect the quality of building. Soundness of cement must not exceed 10mm for OPC, rapid low heat, PPC and alumina cement.

Soundness of cement L1 – L2

The limit for expansion for Portland cement is 10mm by ENV197-1: 1992.

In this research, both substitutes are in conformity with standard as both kaolin and laterite soundness did not exceed 10mm, through results show that compared to the control sample laterite showed minimal expansion at 2% and maximum expansion at 20% which is 4mm where as in the case of Kaolin 2%, 5% and 10% were of the same range except for 20% kaolin that was between 5 and 6mm range.

Conclusion

Based on the experiment results reported and discussed, the substitutes kaolinite and laterite can be used as Partial cement in concrete and mortar.

The work reviewed clearly good consistency for kaolin up to 10% and laterite 20%. The initial setting time falls below recommended range for kaolin at 20% and also decrease in final setting time with increase in both kaolinite and laterite.

The compressive strength for kaolin showed virtually the same strength for control and 2%. There is drastic decrease in strength for both kaolin and laterite.

Soundness of both substitutes kaolinite and laterite are within limit for expansion.

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