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**Research article**

# USE OF BUILDING CLAY IN CONCRETE

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## ABSTRACT

Building clay (red mud) is abundant in Nigeria, and has for ages been used to build stick reinforced walls in traditional village low cost houses and for plastering and brick production.

This paper reviews the use of the building clay for building construction and presents a laboratory investigation of partial replacement of cement up to certain extent with the building clay pozzolana.

It is concluded that up to 15% of cement can be replaced by building clay pozzolana without adverse effect on the setting time and compressive strength of the concrete. 

**Keywords:** building clay (red mud); partial replacement; pozzolana; setting time; compressive strength.

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## INTRODUCTION

Building clay (red mud) is abundant in Nigeria and has for ages been used to build stick reinforced wall in traditional low cost village houses and for plastering and brick production, up to the time of independence; but this was subjected to fluctuating seasonal rain. Building of such affordable houses ceased after the civil war, from which time, the building industry began to use cement since Nigeria could afford the import bills from her "oil boom richness".

However, the boom gradually disappeared over the years, and the need for a local substitute for cement in certain areas of the construction industry became increasingly necessary. The idea of finding a local substitute for cement in these areas of the construction industry was justifiable from the fact that expanding existing cement industry in the country could not immediately meet demands, and continuous importation of cement to augment local production was unattractive from foreign exchange considerations.

## CLAY AVAILABILITY IN NIGERIA

A survey of clay deposits carried out by the geological survey of Nigeria identified the principal clay deposits presented in table 1. Although some of the deposits are small, there are many that are vast and can serve as the source of raw material for the building industry. Further information on clay availability in Nigeria, can be obtained from Proda reports (1970, 1971, 1975,a, 1975b and 1975c)

**Table 1:** Principal clay deposits in Nigeria

| S/No | State | Location of principal deposits |
|---|---|---|
| 1. | Benue and Plateau State | Jos, Ropp and Markurdi areas |
| 2. | Imo, Ebonyi, Enugu and Anambra States | Enugu, Ezi Akwu, Ekwe and Agbahara |
| 3. | Kano State | Kano and Rimi areas |
| 4. | Lagos State | Epe, Ikorodu and Badagry areas |
| 5. | Edo and Delta States | Benin city, Sapele and Ugheli areas |
| 6. | Borno State | Maiduguri and Gombe areas |
| 7 | Sokoto State | Sokoto and Kuban village |
| 8. | Rivers State | Port Harcourt and Andoni areas |
| 9. | Akwa Ibom and Cross River State | Ekpene Obom area |
| 10. | Ogun State | Abeokuta and Ijebu-Ode areas |

## GEOTECHNICAL AND CHEMICAL PROPERTIES OF BUILDING CLAY

Building clay obtained from the Andoni area of Rivers State was used for this study. The geotechnical and chemical properties of the building clay are hereunder shown in Tables 2 and 3.

**Table 2:** Geotechnical Properties of the Building Clay.

| S/No | Geotechnical Properties | |
|---|---|---|
| 1 | Clay Content | 13% |
| 2 | Silt Content | 80% |
| 3 | Sand Content | 7% |
| 4 | Specific Gravity | 3.1% |
| 5 | Optimum Moisture Content | 25.5% |
| 6 | Maximum Dry Unit Weight | 16.2 $Km/m^3$ |

**Table 3:** Chemical Properties of the Building Clay

| S/No | Chemical Properties | |
|---|---|---|
| 1 | $Fe_2O_3$ | 36% |
| 2 | $Al_2O_3$ | 18% |
| 3 | $TiO_2$ | 21% |
| 4 | $SiO_2$ | 7% |
| 5 | $Na_2O$ | 5% |
| 6 | Ca O | 3% |
| 7 | Loss of Ignition | 10% |

## REVIEW OF USE OF BUILDING CLAY IN MORTAR FOR MASONRY AND PLASTERING

Building clay has for ages been used to build stick reinforced walls in traditional low cost village houses. It has also been used as mortar and as a plastering material and it is suitable for bricks (chinwah and Otoko 1988).

a) **Suitability as Mortar**

Considering the plasticity characteristics with cohesion suggested that the building clay would be suitable for use as mortar for plastering as well as for bricks. Therefore, the following tests were conducted.

b) **Shear Tests**

Shear strength tests were carried out by arranging three bricks made of the building clay, with the central one protruding, and the set up tested on a universal testing machine, with the force applied on the central protruded brick till the mortar is sheared off.

c) **Tension Test**

In order to measure induced tension, the bricks were jointed with mortar, connected to the spring balance and loaded, until failure due to tension occurred. Soil alone showed very poor shear strength while soil stabilized with cement ( up to 6% cement) gave good mortar. The study showed that the mortar could safely be used for partition walls which are not directly exposed to rain water.

d) **Suitability as a Plastering Material**

Building clay was used to plaster a set of three bricks, after which the smooth surface was left to dry outside, and be subjected to heat and wind. The resistance to rain water was tested by simulating a water shower on it. The plaster made with soil alone cracked throughout, while the plaster made with soil cement remained smooth surfaced.

e) **Suitability For Bricks.**

Chinwah and Otoko(1988) have shown that building clay is already being used satisfactorily for brick production. Fig 1 shows the location of the brick plants in Nigeria, as at the time of visitation of the author to the brick plants.

## USE OF BUILDING CLAY POZZOLANA AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

As defined in ASTM specification C618-78, pozzolanas are siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It has been suggested that, in addition to reacting with $Ca(OH)_2$, pozzolanas react also with $C_3A$ or its product of hydration (Collepardi et al 1978). A good review of the subject of pozzolanicity has been written by Massaza and Costa (1979).

Pozzolanas are usually cheaper than the Portland cement that they replace but their chief advantage lies in slow hydration and, therefore, low rate of heat development ( Bamforth, 1980); which is of great importance in tropical construction works (Otoko and Chinwah 1991). Also, significant pozzolanic reaction reduces the porosity of the paste (Kovacs, 1975); and reduces the permeability (Higginson, 1966); which is of importance in soil stabilisation.

Fly ash, known also as pulverised - fuel ash, is the most common artificial pozzolana; an extensive review has been written by Berry and Malhotra (1980). The fly ash particles are spherical and are of at least the same fineness as cement (Central Electricity Generating Board, 1972). Modern boiler plant produce fly ash with a carbon content of about 3 percent but much higher values up to 12 percent is acceptable (price, 1975).

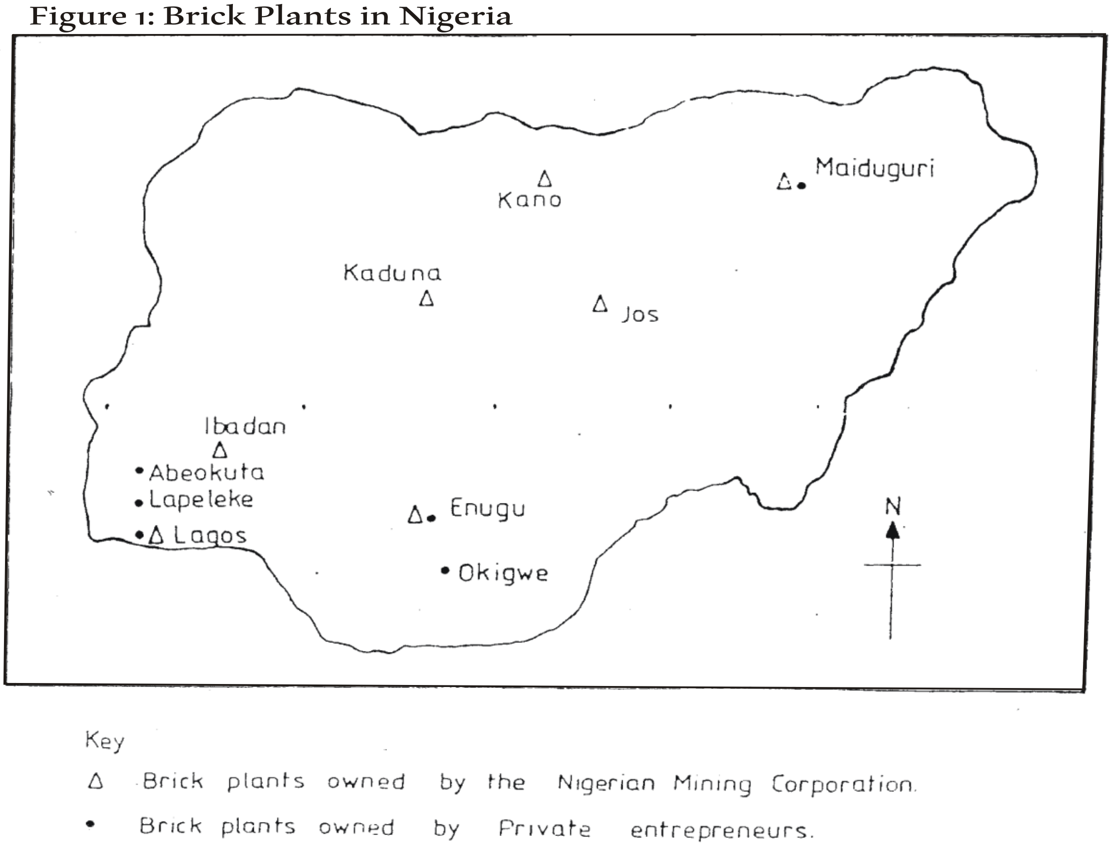
Although Nigeria has about 1296 million metric tonnes reserve of coal at Enugu and substantial deposits at Kaba in Kwara State, Oji River Power Station is using it for the generation of electricity and therefore the only source of fly ash in the country (Ngwu, 1984). Since the annual production rate of fly ash from only one station in Nigeria may not meet local demands, there is therefore the need to explore the potential of the abundant building clay (red mud) as pozzolana.

To prepare the pozzolana, building clay (red mud) was obtained from Ebukuma in Andoni area of Rivers State of Nigeria, calcimined at $700^0$C, which falls within the range $550^0$C - $100^0$C given by price (1975). It was then ground and sieved through the 45μm sieve which is a convenient basis of classification of size (Owens, 1979; Smith and halliwel, 1979).

The effect of the different percentages of the pozzolona in cement and cement concrete were studied with respect to the following;

- Standard consistency, initial and final setting time of cement: tests on cement.
- Compressive strength test on hardened concrete.

**Figure 1: Brick Plants in Nigeria**



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## EFFECT ON CONSISTENCY AND SETTING TIME

**Table 4:** Variations in Standard Consistency, Initial Setting and Final Setting Time with Building Clay Pozzolona in Cement.

| % Replacement | 0% | 5% | 10% | 15% | 20% | 25% |
|---|---|---|---|---|---|---|
| Standard Consistency | 31 | 31.5 | 32.3 | 33.0 | 34.3 | 35.5 |
| Initial Setting Time | 101 | 96 | 95 | 100 | 105 | 110 |
| Final Setting Time | 230 | 225 | 210 | 231 | 255 | 280 |

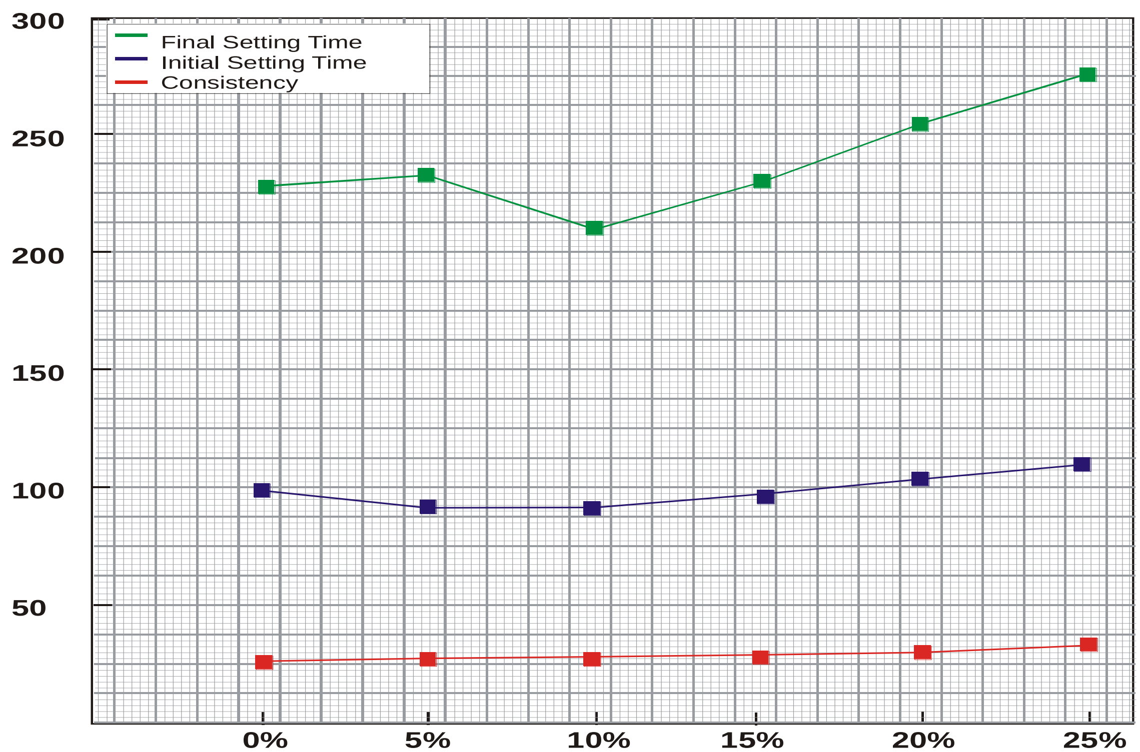


**Fig 2:** Variation in Standard Consistency and in Setting Time.

## EFFECT OF BUILDING CLAY POZZOLANA ON STANDARD CONSISTENCY OF CEMENT

Fig 2 shows the variation of standard consistency with different percentages of building clay pozzolana in cement. The standard consistency of ordinary Portland cement is 30.00, and increased with increase in pozzolana content. The affinity for water also increased with increase in pozzolana content.

The affinity for water increased by 2.55%, 5.50%, 8.50%, 10.0% and 12.5% with pozzolana content of 5%, 10%, 15%, 20% and 25% respectively, compared with water required for standard consistency of ordinary Portland cement, which shows a linear relationship with standard consistency. This proportional increase may have resulted in the lighter weight of the pozzolana (specific gravity for pozzolana was found to be 2.30, compared with 3.15 for cement).

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## EFFECT OF BUILDING CLAY POZZOLANA ON INITIAL SETTING TIME OF CEMENT

Table 4 and fig 2 show the variation of initial setting time with different percentages of pozzolana replacement. BS specification (BS EN 197-1:2011 specifies minimum setting time for OPC to be 30minutes; but for the cement used for this study, the initial setting time was 101 minutes. It is observed from table 4 and fig 2 that initial setting time gradually reduces for 5% and 10% pozzolana replacement whereas for 15% pozzolana replacement, it is nearly the same as that of Portland cement, and thereafter increased for 20% and 25% pozzolana replacement.

## EFFECT ON COMPRESSIVE STRENGTH

The effect of the pozzolana on the compressive strength of the concrete is shown in table 5 and in figures 3 and 4 below.

**Table 3:** Compressive Strength Of Different Amount Of Pozzolana Replacement

| Sample | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 7days compressive strength in $N/mm^2$ | 39.5 | 39.4 | 39.1 | 38.8 | 38.7 | 35.3 |
| 28days compressive strength in $N/mm^2$ | 60.0 | 58.2 | 58.5 | 58.4 | 55.5 | 47.3 |

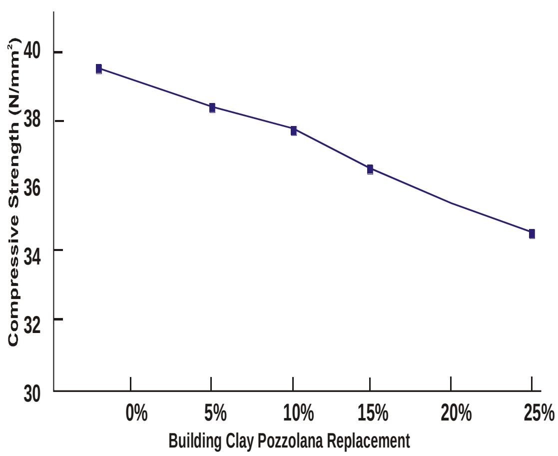


**Figure 3:** Variations in 7days Compressive Strength

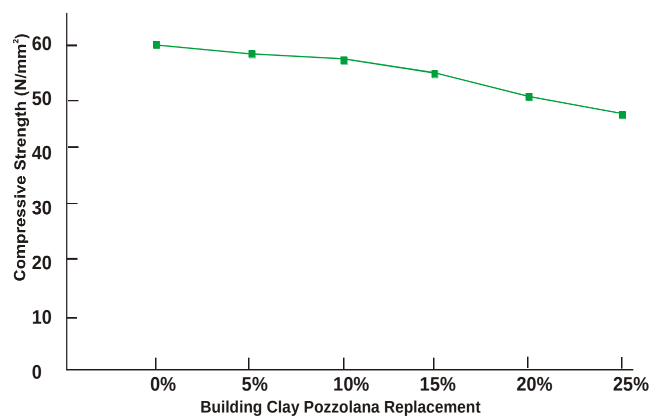


**Figure 3:** Variations in 28days Compressive Strength

## CONCLUSION

The decrease in the initial setting time at 5% and 10% pozzolana replacement may be due to the light weight of the pozzolana. Table 4 shows that the rate of gain in strength decreases with increase in pozzolana content. From Table 2, the optimum pozzolana replacement is 15%, at which the setting time is almost the same as for 0% pozzolana replacement of cement, and at which compressive strength is not more than about 2.68% less than the compressive strength at 0% pozzolana replacement.

This means that up to 15% of cement can be replaced by building clay pozzolana without adverse effect on the setting time and compressive strength of the concrete.

Since ash is produced from only one power state in Nigeria and at a production rate that may not meet demands, it is concluded that the Nigerian Government should embark on commercial production of building clay pozzolana, especially as the clay is abundant in Nigeria, and thereafter specify the use of the pozzolana in all appropriate construction involving Government funds.

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