Effect of Firing Temperature on Abrasive and Compressive Strengths of an Interlocking Compressed Stabilized Earth Block (CSEB)

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Abstract

The Nigerian Building and Road Research Institute (NBRRI) has been involved in the development of an interlocking Compressed Stabilized Earth Block (CSEB), produced from laterite stabilized with cement of 5% weight using a minimum compaction effort of 3N/mm^2 to achieve sustainability within the Nigeria's construction industry. As such, this investigation concerned itself with the determining the effect of Fire Resistance on the compressive and abrasive strengths of the NBRRI interlocking CSEB for a wide range of application towards achieving sustainability. Several laboratory and workshop activities were carried out in the formulation, moulding, curing and testing of the Blocks using standard procedures. At 5% stabilization of the laterite classified as silty SAND, the blocks after being exposed to controlled fire at varying temperatures from 200 ^{0}C to 850 ^{0}C was discovered to have the highest compressive and lowest abrasive strength of 2.37 N/mm^2 and 0.29 cm^2/g respectively at 850 ^{0}C, and lowest compressive and highest abrasive strength of 1.21 N/mm^2 and 3.28 cm^2/g respectively at 200 ^{0}C. This suggests that the blocks have less capacity to resist wearing off after an exposure to severe fire. Hence, Blocks produced with identical formulation may necessarily require plastering after fire incidents.

Keywords – *Compressive strength, Abrasive strength, CSEB, NBRRI*

I. INTRODUCTION

Man has always been using earth (soil) as a construction material right from the ancient time. Earth has been an effective, economical and most abundant construction material available for housing globally [1]. According to [2], earth blocks technology has been utilized in housing one-third of the world's population. [3] also agreed that 30% of the world's population lives in homes constructed of earth. Earth building techniques was commonly used in Nigeria until the influx of Portland cement into the country after independence when sandcrete wall construction became common [1].

The construction sector of every country plays a vital role as the construction process requires significant energy demand and causes environmental side effects, namely: greenhouse gas emissions, high water consumption, as well as the production of solid and liquid wastes [4]. Given the rise in global concerns for sustainable development resulting from environmental problems such as climate change and resource depletion, coupled with the rapid pace of technological advancement in the building sector, interest in alternative building materials such as earth has developed [5], [6]. These alternatives building materials are being fashion in different forms of which one is the Compressed Earth Block, CEB.

A Compressed Earth Block (CEB) also known as a pressed earth or compressed soil is a building material made primarily from damp soil compressed at high pressure to form a block. CEBs use mechanical press to form, out of an appropriate mix of fairly moist inorganic subsoil, non-expansive clay and aggregate. If they are stabilized with a chemical binder such as Portland cement, they are called Compressed Stabilized Earth Blocks (CSEBs) or Stabilized Earth Blocks (SEBs). Typically, around 21 N/mm^2 is applied in compression, and the original soil volume is reduced by about half [7].

In the wake of rising green building consciousness internationally, NBRRI has invested a lot of time, effort and resources in the research, development and deployment of this interlocking CSEB technology towards achieving sustainability in construction. Several qualities that strongly suggest that the NBRRI interlocking CSEB technology has a comparative advantage over other Conventional Walling Materials (CWM) have been established. Nonetheless, other important properties such as the Fire Resistance in terms of Abrasive and Compressive strengths are yet to be specifically established so as to satisfactory ensure the general performance of the NBRRI CSEB in a wide range of domestic or industrial applications. It is therefore imperative to as well determine its capacity to contain fire while retaining its structural integrity considering the incessant fire outbreaks in public buildings and arson in crises prone communities.

II. MATERIAL AND METHOD

A. *Moulding of Block*

As described by [1] and [8], the laterite was first of all prepared by sieving it through BS/ISO 3310 Sieve Size 5mm to remove lumps of clay, gravel or any organic materials. The sieved laterite was the mixed with cement thoroughly at the ratio of 19:1 until the mixture attained a uniform colour. Water was then sprinkled on the mixture and mixed further for homogeneity. The stabilized soil was then fed into the NBRRI Semi- Automated Machine and compressed at 20 N/mm^2 to produce Blocks which were then cured for 21 days.

Plate 1: Stacking and Curing of Blocks

B. *Abrasive and Compressive Strength Test*

Samples were exposed to controlled fire at varying temperatures inside a kiln for duration of 1½ hours, after which the Compressive Strength and the Abrasive Strength of the samples were determined in comparison to the results from unexposed samples. For both compressive and abrasive strength tests, two unfired samples used as control, along with two fired samples at each different degree Celsius were crushed (as in the case of compressive test) and brushed (as in the case of abrasive test) respectively, and the average value of each was recorded.

Plate 2: NBRRI CSEBs Samples arranged in Kiln for Firing

Plate 3: Firing of NBRRI CSEBs

The Compressive Strength test in accordance to BS EN 12390 – 3:2000 was carried out using a Compressive Strength Testing Machine [9].

Plate 4: Testing the Compressive Strength of Block sample

The Abrasive Strength was determined in accordance to Standards ARS 674, 675, 676, 677 where the samples were subjected to mechanical erosion applied by brushing them with a metal brush at a constant pressure over a given number of cycles [8].

Plate 5: Determination of the Abrasive Strength of NBRRI CSEB

III. RESULTS AND DISCUSSION

A. Results

The Table 1 below indicates some established properties of NBBRI CSEBs.

Table 1: Some properties of CSEB

Property	Value
Plastic Limit	33.06
Liquid Limit	59.06
Plasticity	25.94
Thermal Conductivity	0.4841 $Wm^{-1}K^{-1}$

Source: [1]

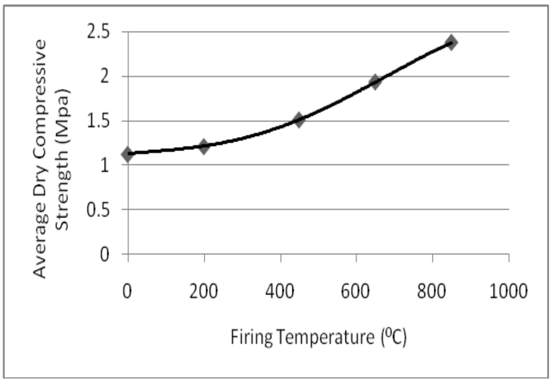

Figure 1: Effect of Firing Temperature on Compressive Strength of Samples

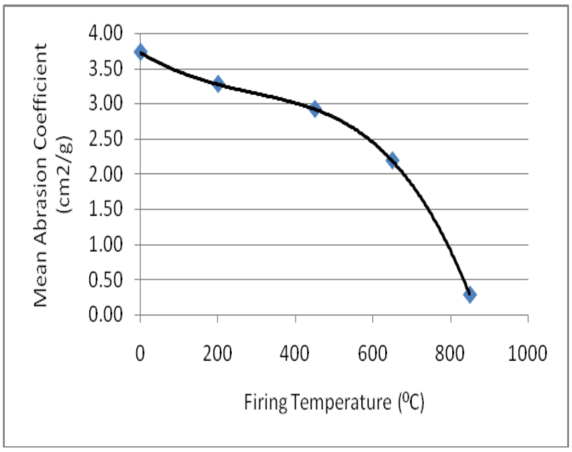

Figure 2: Effect of Firing Temperature on the Abrasive Coefficient of Samples

B. Discussion of Results

Using the ASTM D1633-00 stabilization standard, CSEBs are expected to score at least 2 N/mm^2 (300 pound-force per square inch (p.s.i)). This minimum is a higher standard than for Adobe [10]. The samples produced by the semi-automated machine with a particular formulation of 5% Cement stabilization using laterite sourced in Jos – Plateau State, slightly gave a lower than the required Compressive Strength of 2 N/mm^2. But with an increase in exposure to fire, the blocks showed an excellent capacity to achieve more Compressive Strength as can be seen in Fig. 1 which is a very important structural concern in burnt buildings. This can be attributed to the good plasticity property of the clay as shown in Table 1. [11] argued that a soil with good plasticity will gain more compressive strength with increase in firing temperature as can be seen in the likes of burnt bricks and other fireclays.

Even though Abrasive Strength may not be directly related to structural strength but is a function of the nature of the soil and the percentage stabilization as pointed out by ARSO Testing Procedure for CEBs [8]. The displayed result in Fig. 2 indicates a good decrease in Abrasive strength of NBRRI CSEBs as the firing temperature increases with 3.73cm^2/g at 0^0C, 3.28cm^2/g at 200^0C and 0.29cm^2/g at 850^0C. This suggests that these particular blocks produced from laterite classified as silty SAND sourced in Jos – Plateau State, and stabilized with cement at 5% [1], has a decreasing capacity to resist wearing off after an exposure to severe fire.

IV. CONCLUSION

Though abrasive strength is not directly related to structural strength, but is a function of the nature of soil and the percentage stabilization, as pointed out in the ARSO Testing Procedure of CEB. Hence, with the decrease in abrasive strength of the NBRRI CSEBs, the blocks produced with identical formulation may necessarily require plastering after fire incidents. Other materials such as wood, cork board may show lower Thermal Conductivities yet are combustible when exposed to fire. Hence the NBRRI Interlocking CSEB's capacity to contain fire with an increasing Compressive Strength when burned is unlike other CWMs that often get structurally degraded or burned away by fire.

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