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# Evaluation of the Cement-Lateritic Bricks Stabilized with Sawdust Ash - Abrasion and Sulphate Attack Resistance Properties

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**ABSTRACT**: This study sought to evaluate the abrasion and sulphate attack resistance capabilities of cement-lateritic bricks stabilized with sawdust ash (SDA) in response to the need to identify less expensive and more environmentally friendly construction materials to address housing demand in developing nations like Nigeria. Analytical techniques were employed in the laboratory to ascertain the SDA's chemical composition. The amount of cement used ranged from 0% to 5%, which was substituted by 0% to 5% of the SDA, while the amount of water utilized ranged from 20% to 25%. Response Surface Methodology (RSM) of Design Expert software was used to determine the numbers of bricks' production (i.e. seventeen (17)). The cured bricks were tested for abrasion and sulphate attack resistance in the laboratory after being cured for 28, 56, and 108 days. SDA is an excellent pozzolan that contains a lot of calcium oxide (CaO). The SDA-made bricks were excellent because every sample met the specified requirement of ≤ 10%. The majority of the samples showed an increase in sulphate and abrasion resistance as the curing age increased. This could be attributed to SDA's high content of calcium, aluminium, and iron oxides; as a result, bricks built with SDA are safe to use during the construction of buildings at the substructure level.

**KEYWORDS:** Abrasion, cement lateritic brick, resistance, pozzolan, Sulphate attack, substructure.

## I. INTRODUCTION

It is impossible to overstate the significance of housing in human history. One of the best markers of someone's style of living and social standing is their housing, according to several experts. According to Raheem et al. (2012), housing and construction conditions also give a good indication of a society's standard of life. As a result, the need of having access to affordable housing became more prominent around the middle of the 21st century. In terms of access to adequate and cheap housing in emerging countries, the low-income group, whose number is growing as a result of fast urbanization and population expansion, has undoubtedly become the most susceptible. This has prompted numerous studies into the creation of locally accessible building materials and construction methods to improve everyone's access to homes.

In December 1988, the United Nations General Assembly adopted the "Global Strategy for Housing to the Year 2000," which calls for the acquisition of local building materials and methods to ensure that everyone has access to adequate and long-lasting housing by the year 2000. The assembly suggested drawing on significant official and informal private sector involvement in the housing industry. By examining the previously untapped riches of existing human resources and their shaping culture and social dynamics, the plan sought to end reliance on the public sector for housing provision.

In the tropics, weathering processes that facilitate the development of iron, aluminium, manganese, and titanium oxides lead to the creation of lateritic soils. Through these procedures, silicate minerals are converted into clay minerals like kaolinite and illite. Lateritic soils contain significant amounts of iron and aluminium oxides, which together with the seasonal variations in the water table give the soils their characteristic reddish-brown colour. For a very long time, the majority of the world's highways and the walls of residential homes were built using these soils, which are found in tropical and subtropical regions. With the aid of various stabilizers, new applications for these lateritic soils in civil engineering are constantly being discovered. As a result, the stabilized soil-based products are regarded as affordable and environmentally beneficial energy materials for applications in sustainable construction (Fetra et al., 2010). Other benefits of lateritic soil make it potentially a very good and suitable building material, particularly for the construction of rural structures in poor nations. These advantages include the need for little to no specialized skilled labour for the manufacture of laterized compressed bricks and their use in other construction projects (Fetra et al., 2010).

According to ASTM - C618 (2005), pozzolana is a siliceous and aluminous material with little to no cementation value on its own, but it will react chemically with calcium hydroxide in finely divided form in the presence of moisture at room temperature to generate compounds having cementation qualities. In reality, Ordinary Portland Cement (OPC) ranks second in terms of material consumption to water. All around the world, construction sectors use it as their primary binding substance. However, it consumes a lot of energy and contributes to carbon dioxide ($CO_2$) gas emissions. Utilizing $CO_2$ free pozzolanic materials as supplementary cementing materials, such as sawdust ash, ground granulated blast furnace slag, palm oil fuel ash (POFA), rice husk ash (RHA), fly ash, silica fume, etc., has become a major area of research interest in the field of cement and materials research in recent decades. This is done to reduce consumption and dependence on cement. In addition to producing $CO_2$ emissions, the burning of portland cement clinker requires more fuel than is necessary. Therefore, in addition to producing $CO_2$, the cement-making process also contributes to the planet's steady loss of natural stone and energy from fossil fuels. One of the top challenges that needs to be addressed before the creation of sustainable binding materials is the depletion of the most precious fossil fuels in the world and the need to lessen the damaging effects of cement manufacturing on the environment (Karim et al., 2014).

The recent sharp increase in building construction costs is related to the fact that common building materials like cement and aggregates are getting more and more expensive as a result of the high costs associated with their manufacture, processing, and shipping. The wall, which makes up a large portion of a building, is the most expensive because it consumes the majority of the resources and money needed during construction. This study examines the use of industrial and agricultural waste products as alternatives to or reductions in cement, a more traditional and expensive building material. This study investigated the use of sawdust ash (SDA) as a partial substitute for cement in the manufacture of earth bricks. It looked at how sulphate resistance and abrasion resistance affected cement-lateritic bricks stabilized with sawdust ash (SDA).

## II. MATERIALS AND METHODS

Lateritic soil, cement, SDA, and water are the materials used. Lateritic soil is a naturally occurring aggregate utilized in civil engineering projects. The lateritic soil was acquired in its disturbed state from a borrow hole located beside CBN's new Iyin Road in Ado-Ekiti at a depth of 0.75 to 1.2 meters. To preserve its natural moisture content, the soil sample that was taken was placed in a polythene bag. To ensure that all moisture was removed before mixing, it was air dried.

Cement as a stabilizer, Portland Limestone CEM II, BUA cement of grade 42.5N was utilized. To keep the cement from absorbing moisture, it was kept in an airtight drum. SDA was employed in the combinations as a whole or partial replacement for cement. Waste sawdust was obtained from a nearby sawmill on the Ado-Ijan Ekiti route. The samples were gathered in sack bags, turned into ash in a metal drum by open burning, cooled, and sieved through a 300 m sieve. Water is necessary for the chemical reaction known as "hydration," which involves cement and other materials. The cement hardens and creates a matrix that holds the bricks together after the reaction. For this, potable water was obtained from Civil Engineering laboratory, the Federal Polytechnic of Ado-Ekiti.

Oxide composition of SDA: This was conducted in the laboratory by analytical method. Creation of experimental runs: As stated in Table 1, variables were created using the Response Surface Methodology (RSM) of Design Expert software (version 13) for the manufacturing of Compressed Earth Bricks (CEB). Cement content ranged from 0 to 5 percent, RHA content from 0 to 5 percent, and water content from 20 to 25 percent. Production and curing of CEB: The ratios of cement, SDA, and water were calculated based on the results of created trial runs. Lateritic soil (4500g), water, RHA, and cement were manually mixed to create CEBs before being fed into a machine that compresses the mixture into bricks. The raw bricks were covered with tarpaulin for 28 days as part of the study's curing procedure to prevent moisture loss.

At the ages of 28, 56, and 108 days, the CEBs underwent abrasion and sulphate assault resistance tests. The soil mechanics laboratory at the Federal Polytechnic in Ado-Ekiti is where the abrasion test was conducted. The abrasion resistance of solid materials is evaluated using abrasion testing.

**Table 1: Variables generated for the experimental runs**

| Variables | Composition | | |
|---|---|---|---|
| | SDA (%) | Cement (%) | WC (%) |
| CEB1 | 3.75 | 1.25 | 21.25 |
| CEB2 | 0 | 5 | 20 |
| CEB3 | 1.25 | 3.75 | 22.5 |
| CEB4 | 1.25 | 3.75 | 21.25 |
| CEB5 | 5 | 0 | 20 |
| CEB6 | 0 | 5 | 25 |
| CEB7 | 3.75 | 1.25 | 22.5 |
| CEB8 | 1.25 | 3.75 | 23.75 |
| CEB9 | 5 | 0 | 25 |
| CEB10 | 3.75 | 1.25 | 23.75 |
| CEB11 | 0 | 5 | 22.5 |
| CEB12 | 2.5 | 2.5 | 22.5 |
| CEB13 | 5 | 0 | 22.5 |
| CEB14 | 2.5 | 2.5 | 23.75 |
| CEB15 | 2.5 | 2.5 | 25 |
| CEB16 | 2.5 | 2.5 | 21.25 |
| CEB17 | 2.5 | 2.5 | 20 |

The brick's capacity to withstand abrasion should indicate if it may be used in an abrasive or erosive environment. This number is often strongly related to the types of soils and rates of material stabilization, but it is not directly related to mechanical strengths. The abrasion resistance was calculated using Equation 1.

$$\text{Abrasion value} = \frac{\text{Difference in weight}}{\text{Original weight}} \text{ X } 100\% \qquad (1)$$

For sulphate attack resistance test, two test media were produced according to ASTM C1012/C1012M (2015), the first one - a water bath and the other one - a sulphated bath of 3% $Na_2SO_4$ solution. The sample was firstly weighed prior to being submerged in water (a sample immersed in each medium) for five hours, after which the samples were removed, drained and oven dried at $71^0$C for 42 hours. After drying, samples were allowed to cool for two hours, brushed and re-weighed to determine the weight losses in both media.

## III. RESULTS AND DISCUSSION

**Table 2: Oxide composition of SDA**

| **Oxide** | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $SO_3$ | $K_2O$ | $Na_2O$ | $M_20$- | $P_20_5$ | $TiO_2$ | LOI | $SiO_2$+ $Al_2O_3$+ $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SDA (%)** | 62.43 | 2.37 | 5.35 | 14.62 | 6.36 | 1.14 | 1.31 | 0.16 | 0 | 3.47 | 0 | 8.76 | 70.15 |

**(a) Oxide composition of SDA**

The oxide composition of SDA, a local substance with significant oxides that govern any construction material's cementing potentials, is shown in Table 2. According to ASTM - C618 (2005) standards, the addition of the three oxides, $SiO_2$+Al2$O_3$+$Fe_2O_3$, is greater than 70%. SDA is a pozzolan as a result.

**(b) Abrasion resistance test results**

Table 3 displays the outcomes of the abrasive strength tests done on the bricks. A high number implies that the bricks' abrasion resistance is inadequate. According to Gupta and Gupta (2004), the abrasion value shouldn't be higher than 30% for wearing surfaces and 50% for other surfaces. For Type III bricks used for floors or patios in residences, ASTM-C902 (2006) specifies an abrasion limit of 5%. As a result of the findings, it was determined that the abrasive strength of the bricks stabilized with 5 percent cement (i.e. CEB2, 6, and 11), which ranges from 1 to 16.12 percent at the corresponding curing age, was within the range specified by Gupta and Gupta (2004) and that they are therefore suitable for use in the construction of buildings as a walling material. While CEB 2, 3, 4, 6, 15 and 16 met ASTM-C902 (2006) requirements at 28 and 56 days; CEB 1, 3, 4, 5, 7, 8, 9, 10, 12, 13, 14, 15, 16 and 17 also met the standard set out by Gupta and Gupta (2004) for worn surface and other surface.

Additionally, it was shown that abrasive strength increased with a water content of 22.50 percent, whereas a water level of 20 percent caused abrasive strength to decrease throughout the course of the curing age. In terms of abrasion resistance, it was found that a water concentration of 22.50 percent was suitable for bricks with 5 percent cement content.

**Table 3: Summary of average abrasive resistance of the bricks**

| | Composition | | | Avg. Abrasion Resistance (%) | | |
|---|---|---|---|---|---|---|
| Variables | SDA (%) | Cement (%) | WC (%) | 28 days | 56 days | 108 days |
| CEB1 | 3.75 | 1.25 | 21.25 | 7.8 | 10.32 | 10.85 |
| CEB2 | 0 | 5 | 20 | 2.4 | 2.6 | 3.14 |
| CEB3 | 1.25 | 3.75 | 22.5 | 2.7 | 2.78 | 4.82 |
| CEB4 | 1.25 | 3.75 | 21.25 | 2.73 | 2.82 | 4.97 |
| CEB5 | 5 | 0 | 20 | 11.3 | 12.05 | 16.36 |
| CEB6 | 0 | 5 | 25 | 1.72 | 1.74 | 1.87 |
| CEB7 | 3.75 | 1.25 | 22.5 | 13.27 | 13.15 | 13.66 |
| CEB8 | 1.25 | 3.75 | 23.75 | 4.13 | 4.31 | 11.84 |
| CEB9 | 5 | 0 | 25 | 7.01 | 7.06 | 14.12 |
| CEB10 | 3.75 | 1.25 | 23.75 | 6.86 | 7.48 | 14.36 |
| CEB11 | 0 | 5 | 22.5 | 6.34 | 6.58 | 6.79 |
| CEB12 | 2.5 | 2.5 | 22.5 | 6.15 | 6.56 | 6.69 |
| CEB13 | 5 | 0 | 22.5 | 6.95 | 6.26 | 6.46 |
| CEB14 | 2.5 | 2.5 | 23.75 | 2.19 | 4.01 | 9.85 |
| CEB1 | 2.5 | 2.5 | 25 | 4.73 | 4.82 | 9.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | | | | | | |
| CEB16 | 2.5 | 2.5 | 21.25 | 3.44 | 4.99 | 6.86 |
| CEB17 | 2.5 | 2.5 | 20 | 6.86 | 7.23 | 14.2 |

**(c) Sulphate attack resistance results**

The graph in Figure 1 shows the sulphate assault on bricks using SDA pozzolan. All bricks, with the exception of CEB5, 9 and 13, exhibit an increase in sulphate attack resistance with longer curing times. After 108 days, the CEB5, 9 and 13 were unable to withstand the sulphate onslaught. This can be attributed to the fact that the mix proportions comprise 100% pozzolan and that there is no cement present. Hydration could not occur as a result, and the bricks disintegrated in the water. It has been found that the mix ratios CEB11 (SDA – 0 percent, Cement – 5.00 percent, and W/C – 22.50 percent) and CEB15 (SDA – 2.50 percent, Cement – 2.50 percent, and W/C – 25.00 percent) have the least sulphate attack values for 28 days, 56 days, and 108 days, respectively.

Brick samples without SDA (CEB2, 6, and 11) showed sulphate attack values during 28, 56, and 108 days, respectively, varied between 15.0 and 20.0 percent, 15.0 and 20.0 percent, and 15.0 and 20.0 percent. Sulphate attack values ranged between 18.0 and 20.0 percent, 15.0 and 25.0 percent, 8.0 and 12.0 percent, respectively, for those with 1.25 percent SDA content (CEB3, 4, and 8). Brick samples with a 2.5 percent SDA content (CEB12, 14, 15, 16 and 17) had sulphate attack values that ranged from 0 to 20.0 percent, 10.0 to 20.0 percent, and 10.0 to 15.0 percent. The range of the 3.75 percent SDA content (CEB1, 7, and 10) was 12.0 to 25.0 percent, 15.0 to 18.0 percent, and 5.0 to 8.0 percent, respectively.

While sulphate attack values for brick samples with 5 percent SDA content (CEB5, 9 and 13) varied between 95.0 and 100.0 percent for 28, 56, and 108 days. The best resistance to sulphate attack often comes from brick samples lacking pozzolan (CEB2, 6 and 11), while the worst resistance comes from those with the highest pozzolanic levels. Accordingly, the lower the pozzolanic content, the higher the resistance to sulphate attack. According to Adetoro and Faluyi (2015), this could be caused by a lack of cementation when the pozzolanic component is high. As required by NBRRI (2011) standard at 108 days, the majority of the pozzolan samples displayed sulphate attack resistance of less than 10%.

## IV. CONCLUSION AND RECOMMENDATION

Based on the findings and analyses of this study, it was determined that as the curing ages of compressed earth bricks (CEBs) increase, so does their ability to resist sulphate attack. The resistance to sulphate attack is better with lower pozzolanic concentration. Larger amounts of Calcium, Aluminium, and Ferric oxides contributed to their greater abrasion and sulphate attack resistance. The bricks can therefore be utilized safely at the substructure level. There should be further research on this.

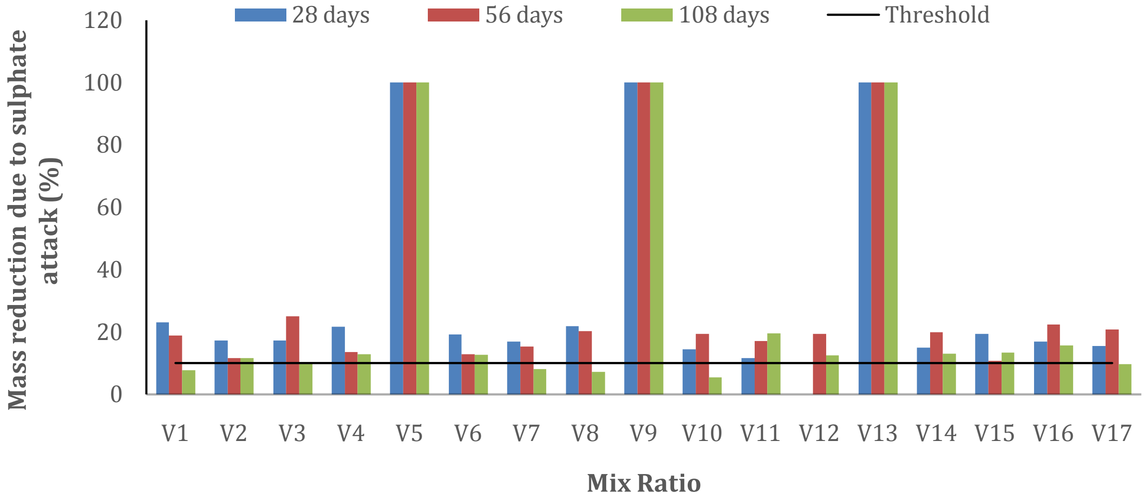

**Figure 1: Graph of sulphate attack resistance with SDA**

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