ANALYSIS OF SOLDIER ANT MOUND FOR CONCRETE APPLICATION

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This work investigates the effect of partial replacement of cement with uncalcined Soldier Ant Mound (SAM) in concrete. The crystal structures of uncalcined SAM were determined using X-ray diffraction, while the microstructure was characterized via scanning electron microscopy. Fourier transform infra-red spectroscopy was used to analyse the composition and identify specific functional groups. Fresh properties and mechanical properties of uncalcined SAM concrete at different water-cement ratios were investigated. The compressive strength of uncalcined Soldier Ant Mound Concrete (SAMC) was reduced compared to the reference concrete, although not significantly at early ages (up to 21 days). After 120 days of curing, the 5% and 10% SAMC recorded a 10.59% and 20.22% reduction respectively, in compressive strength compared to the reference concrete. The 5% replacement level of uncalcined SAM is recommended for concrete use as it improves workability, the loss in compressive strength is minimal and its concrete shrinks just as the conventional concrete.

Keywords: Cement, Workability, Shrinkage, X-Ray diffraction, Infra-red spectroscopy.

1 INTRODUCTION

Blended cements are careful mixes of Portland cements with at least one additional cementitious material. The additional cementitious material regularly makes up about 5%-30% by weight of the complete mix. Fuse of beneficial cementitious material with Portland cement have been accounted for to decrease concrete's porosity, improve concrete's resistance to chemical attack, may improve the rheological characteristics of concrete and produce a concrete having about the equivalent long term quality as ordinary Portland cement based concrete (Mahamat et al. 2021a).

Nonetheless, supplementary cementitious materials by and large decrease the early strength of concrete, which is unfavorable to specific applications (Mahamat and Salifu 2018).

Underground insect homes are ordinarily made of soil and rubble blended in with dead plant bodies, subterranean insect discharges, and other natural substances. The clay content is high and they exhibit pozzolanic properties (Olanrewaju et al. 2019). Natural clays regularly contain a blend of earth minerals related with non-clay minerals. Most characteristic pozzolans build up their property from clay minerals, for example, kaolinite, illite and montmorillonite (Mahamat et al. 2021b). Each sort of clay has an ideal calcination temperature run that causes the breakdown of the translucent structure of the clay and the arrangement of amorphous silica and alumina. Claudius (2017) proved Calcined Termite Mould CTM to be pozzolanic and that it can be used to replace cement but the replacement level should not exceed 10% by weight of cement.
researchers in their investigation on the basic properties of calcined underground ant nest materials reported that chemical composition analysis showed that the amounts of SiO$_2$, Al$_2$O$_3$ and Fe$_2$O$_3$ for 800°C Calcined Ant Nest Clay Powder (CANCP) and 600°C CANCP reached 88.76% and 83.37%, respectively. These values exceed the minimum standard of 70% specified by ASTM. The calcination of CANCP was reported to be optimum at 800°C. They found that CANCP concrete gained early strength faster, and the compressive strength up to 20% replacement level, compares well with that of reference concrete.

Researchers in recent time have looked into the pozzolanic ability of uncalkined soldier-ant mound clay. Termite Mould Cement (TMC) was reported by Elinwa (2018) to be water-demanding, and it accelerates the setting time of mortar. He found that the use of TMC as partial replacement for cement produces concrete of slightly lower compressive strength. However, at 5% to 20% replacement levels, TMC is able to produce good quality concrete. Ikponmwosa et al. (2011) in their research indicated that with the addition of Soldier Ant Mound (SAM), the setting time of blended cement paste is accelerated. The workability of the mix is enhanced as SAM content increased. Also, the densities and compressive strengths of concrete containing SAM was reported to decrease as the percentage of SAM content increased in the mix. Furthermore, they found that at 5% SAM content, flexural strength is higher than that of reference concrete.

The objective of this research is not limited to the replacement of cement with low cost material but also to ascertain a satisfactory performance of the concrete under immediate and long term stress. The replaced material must have the characteristics properties of not causing high deformations over a long term. These raises the need to determine the extent of shrinkage strain as a result of this replacement, coupled with the mechanical properties.

2 MATERIALS AND METHOD

The constituents used in the course of this experiment include coarse aggregate, with a maximum diameter of 20mm and density of 2065kg/m$^3$. The fine aggregate was river sand, the particle sizes range between 2.0mm and 150μm. The soldier ant mound was collected from a heap of termite mound at the lagoon front area of the University of Lagos. The inner clay was milled into fine powder form and sieved through a 45μm sieve. Samples were taken for X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Fourier Transform Infra-Red spectroscopy (FTIR) analysis. Ordinary Portland Cement (OPC) of 42.5N grade, with a specific gravity of 3.15 conforming to specifications of [BS 12] was used. A mix proportion of 1:2:4 (Cement/SAM: River Sand: Granite) and water-cement ratio of 0.65 was adopted. Seventy-two concrete cubes (150 x 150 x 150mm) were cast for density and compressive strength test and eighteen numbers of concrete prisms (100 x 100 x 500mm) for shrinkage measurement. SAM was used to replace OPC at replacement levels of 0%, 5% and 10% by weight of cement.

3 RESULTS AND DISCUSSION

3.1 SEM Images

Figure 1 displays SEM images of both calcined and uncalkined SAM. The SEM image shows mineral interlocking within crystal aggregates. The high density of the structure representing the uncalkined SAM was visible in Figure 2(a). Figure 2(b) shows non-homogenous crystal structures with particles of different sizes and shapes in the calcined SAM, whereas the uncalkined SAM has a more homogeneous structure. It is also worth noting that deformations, which are densely connected particles with some surface level pores, were abundant in the calcined samples.
3.2 XRD Analysis of Uncalcined SAM and Calcined SAM

The X-ray diffraction (XRD) patterns of samples are shown in Figure 2 and 3. Albite (17%), Orthoclase (19%), Quartz (43%), Muscovite (13%), and Chlorite (8%) were identified in the uncalcined SAM sample. Quartz (70.3%), Muscovite (13.5%), Albite (0.3%), sodalite (5.1%), and illite (10.7%) were identified in the calcined SAM sample. Both SAM samples had major peaks at 2θ = 20.72°, 21.22°, 26.84°, 36.84°, and 68.35°. The peaks are sharp, indicating that the sample is crystalline. According to the XRD analysis results, the calcined SAM sample was primarily composed of crystallized SiO$_2$ and amorphous minerals. Some dissolvable minerals such as quartz, albite, and Muscovite have remained in the product after calcination. For both calcined and uncalcined samples, the intense peak is around 26.5° in 2θ. The intense peak in the calcined sample corresponds to quartz, whereas the intense peak in the uncalcined sample corresponds to the quartz, muscovite, and orthoclase phases. It was also discovered that calcination reduced the intensity of this XRD peak.

![Figure 2. XRD image for Uncalcined SAM.](image-url)
3.3 FTIR of Uncalcined and Calcined SAM

Figure 4 shows FTIR spectra of uncalcined and calcined SAM. The spectrum of the samples (calcined and uncalcined SAM) exhibits the principal bands of clayey soil, a Hydroxyl O-H stretching and bending occur at 3700–3650 cm\(^{-1}\) and 1000–650 cm\(^{-1}\), respectively. This indicates the presence of inorganics minerals; most common is quartz, for wavelengths below 1000 cm\(^{-1}\). The uncalcined contain more organic groups than the calcined, resulting in a new trough appearing around 1647 cm\(^{-1}\) corresponding to the carbonyl group, C=O stretch.

![Figure 4: FTIR image for (a) Uncalcined SAM (b) Calcined SAM.](image-url)
3.4 Workability of Uncalcined Soldier Ant Mound Clay (SAMC) Concrete

Six different water-cement ratios were considered for the slump test as shown in Table 1 above, from 0.5 to 0.75 in steps of 0.05. At all the three percentage replacements of cement with SAM, slump value was found to be directly proportional to water-cement ratio, this means workability increased as the water-cement ratio increased. It was also found that the higher the percentage replacement of cement with SAM, the higher the slump value, this means addition of SAM to concrete improved workability. This is because cement has higher surface area than SAM, because it is finer, it therefore absorbs more water than SAM.

Table 1. Slump values of Uncalcined SAMC at varying water-cement ratio.

<table>
<thead>
<tr>
<th>Water – Cement Ratio</th>
<th>Percentage Cement Replacement</th>
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<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>0.75</td>
<td>92</td>
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<tr>
<td>0.7</td>
<td>85</td>
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<tr>
<td>0.65</td>
<td>67</td>
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<tr>
<td>0.6</td>
<td>55</td>
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<tr>
<td>0.55</td>
<td>48</td>
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<tr>
<td>0.5</td>
<td>43</td>
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3.5 Effect of Uncalcined SAM on Density and Compressive Strength of Concrete.

The compressive strength and density results of uncalcined soldier ant mound clay concrete are as presented in Figures 4(a) and (b). It was found that both density and compressive strength increased with increasing curing days. It was observed that at early ages (7 - 28 days), density of uncalcined SAM concrete was higher than the reference concrete and it increased with increase in SAM content. However, as the curing days increased and the concretes gained more strength, the reverse became the case, as the reference concrete gained the maximum density recorded and density reduced with increase in SAM content. Nonetheless, the reduction in density was not significant as it was less than 0.5%. The compressive strength of SAMC was reduced compared to the reference concrete, also not quite significantly at early ages (up to 21 days). However, after 120 days of curing, the 5% and 10% SAM concrete recorded 24.90 N/mm² and 22.22 N/mm² as compressive strength respectively. This is a 10.59% and 20.22% reduction respectively, in compressive strength compared to the reference concrete, which recorded 27.85N/mm².

![Figure 5](image_url)
4 CONCLUSION

From the experimental investigation of uncalcined soldier ant mound concrete, the following conclusions were drawn:

1. The uncalcined sample has a microstructure with higher density and more homogenous crystal structure. The calcined sample showed deformations within its matrix.

2. It was found that the higher the percentage replacement of cement with SAM, the higher the slump value, this means addition of SAM to concrete improves workability.

3. XRD analysis of uncalcined and calcined SAM samples had major peaks at 2θ = 20.72°, 21.22°, 26.84°, 36.84°, and 68.35°. The peaks are sharp, indicating that the samples are crystalline. The calcined SAM sample was primarily composed of crystallized SiO$_2$ and amorphous minerals. Some dissolvable minerals such as quartz, albite, and Muscovite have remained in the product after calcination.

4. The spectrum of the uncalcined and calcined SAM samples exhibits the principal bands of clayey soil, a Hydroxyl O-H stretching and bending occur at 3700–3650 cm$^{-1}$ and 1000–650 cm$^{-1}$, respectively. The uncalcined contain more organic groups than the calcined, resulting in a new trough appearing around 1647 cm$^{-1}$ corresponding to the carbonyl group, C=O stretch.

5. Density reduced as the percentage of SAM increased in the mix but not significantly as the reduction was less than 0.5%.

6. The compressive of uncalcined SAM concretes were reduced compared to the reference concrete, although not significantly at early ages (up to 21 days). However, after 120 days of curing, the 5% and 10% SAM recorded a 10.59% and 20.22% reduction respectively, compared to the reference concrete.

The 5% replacement level of uncalcined SAM is recommended for concrete use as it improves workability, the loss in compressive strength is minimal and its concrete shrinks just as the conventional concrete.

References


Zhou, W., Zhu, P., and Qu, W., Basic Properties of Calcinated Underground Ant Nest Materials and Its Influence on the Compressive Strength of Concrete, Materials, MDPI, 12(7), 1191-1199, April, 2019.