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Strength Properties and Microstructure of Sandcrete Blocks Incorporated with Maize Straws

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Abstract. Major constituents of materials used for building such as cement and river sand are used in making sandcrete blocks. Extracting these materials have negatively impacted the environment, thus causing the depletion of mining sources. The cost implication of construction has also increased significantly causing a shortage of decent housing. This research investigates the strength properties of sandcrete blocks incorporated with maize straws. Sandcrete blocks (450 × 150 × 225 mm) were made with maize straws as a constituent with a mix proportion of 1:4 (cement: sand). Thirty-six (36) sandcrete blocks were produced and their compressive strengths determined at 7, 21 and 28 days. The 28th-day compressive strengths of mixes containing 0, 5, 7.5 and 10 % by volume of maize straws were 3.35 N/mm^2, 2.57 N/mm^2, 2.27 N/mm^2 and 1.90 N/mm^2 respectively. The 28 days strength of maize straw-sandcrete-blocks at 0 and 5% of maize straw generated the highest compressive strength and both results met up with the strength recommendation by the Nigerian Industrial Standard No. 87 of 2004.

Introduction

Sandcrete blocks comprising a mixture of cement, sand, and water are extensively used in many parts of the world predominantly in Africa [1, 2]. In several parts of Nigeria, sandcrete block is a major component in most common buildings. The high and ever-rising financial implication of constituent materials in sandcrete blocks makes it difficult in acquiring adequate housing for both urban and rural dwellers [3]. Observation has shown that the presence of admixtures in construction materials has led to a drastic improvement in the durability, strength, and workability of cementitious products over the few decades [4].

The use of sandcrete hollow blocks has been in existence in most countries of the world including Nigeria, playing an extensive role in the building industry [5]. Sandcrete blocks and bricks are masonry units produced from a mixture of cement, sand, and water. In the construction of housing and other infrastructures, they are principally used as walling materials [6].

Abdullahi [7] argued that sandcrete blocks have been in use in several parts of West Africa for over five decades as a common material for making walls. It is largely used and suitable for non-load and load-bearing walls, and foundations. The material constituents, their mix proportion, the inclusion of admixtures and the production process are important factors that to a large extent, affect the physio-mechanical states of the sandcrete blocks.

Anwar *et al.* [8] opined that sandcrete-made-walls have enough strength and stability, provide good resistance to ground moisture and weather, are easy to maintain and are durable. Provision is therein made for reasonable heat, fire, and sound impact resistance. As a wall-making material, its strength is lower when compared with fired clay bricks, but considerably less expensive.

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Oyekan and Kamiyo [3] also alluded to the fact that hollow sandcrete blocks are mostly used for building construction in Africa. In several states in Nigeria, sandcrete blocks are the basic cost component in building construction. The non-realization of sufficient housing for both rural and urban residents is traceable to the high and snowballing cost of the integral materials of sandcrete blocks. Hence, considering the drive for socio-economic development in both short and long terms, the availability of options for these construction materials is of immense necessity.

Cisse and Laguerbe [9] observed that the mechanical resistance of sandcrete blocks obtained when cement was partially replaced with unground ash was higher than that of classic mortar blocks. It was revealed by the study on Senegalese Rice Husk Ash (RHA) that the use of unground RHA enabled the production of lightweight sandcrete blocks with insulating properties at a reduced cost.

Odeyemi *et al.* [4] studied the strength properties of sandcrete hollow blocks produced from different brands of Nigerian cement with different compaction methods. It was established from results obtained that the brands of cement and the methods of compaction played a significant role on the 28^{th}-day strength development of the sandcrete blocks. Also, it was observed that an increase in the curing age resulted in a corresponding increase in the compressive strength of the sandcrete blocks.

Akeem and Umar [10] studied the quality assurance of sandcrete hollow blocks produced by local block moulding factories in the Gombe metropolis and the blocks produced from these factories were found not to have complied with the established standard. In the same vein, Wilson *et al.* [11] reported that sandcrete blocks obtained from four geo-political zones of Nigeria fall below the recommended strengths when compared with Standards. Therefore, there is an urgent need for close monitoring of block-moulding factories in the country by appropriate government agencies to enforce compliance with the established standards for block production.

The use of maize straws in sandcrete blocks to form solid block units as walling materials for building construction in Nigeria was investigated in this study.

Materials and Methods

Materials

Ordinary Portland cement of grade 32.5R manufactured by Dangote Group Nigeria was used and it conforms to NIS 444-1 [12]. Potable water as specified by BS 3148 [13] was used for the production of the sandcrete blocks. Clean sharp sand free from deleterious materials was used in the production of the sandcrete blocks used in this research work.

Straws obtained from maize stalks were used and they were left in the open space to dry for two weeks after acquisition from a local farm. The useful straws were cleaned and severed from debris and other leaves. The straws were cut to sizes of 5-10mm long using cutlass after natural air drying.

Methods

Cement and fine aggregate particle size distribution utilized for this study was conducted as stipulated in BS 812-103.1 [14]. The test samples were dried to a constant weight at a temperature of 110 5 C ± 0 and weighed. The samples were sieved by using a set of BS sieves and an electric sieve shaker. The percentage of the particles passing through the sieves was plotted against the particle diameters. The fineness modulus for fine aggregate was obtained from Equation 1 while the Uniformity coefficient, which reveals the grading of the aggregate, was calculated from the graph using Equation 2.

$$\text{Fineness Modulus} = \frac{Total\ cumulative\ percentage\ retained}{100} \quad (1)$$

$$C_U = \frac{D_{60}}{D_{10}} \quad (2)$$

where: C_u is the Uniformity coefficient, D_{60} represents the diameter of particles matching 60% fines on the cumulative particle-size distribution curve while D_{10} represents the diameter of particles matching 10% fines on the cumulative particle-size distribution curve. If the C_u of the soil sample is less than 4.0 it can be deduced that the material sample is uniformly graded but if C_u of the sample is greater than 4.0 the material is well graded [15-17].

The specific gravity of the fine aggregate used was determined according to specifications by BS 1377:2 [18]. A set of BS sieves was used to thoroughly screen the samples to first remove grass particles and other deleterious materials. A density bottle was weighed and recorded as W_1. The weighed density bottle being filled with the dry sample was weighed and recorded; this weight was recorded as W_2 (weight of dry sample + density bottle). Distilled water was used to fill the density bottle containing the dry sample to a marked gauge. Just sequel to the end of soaking, the density bottle was heated in a water bath to remove the entrapped air and bubbles on the surface of the aggregate sample, after which it was removed, weighed, and recorded as W_3 (weight of dry sample + distilled water + density bottle). Hereafter, the density bottle containing the dry sample and distilled water was emptied and left to dry. The empty and dry density bottle was filled with distilled water to the gauge mark, weighed and recorded as W_4 (weight of distilled water + density bottle). The specific gravity of the aggregate was determined from Equation 3.

$$\text{Specific Gravity (SG) of aggregate} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

The straws were removed from the maize stalk and were cut to sizes of 5-10mm long. The batching was done by weight. Maize straw pieces were added as a constituent to sandcrete blocks at 5, 7.5 and 10%. A total of 36 blocks were produced, 9 blocks per percentage and were cured for 7, 21 and 28 days by the sprinkling of water. The sandcrete blocks (all hollow) were produced with the use of a vibrating machine using a mix proportion of one part of cement to four parts of sand as submitted by Odeyemi et al. [5]. The dimension of the blocks produced is 450 × 150 × 225 mm as shown in Fig. 1. The blocks were subjected to compressive strength test after each curing age.

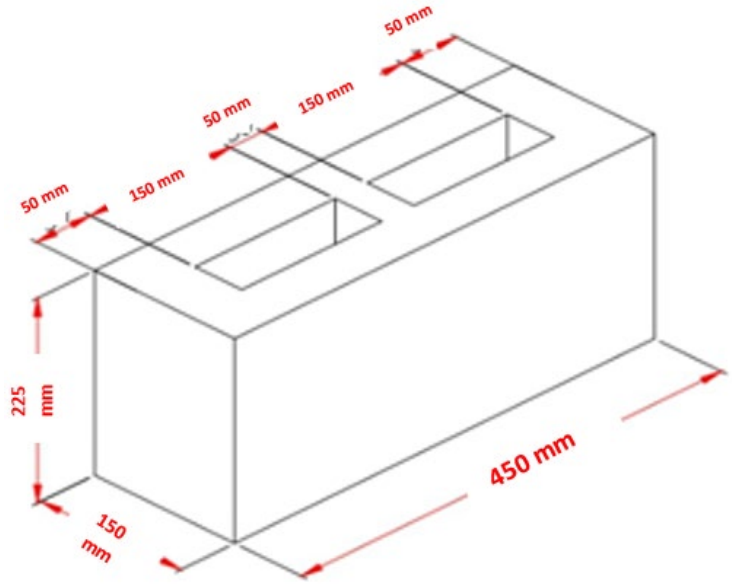


Fig. 1: Hollow Sandcrete Blocks

The compressive strength test of the sandcrete blocks was carried out immediately after the curing process. The blocks were cautiously placed in the compressive testing machine in contact with the plates of the machine. Then, the compression testing machine was turned on from the control source with the gear of the machine turned clockwise. At failure, the dial gauge of the compression testing machine stopped, and the gear was reversed. The load at which the failure occurs was recorded. The equation used to determine the compressive strength is given in Equation 4.

$$CompressiveStrength = \frac{F}{A}(N/mm^2) \quad (4)$$

Where: F = Failure Load (N); A = Cross-sectional area of cube (mm^2)

Scanning Electron Microscopy (SEM) analysis was done on the crushed blocks in Material Science and Engineering Laboratory Department, at Kwara State University, Malete using a SEM ASPEX 3020 at 16.0 kV accelerating voltage. The samples were covered in gold utilizing Balzer's sputtering device before inserting them under the microscope.

Results and Discussion

Particle size distribution

The particle size distribution result for the fine aggregate is as illustrated in Fig. 2. The dimension of the aggregate ranges between 0.10 mm and 1 mm indicating that it falls within the category of fine and medium sand [16]. The aggregate's fineness modulus was obtained as 2.99. This conforms to the specified limit recommended by BS EN 933-1 [19]. The $C_u = 3$ is reflective of the uniform grading of the fine aggregate [15,16]. These results agree with the previous study by Odeyemi *et al.,* [6].

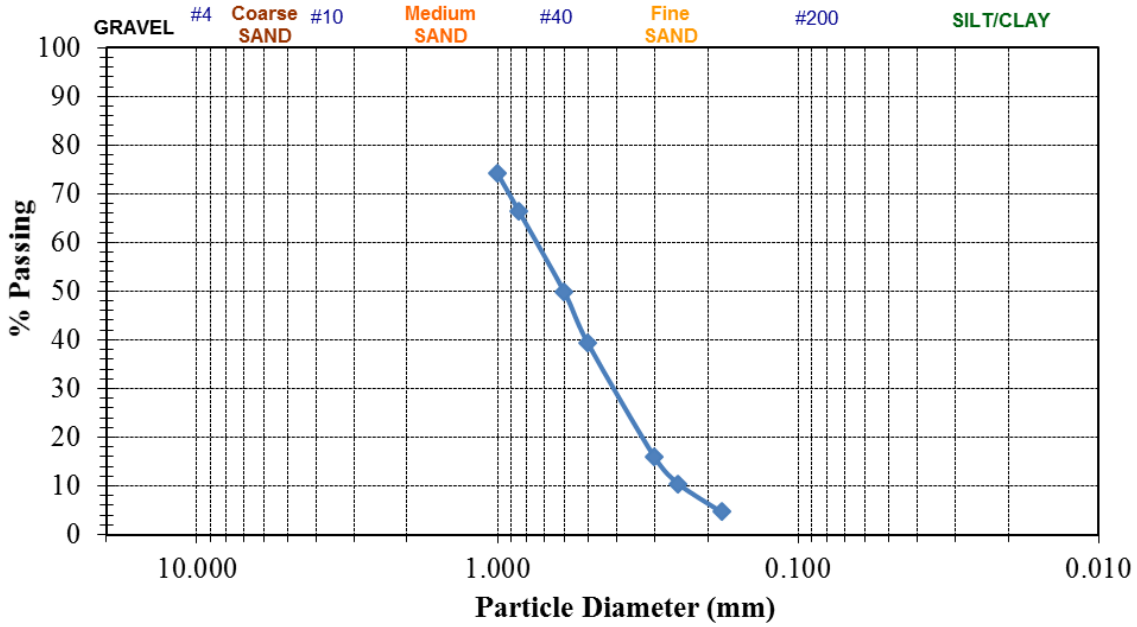


Fig. 2: Fine Aggregate Particle Size distribution

Specific gravity of aggregate

The specific gravity for fine aggregate was found to be 2.54. American Concrete Institute [20] and Neville [16] specified the range of specific gravity of aggregates to be from 2.30 to 2.90. Therefore, the results obtained for the specific gravity in this study is within the boundary for fine aggregates.

Compressive strength test

Fig. 3 depicts the result of compressive strengths gotten from the different mix proportions at different curing ages. The strengths obtained varied between 1.88 N/mm^2 and 3.35 N/mm^2. The 10% of maize straws had the minimum compressive strength at all curing ages while the control (0%) gave the highest compressive strength at all curing ages. The compressive strength at 0 % and 5 % fall within the specified minimum compressive strength of 2.5 N/mm^2 and 3.45 N/mm^2 for sandcrete blocks prescribed by NIS 87 [21] for load-bearing and non-load-bearing walls respectively, at 28 days of curing. Results of 7.5 and 10 % inclusion of maize straw were not found to be within the specified limit. It was also observed that as the percentage of maize straws increases, the compressive strength decreases at all curing ages. This finding follows the same pattern of results presented by Bahari *et al.* [22] when they used rice husk and viscocrete in concrete bricks.

The reduction in compressive strength of the sandcrete blocks was 23 %, 32 %, and 43 % for 5 %, 7.5 % and 10 % inclusion of maize straws in the sandcrete blocks respectively. This could be because of the weakening of the structure of the sandcrete blocks developed from the interaction of the maize straw with the constituents of the block. Thus, the more the straws, the more the spatial disarrangement of the structure of the blocks.

Also, as the curing age increases, the compressive strengths obtained increase for all mix proportions.

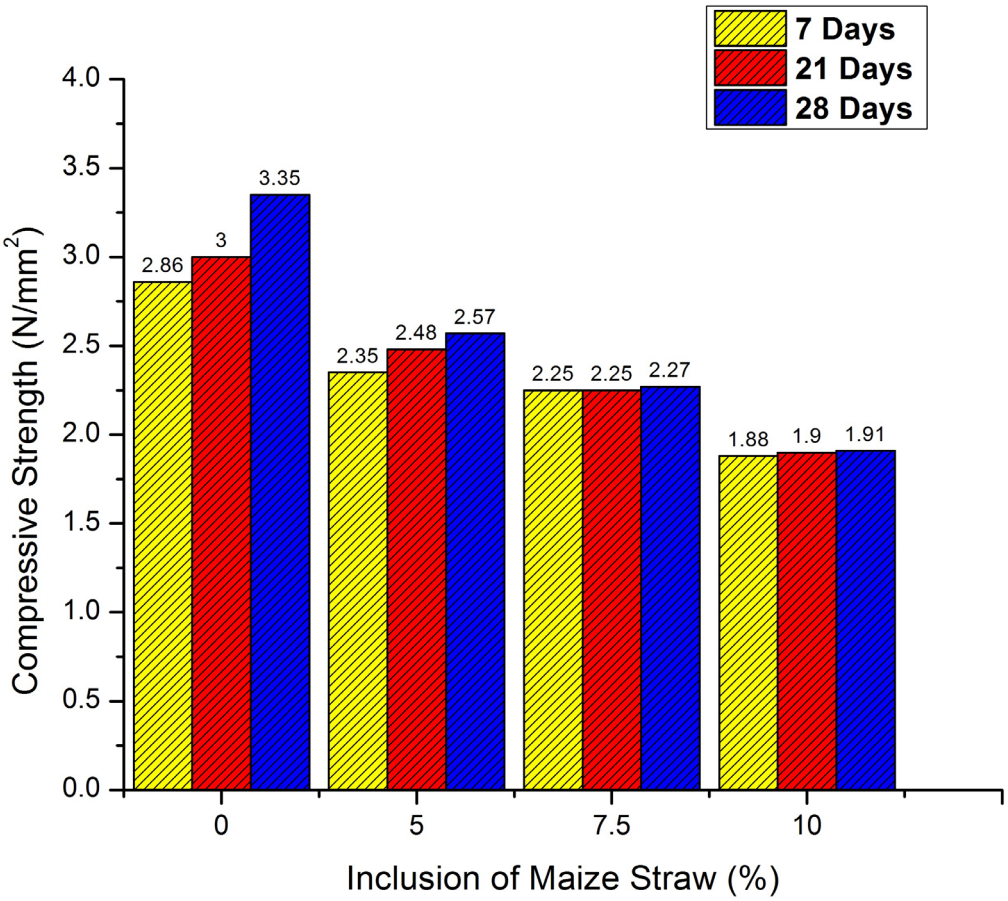


Fig. 3: Compressive Strength–Maize straw (%) Relation for Hollow Sandcrete Blocks

SEM Analysis

Fig. 4-7 shows the micrographs of maize straw modified concrete determined at 28 days of curing, having varying proportions of maize equalling 5 %, 7.5 %, and 10 %. The images were observed at an accelerating voltage of 16.0 kv, display magnification of 50 and a scale of 2000 µm.

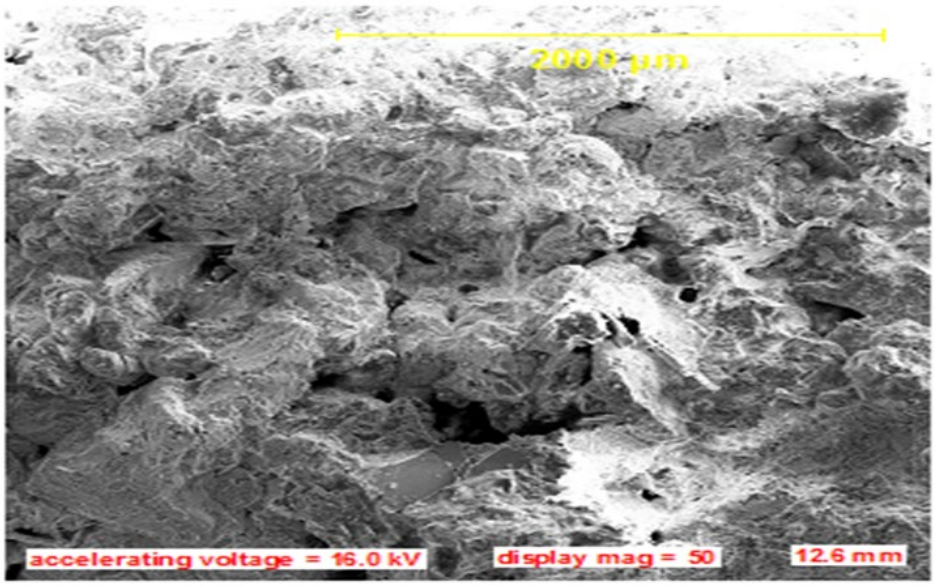


Fig. 4: SEM Analysis of 0% incorporation of maize straw

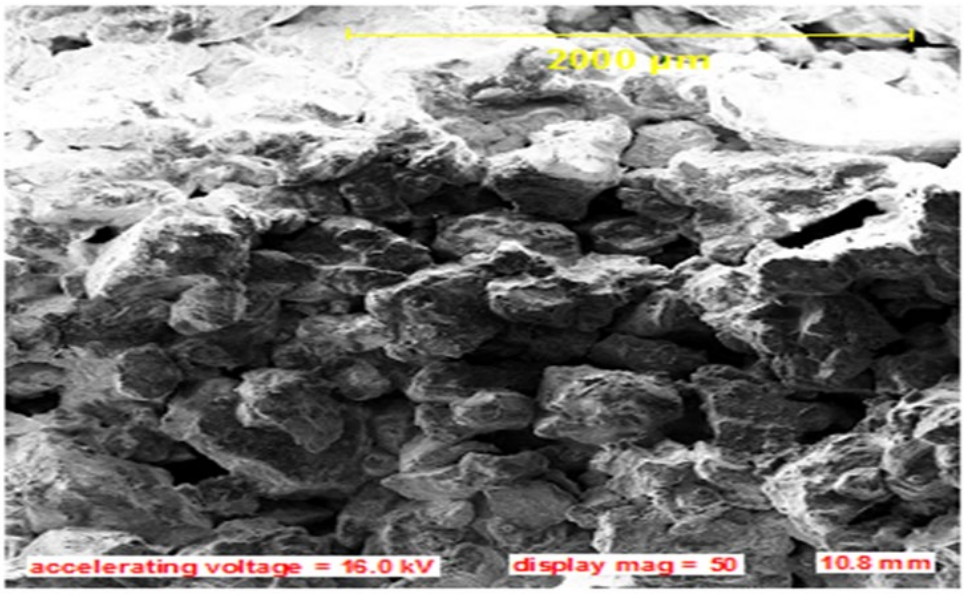


Fig. 5: SEM Analysis of 5% incorporation of maize straws

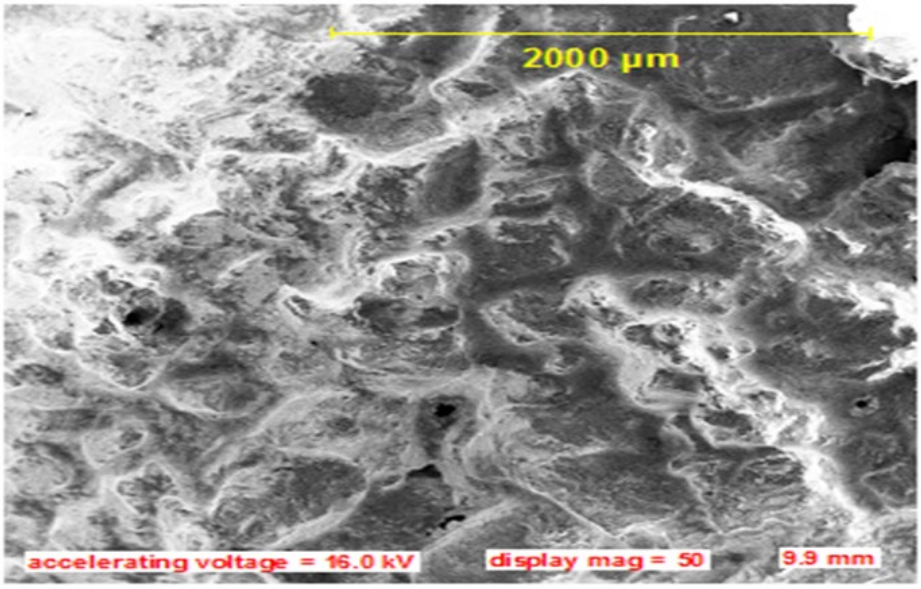


Fig. 6: SEM Analysis of 7.5% incorporation of maize straws

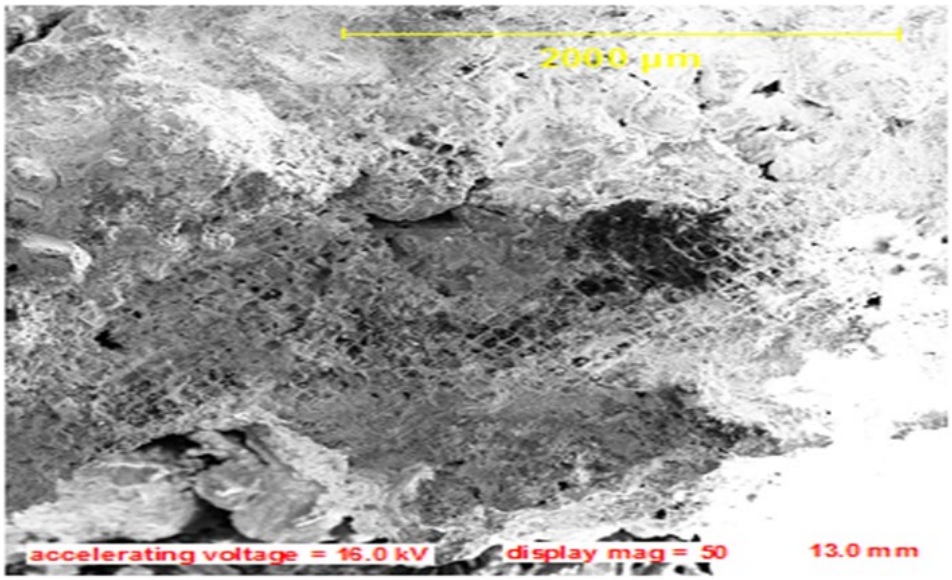


Fig. 7: SEM Analysis of 10% incorporation of maize straws

The micrograph in Figure 4 which is the control concrete without maize straw addition has many concrete grains connecting one another to form a single solid body having numbers of holes or defects acting as regions of discontinuities within the concrete. The defects/discontinuities always act as stress raisers, that is, regions where stresses most concentrate. Uneven stress distribution normally results in local deformation of the material at a stress level much lower than expectations because of the inability of the remaining parts of the concrete to share from the applied stress burdens due to discontinuities in the concrete. The presence of holes or voids could be linked with air trapped within the concrete grains during processing which later open as voids after curing/setting.

After the addition of maize straws, the spatial arrangement of concrete grains appears different from that of the control. This causes variations in microstructural properties among maize straw modified concretes compared with that of the control. Since mechanical properties rely on materials microstructure, discrepancies observed in the hollow sandcrete blocks' microstructures account for differences in the compressive strengths presented in Figure 3. The greatest compressive strength of the control concrete compared with those of maize straw modified concrete could be linked with its relative microstructural integrity compared with others. The number of defects seen on the surface of the microstructure (Fig. 4) is fewer compared with those in Fig. 4 to Fig. 7 where most of the concrete grains appear disjointed. The microstructure in Fig. 6 appears better than that in Fig. 4 because its number of surface defects are lower than those in Fig. 4 but its lower compressive strength than that of the control could be linked with the weakness of the structure developed from the interaction of the maize straw (7.5%) with that of concrete since the maize straw itself is weaker than the concrete.

Conclusions

The following deductions were drawn from the study:

i. A decrease in the compressive strength was observed as the percentage of maize straw increases and the compressive strength also increases as the curing age increases
ii. The compressive strength results of sandcrete obtained at 28 days of curing for 0 and 5 % maize straw-sandcrete-blocks were found to be within the limit specified by the Nigerian Industrial Standard, which implies that the addition of maize straw above 5 % will decrease the strength properties of sandcrete block.
iii. Incorporation of 5 % maize straw for hollow sandcrete blocks production is hereby recommended for the production of non-load bearing sandcrete blocks.

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