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Characterization of Selected Biomass Materials as Potential Additives for Developing an Eco-friendly Ceiling Composite

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Abstract

The objective of this paper is to investigate the potentials of agrowaste materials and aluminium dross industrial waste in building construction applications. The sieve sizes, specific heat capacity and microstructure were analyzed. Aluminium dross along with bentonite, carbon graphite and silicate surface characteristics were examined by scanning electron microscope equipped with energy dispersive X-ray spectroscopy. The examined materials find application as ceiling and wall tiles. The study confirmed the feasibility of using agricultural wastes and industrial aluminium dross waste as a building materials.

Keywords: Aluminium dross; agrowaste, scanning electron microscope, building materials

1. INTRODUCTION

Ceiling composites finds applications in buildings as ceiling tiles, wall decorators, and heat absorbent media and sometimes in automobile brakes and clutch systems owing to its insulating properties, fire resistance, reduced maintenance cost, and lesser maintenance [1]. Despite the several efforts by clinical researches to unveil the mechanisms behind the toxicities associated with ceiling composites, few studies have been able to elucidate this phenomenon [2]. For instance, Douglas & Van den Borre, [3] reported that, the low awareness and understanding of how to prevent the risk associated with ceiling composites remained a major challenge to users. Characterization and quantifications of exposure and risks associated with ceilings would provide a better understanding of the types and health challenges which it could pose to users [4,5]. However, despite the risk factors, there are ways of improving the properties of the ceilings materials such as heat treatment to declassify some hazardous element to make it non-hazardous for structural purposes [6,7]. Although, the practice is quite cheap and affordable, yet remained a temporary solution to the release of fibre from the ceiling composite [8]. According to Dirisu et al. [9], material characterization would help to develop an optimal eco-friendly ceiling composites. Thus, improving the thermal environment and efficient green energy production [10]. Also, study by Ezenwa et al. [11] showed that optimization of the process parameters like press pressure, press time, and press temperature during ceiling composite production would lead to a ceiling product of adequate physical and thermal characteristics. However, the comparison of the insulation properties with the interfacial heat transfer coefficient remained a major problem to ceiling materialists [12]. Recently, studies have shown the suitability of recycled biomass materials (sawdust) for developing an eco-efficient building materials (ceiling) without lessening its properties [13-16]. Thus, sustainable building design requires the use of energy efficient materials, especially for cooling purposes (ceiling composites) [17-19]. More so, the invention of a thermoelectric ceiling composites has brought immense improvement in the cooling/ventilation system of buildings [20,21]. Based on these, it is possible to derive some numerical models for predicting the convective, radiative, and the average interfacial heat transfer coefficient for different surface emissivity, thermal conditions and dimensions [22]. Also, extreme weight and approximate density of 1 g/cm^3 of these novel ceiling composites gives it the improved properties such as heat and sound insulation as well as fire-retardant property [23]. Indeed, many research have used different materials to develop ceiling composites in order to reduce the toxicities associated with ceiling composites. But few have actually paid attention to the use of organic materials (biomass). This study, therefore, intend to use some selected biomass (coconut shell, egg shell, and oil bean stalk) with aluminium dross as the parent material to develop an eco-friendly ceiling composites with improved thermal and acoustic properties. All the selected biomass has been established to have the strengthening property and non-hazardous, thus, making them sustainable materials for reinforcing building materials.

2. EXPERIMENTAL DETAILS

2.1 Materials and sample preparations

The materials used for the ceiling composite include: aluminium dross which formed the matrix of the composite, binders (cement, silicate, and bentonite), additives (coconut shell, egg shell, and oil bean stalk), fire retardant (carbon graphite), and moulding box. The dross, bentonite, and silicate were obtained and sieved using different mesh sizes of sieve to determine the approximate size of the material that will be suitable for the development of the ceiling composite. The dross formed 60 wt% of the overall material, and it was selected owing to its good thermal and excellent wear properties. In comparison, the binders formed a total of 30 wt% of the material, which was selected based on their superb ability to improve strength. Also, additives and carbon graphite formed 10 wt% of the content. The selected additives (biomass) have been found to have the ability to increase the hardness and strength of a composite while the carbon graphite was used as fire-retardant material.

$$C_S = \frac{(M_l – M_c)\, C_w(\theta_3 - \theta_1) + M_c\, C_c(\theta_3 - \theta_1)}{M_S\, (\theta_2 - \theta_3)}$$

Where M_S is Mass of the sample, M_c is Mass of calorimeter & stirrer, M_1 is Mass of calorimeter & stirrer + water, θ_1 is Initial temperature of normal water, θ_2 is the temperature of boiling water, θ_3 is Final temperature of the mixture, C_s is Specific heat capacity (S.H.C.) of sample C_c is S.H.C. of the copper calorimeter.

3. RESULTS AND DISCUSSION

3.1 Specific Heat Capacities of selected Biomass

The specific heat capacity of the materials, as mentioned earlier, was evaluated—the values obtained from the specific heat capacity test by method of mixtures [24-25]. Table 1 and Table 2 present the specific heat capacity (S.H.C.) of various selected reinforcement materials for aluminium dross matrix for building applications. The calculations of S.H.C. values were analyzed using both Graphpad 8.0.1 and Microsoft excel 2016. The specific heat capacity of pulverized coconut shell 1.77 KJ/kgK, which is slightly comparable to the value obtained by [26] at 1.536 MJ/kgK for coconut shell1 while coconut coir is 1.26 MJ/kgK [26]. Carbon graphite is 2.11 KJ/kgK, which is different from the value717 J/kg ºC by [27]; the reason is due to differences in allotropes of carbon. The S.H.C. value of pulverized eggshells is 6.62 kJ/kgK. The S.H.C. of the egg was obtained at 3.3 KJ/kgK. The S.H.C. of oil beanstalk is at the value of 1.9kJ/kgK, which is marginally higher than the value obtained by [30] at 1.56KJ/kgK. The extent of moisture content accounts for the differences in S.H.C. value [33]. Oil bean seed is of the range 3.2-4.02 kJ/kgK values are dependent on moisture content [33].

Table 1: Data to determine specific heat capacity for various components for the first run

Parameters	Coconut shell	Oil beanstalk	Eggshell	Carbon graphite
M_s	4.5	4.7	0.5	5
M_c	203	203	203	203
M_1	323.8	310.7	323.5	310
Θ_1	28.9	29	28.9	28.2
Θ_2	100	100	100	100
Θ_3	30	29.8	29.2	30
C_w	4200	4200	4200	4200
C_c	385	385	385	385

Table 2: Data to determine specific heat capacity for various components for the second run

Parameters	Coconut shell	Oil beanstalk	Eggshell	Carbon graphite
M_s	5	5	0.6	6
M_c	203	203	203	203
M_1	310	311	311	311
Θ_1	30	31	32.2	32
Θ_2	100	100	100	100
Θ_3	31	32.7	32.8	33.2
C_w	4200	4200	4200	4200
C_c	385	385	385	385

Table 3: Specific Heat Capacity Calculation from data of Table 1 and Table 2

	Pulverized Coconut Shell			Pulverized Oil Bean Stalk			Pulverized Egg Shell			Pulverized Carbon Graphite		
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Mass of Sample (g)	4.75	0.353	2	4.85	0.212	2	0.55	0.070	2	5.5	0.707	2
Mass of Calorimeter and Stirrer (g)	203	0	2	203	0	2	203	0	2	203	0	2
Mass of Calorimeter and water (g)	316.9	9.758	2	310.85	0.212	2	317.25	8.838	2	310.5	0.707	2
Initial Temp. water/Temp. Solid (°C)	29.45	0.777	2	30	1.414	2	30.55	2.333	2	30.1	2.687	2
Temperature of boiling water (°C)	100	0	2	100	0	2	100	0	2	100	0	2
Final Temperature of Mixture (°C)	30.5	0.707	2	31.25	2.050	2	31	2.545	2	31.6	2.262	2
Specific heat Capacity of water J/kgK	4200	0	2	4200	0	2	4200	0	2	4200	0	2
Specific heat Capacity of Copper Cal. (J/kgK)	385	0	2	385	0	2	385	0	2	385	0	2
Specific heat capacity of Sample (J/kgK)	**1770.12**			**1991.10**			**6616.66**			**2111.862**		

3.2 Sieve Analysis

Particle size has a significant impact on sieve-analysis effects such as the bond of the composite and the thermos-physical strength. The sieve size is given as the size of the hole measured at right angles to the wires through the midpoint of the opening [31-32].

The particles were hand sieved using sieve sizes of 12.5 mm, 9.5 mm, 6.3 mm, 4.75 mm, 2 mm, 1 mm, 600 µm, 300 µm, 150 µm, and 75 µm. In the actual hand sieving, the particles were agitated in all directions to see if they would pass through the sieve opening. From Fig.1, at sieve sizes 12.5mm-4.75mm, all particles of aluminium dross pass through without retaining. 1mm sieve size kept the most compared to 600 µm to 75 µm. Finer particles will be obtained as the sieve size attain nanoparticle, which will achieve a homogenous composite with an excellent bond and better mechanical properties. Sieve size gives a better quantity of retained aluminium dross despite milling the dross.

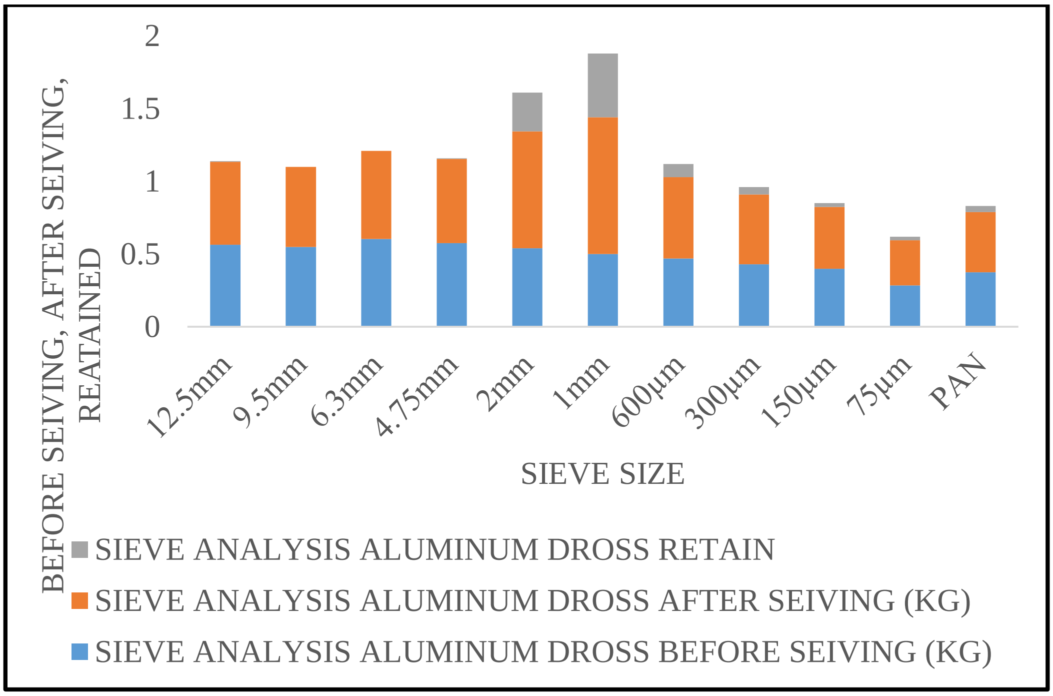

Fig 1: Aluminium dross graphical representation of particle area

Similarly, in Figure 2, it is observed much silicate was retained at sieve size 300 µm followed by 150µm mainly due to the particle diameter, thus becoming the suitable sieve dimensions for silicate.

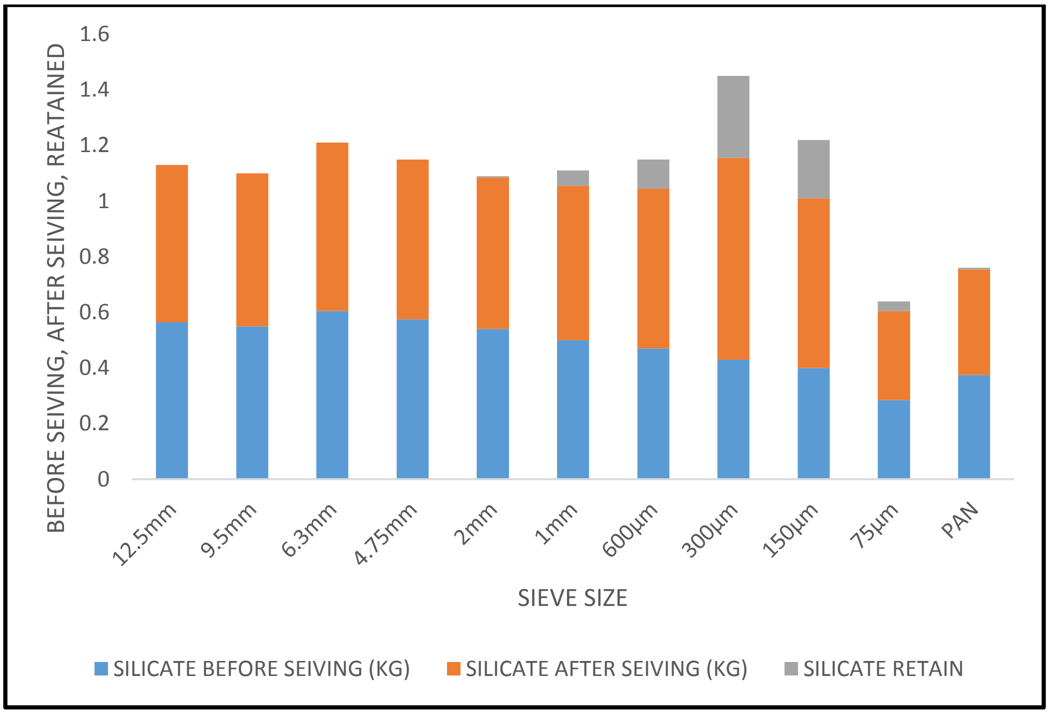

Fig 2: Plot showing sieve analysis for silicate

Figure 3 shows the sieve analysis of bentonite. Particles begin to be retained from 2 mm to 75 µm

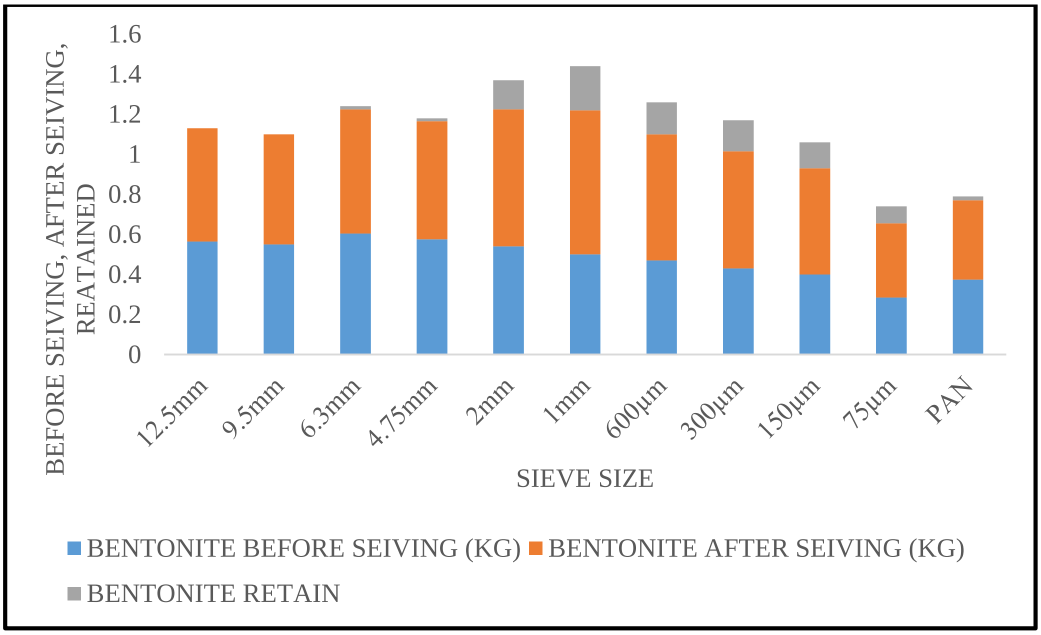

Fig 3: Graph showing sieve analysis for bentonite

Among the three sand particles, silicate gave the larger quantity at 300 µm followed by bentonite, while aluminium dross gave the least. A large volume of material will be needed to obtain required sieve size especially finer particle at 75 µm for the three raw materials

3.3 S.E.M. Analysis

The S.E.M. photograph of 60% aluminium dross with 30% bentonite and 10% cement is shown in Figure 4. It can be seen that the microstructure is not fairly homogenous due to the limited presence of pozzolanic compound that is evident in cement, silicate and aluminium. An increase in percentage weight of cement or the introduction of siliceous and aluminous materials will suffice. The absence of fibre that will improve the chain and eventual mechanical properties of the structure is seen is evident from the micrograph. This will permit void and the collapse of the structure due to interfacial instabilities among the materials used for this composite. Epoxy resin was bonded with aluminium dross by [28], which gave a quasi-homogeneous microstructure. The white lustre is an evidence of aluminium dross with the presence of titanium hydride [28] while the dark portion shows the presence of hydrated silicon in the dross-clay-cement mixtures.

Figure 5 presents the S.E.M. image of carbon graphite depicting the shape of flakes that are interconnected in the form of a spheroid. Graphite morphology determines the thermos-physical properties of the composite it is embedded in [29]. The layers of carbon graphite can serve as a barrier for and a shield over the composite matrix, which will potentially improve resistance to thermal and electrical inflow, thus becoming a potential thermal and electrical insulator [29].

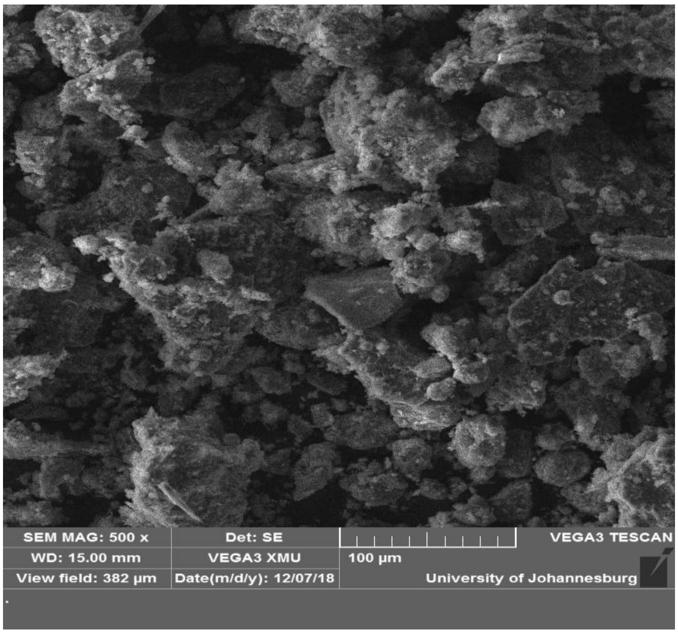

Fig 4: S.E.M. morphology of Aluminium dross with bentonite

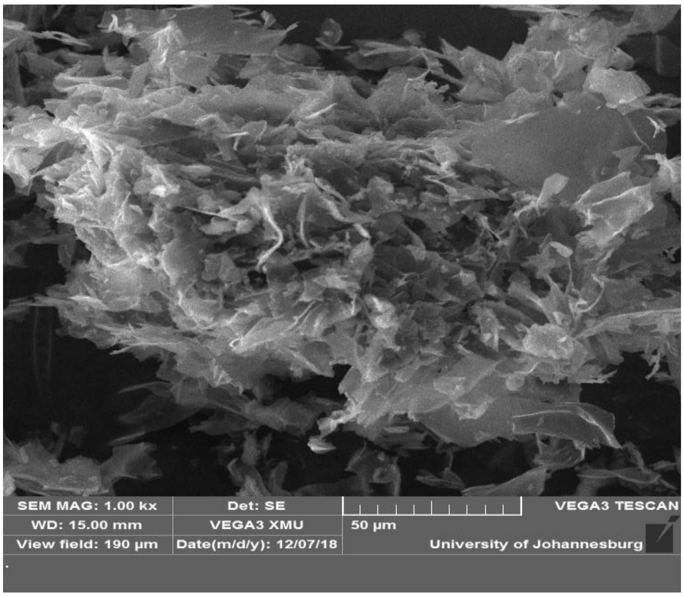

Fig 5: S.E.M. morphology Carbon Graphite

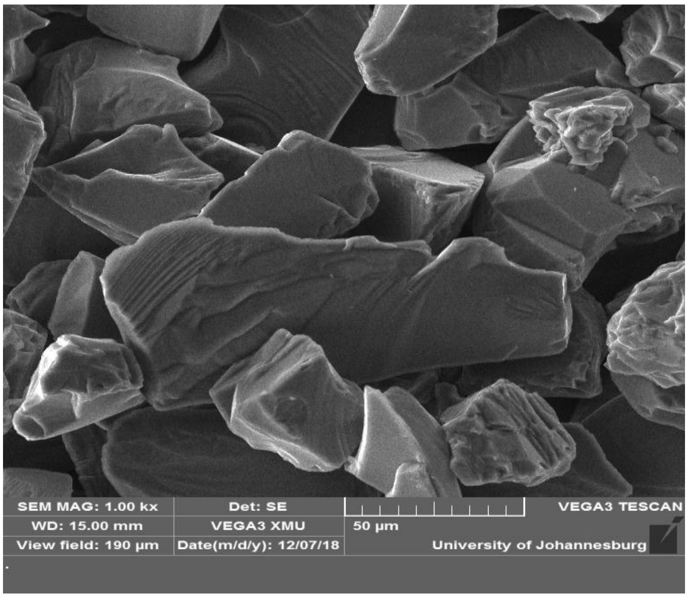

Fig 6: S.E.M. morphology Silicate

CONCLUSIONS

In this study, agricultural wastes and industrial waste were assessed as probable materials for building insulation composite. The specific heat capacities of coconut shell, oil beanstalk, eggshell, and carbon graphite were examined and compared with literature. The microstructural characteristics of aluminium dross, which serve as an industrial waste, was investigated to ascertain its combination with probable binding agents. The use of industrial and agricultural waste serve as an alternative to energy-demanding conventional products as it would provide a sustainable method for building applications such as the production of the ceiling and wall tiles. Aluminium dross serves as a matrix to composites, while cement and option of silicate and bentonite function as a binder to the aluminium matrix. Oil beanstalk and coconut shell are alternative as reinforcement to the base material. At the same time, carbon graphite possesses flame retardant constituents to inhibit flame spread into the composite, which will help manufacturers and stakeholders in the construction industry in factoring safety.

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