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Thermal-emission assessment of building ceilings from agro-industrial wastes

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ABSTRACT

Most of the building ceiling tiles used today from studies, such as polyvinyl chloride (PVC) composite ceilings, cardboard, plywood, particleboard, are flame friendly. Except for asbestos, which is confirmed to emit asbestosis, cancer from asbestos; already warned by the Environmental Protection Agencies and other health standard organizations. Studies have shown inherent harmful elements associated with the use of PVC Ceiling composite, plant-based ceiling, and asbestos, which propagate noxious emission at the instance of fire; their widespread use is quite enormous. The noxious behaviour during an inferno is a representation of the elemental make-up of these ceiling materials. Moreover, their vulnerability due to emission and combustion threat call for alternative materials with eco-friendly constituents for building ceiling applications. Problems associated with these building ceilings during fire include noxious gaseous emissions; fuel for the flame from ignition from other roof frame structures; after flame effect of inhaling poisonous gasses against the recommended exposure limit of 35 ppm by the World Health Organization (WHO). Flame retardance is credited to asbestos. However, for other ceiling tiles, some of the challenges of high heat flux, high thermal conductivity, and combustibility tendencies, are still current issues. The undesirable side effects of using ceiling tiles have necessitated a replacement with suitable flame retardant and eco-friendly influences. This is made to bear by appropriate material selection and by employing industrial wastes and agricultural wastes coupled with suitable binders to solve flame propagation challenges. It is, therefore, necessary to develop a flame retardant ceiling composite that will solve the identified anomalies in the existing ceiling tiles in the market in building industries. The developed materials are tested for thermal and emission characteristics to ascertain their integrity by employing advanced test equipment. The result shows that there are low values in thermal conductivity of the developed building ceiling samples. Sample 2 has the lowest value compared to the developed and existing ceiling tiles, much < 0.0802 W/mK, which is a desirable property in ceiling application. Low thermal diffusivity is required to suppress flame propagation. This is exhibited by sample 1, with a value of 0.85×10^{-8} m^2/s as the lowest amongst developed ceiling samples The result showed null and negligible SO_2 detection for all samples. The three samples' time to attain pre-set temperature varies in the ascending order of sample 1 at 24 min, sample 3 at 37 min, and sample 2 at 42 min. Sample 3, $_{0.6}Aldr_{0.34}Cmt_{0.05}G_{0.01}OBS$**;** Sample 2, $_{0.6}Aldr_{0.32}Cmt_{0.05}G_{0.03}OBS$ and sample 1, $_{0.6}Aldr_{0\cdot3}Cmt_{0.05}G_{0.05}OBS$ are in the order in terms of safe emission characteristics while sample 2 ranks best in terms of flame retardancy.

This study has established that the developed building ceiling composite material is flame retardant capable of preventing fire propagation, unlike the flammable polyvinyl chloride (PVC) ceiling composite. The developed building ceiling composite can minimize the emission of harmful elements in the make-up of the ceiling, as revealed in the results. The tiles are alternative to both noxious PVC and asbestos ceiling tiles. Oil beanstalk is a novel material introduced as a reinforcement to the developed composite. The manufacturing industries should

; PVC, polyvinyl chloride; WHO, World Health Organization; OBS, Oil Bean Stalk; Cmt, Cement; Aldr, Aluminium dross; CSH, calcium silicate hydrate; CASH, calcium Aluminium silicate hydrate; SEM, Scanning Electron Microscope; EDS, Energy Dispersive Specroscopy; G, Carbon Graphite.

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explore materials with excellent eco-friendly flame retardant constituents to encourage sustainable building production.

Introduction

In this study, materials employed for the development of ceiling tile composite were investigated, and previous works carried out by various authors on thermo-mechanical properties of developed ceilings were reviewed. There is a similar challenge of utilizing aluminium dross, which is currently occupying landmass due to underutilization. Various authors reported the potentials of applying aluminium dross, and this current research seeks to explore its capacities in building ceilings. Materials exist with environmental concerns such as the indiscriminate use of plastics packaging films and volatile organic derived materials. The concern here is their complete non-biodegradability and threat to the aquatic organisms. In ensuring a sustainable ecology, the use of plastics should be restricted [1–2]. The awareness of the negative impact of petroleum-based plastics, the depletion of petroleum resources has led to a shift in using materials that are compatible with the environment, thus aiding natural conservation and a pollution-free atmosphere. The new concept of bio-based plastics produced from renewable sources degrades in the background after service life. This new concept helps to solve waste disposal concerns [3]. In achieving a user-friendly and biodegradable product, the materials should be derived from either replenishable agricultural feedstock such as starch and proteins or food processing industrial wastes such as chitosan. Engineering eco-friendly components in the design, such as brake friction materials with null lead, antimony sulphide, and whisker materials, help reduce the potential negative impact of these on the environment [4]. Green composite is a product of such a quest by researchers to achieve eco-friendliness [5]. The development of an eco-friendly ceiling composite is worth pursuing to obtain a green environment. This development can come through a careful individual material selection that makes up the overall composite structure.

Researchers study materials to minimize the cost of raw materials and improve the quality of the product. To achieve improvement of material, engineers embark on recycling of waste from agriculture and industries. The utilization of coconut shell, oil palm fibre, palm kernel shell, oil beanstalk, fly ash, kenaf fibre, aluminium dross, iron slag, metal chip, etc., are examples of a breakthrough in waste recycling. Utilization of waste reduces the volume of waste occupying the landmass and a probable decrease in pollution of the ecosystem [6–9]. Currently, developing countries have an abundance of both agricultural and industrial waste broadly dwelling the landmass. Waste is categorized as agro-waste, industrial waste, mineral waste, and non-hazardous and hazardous waste. Hazardous waste amongst the categories can be helpful in the production of bricks, wall tiles, ceiling tiles, board, ceramic, and cement [10–13].

Composite is an admixture of two or more materials, each having its unique desired physical, mechanical, chemical, and thermal properties such that the structural composure should achieve its intended application [14–16]. Composite can also consist of polymer reinforced by fibre where the polymer can be biodegradable or non-biodegradable. Starch is an example of a polymer that is biodegradable. The fibre can be natural, synthetic, or hybrid, and it is the main component in polymer composite [17].

Polymer composite finds applications in most manufacturing and processing industries. Around us are materials that are composite in structure [18–21]. Unused materials are reusable and will eventually form a particular type of composite. Composites comprise metal matrix composite, ceramic matrix composites, and polymer matrix composites. In this study, aluminium dross reinforced agro-waste composite will be employed to solve industrial waste dumpsite and noxious emission concerns [22]. Natural fibres have vast exploration possibilities because they are nature-friendly and sustainable. More attention is given to natural fibre since fossil-based composites are not biodegradable, and fossil fuel is non-renewable [23]. The combination of biomaterials to form biocomposites results in a biodegradable and eco-friendly product. Natural rubber, corn, wheat, animal bone powder, fly ash, sisal fibre, and barley waste are examples of such materials. Such materials are also utilized as composites, thus solving agricultural landfill trash [24]. Selecting materials to achieve sustainable building will involve proper strategy in building and construction [25]. Wood is seen as the most widely used material in the United States and probably the globe due to its environmental benefits. Its economic benefit is not farfetched as it can be combined with other elements to form a composite. Its renewability will be possible if the policy of harvesting and planting is followed [26]. Fig. 1 shows recycled waste from agro-industrial waste.

Building technological practices have evolved through the ages. The application of this technology reveals the standard of living in society.

Materials in the early decades employed as building columns and roofs such as thatches, leaves, mud, and timbers were not durable and were fire-friendly, which eventually were not sustainable. New materials are coming up today, such as cement, steel, plastics, and smart composites, now forming modern building materials, which are energy demanding in production than primitive elements but with better structural properties [27]. John [28] opined that durable sustainability would not be achieved by a measly combining modern method, such as using energy and material resourcefully. However, a genuine understanding of processing and how they interact with the user of the environment will enable the creation of buildings whose materials are quasi-natural, pleasant, dynamic, and regenerative in their design. The author introduced the term biomimetic, a multi-scientific concept of categorizing properties and structures of materials in terms of hierarchy. This notion helps to acknowledge the natural environment to achieve ergonomically sustainable building, and this helps to build stakeholders to apply this idea in delivering a sustainable building design. It was well observed that scientists and biologists work separately, operating in different worlds.

Technologists innovate through design by implementing the studies and hypotheses of the scientist. Innovative design will require the integration of this trio in achieving a satisfactory sustainable structure. The natural world is viewed to inform building stakeholders and science researchers on how to achieve sustainability. Even in natural activities, the Bedouins were known to protect themselves from solar radiation by wearing black protective clothing, which helps maintain the water level in the body by preventing dehydration. Sustainable building involves bearing in mind the building lifespan from start to salvage year, its effect on the environment in terms of quality impact at present and the future. This view will integrate architect, scientist, mechanical, electrical, and civil engineering into the building plan. The material make-up of the building and ergonomics of building design influence the quality of life of the building inhabitants. In this view, biomimetic aims at employing renewable, bio-friendly, and eco-friendly materials in buildings to control and eliminate hazardous substances from their composition. A sustainable building can be viewed as a design with a minimal adverse effect on the natural and built environment and, by extension, on the globe. It is also seen as a best practice in involving quality control to reduce energy consumption, pollution control, noise diminution, and improvement of eco-environmental value. Sustainability in building design is feasible when the materials employed are of a natural basis. Building insulations from chemical admixtures such as petrochemicals or processed natural materials are not environmentally friendly and not sustainable in the long term. However, there exist building materials that are sustainable, renewable, and environmentally friendly such as palm kernel fibre, kenaf fibre, pineapple waste, rice husk, coconut fibre, sugar cane, amongst others.

They are good thermal insulators but with porosity, fungal attack, and short-term fire retardants [29]. Fig. 2 shows the thermal insulators agro-industrial waste.

The purpose of thermal building insulation is to reduce heat transport into the interior of the building. Thermal insulation can be assessed through thermal conductivity, transmittance, inertia, absorptivity, and thermal resistivity. Thermal conductivity is the steady-state heat transfer into a unit material per 1 m thickness per temperature difference, as expressed in W/mK. Material is typically seen as a thermal insulator; its thermal conductivity is lower than 0.07 W/mK [29].

Thermal transmittance, also called U-Value, is the steady-state heat flow into a unit surface area made by a 1 K difference of temperature by considering convective and radiative heat transfer as expressed in W/m^2K. At the steady-state condition, the insulation characteristics are well explained by the thermal conductivity and thermal transmittance. However, for the unsteady state, thermal diffusivity is used to compare a material's ability to conduct and store thermal energy. It is dependent on the thermal conductivity, density, and specific heat capacity of the material. It is expressed in m^2/s. The specific heat is a material's ability to store energy, which is the quantity of heat required by 1 kg of material to change its temperature of 1 K, and it is expressed in J/kgK. A low thermal diffusivity is a function of high specific heat capacity and probable varying density. Insulators characterized by thermal conductivity under 0.05 W/mK and specific heat over 1.4 kJ/kg K perform gradually in unsteady-state conditions. The response to fire in a material can be assessed by temperature change, heat release rate, smoke development, mass loss rate, the heat of combustion, and many other parameters.

The most negligible response to the fire, which is non-combustible, is A1. The most responsive to fire is E. Researchers propagate the quest to apply renewable source material to enhance sustainability. Energy consumption in the suburban and urban regions is mainly on the high side in industrialized nations. There is an excellent prospect for energy savings in these regions. Innovative technologies, such as renewable energy should be applied to achieve a significant reduction in energy consumption [30]. In making sustainable buildings, steps are required regarding energy, water, land, and material conservation, together with environmental loading and indoor and outdoor environments [31]. The procedure and process of building design combine many materials all through its service life cycle. The choice and usage of sustainable building tools play a significant part in designing and constructing green buildings [32]. Minimizing the use of energy is a central task in sustainable building. Reducing the use of natural resources and maximizing the recycling potential are other essential tasks to consider. In low-energy buildings, the embodied energy accounts for a considerable part of the total energy use of the building. Therefore, it is also imperative to pay attention to the building materials' choice [33].

In seeking solutions to minimize the challenge of building ceilings with noxious emissions, a quality check of their materials becomes a viable option. Ceiling tile production check has, over the years, been centred on the investigation of mechanical properties and the endorsement of thermal insulation. For instance, [34] investigated the properties of retrofitted ceiling tiles with sawdust additives. The study showed that the lighter density retrofitted tiles (0.745–1.022 g/cm^3) have a 51.8% decrease in bulk density compared with the non-retrofitted tiles (1.82–1.98 g/cm^3). The retrofitted material caused a reduction in flexural strength from 61.26% −50% 50% of clay was replaced by sawdust. The reduced flexural strength in the range of 21–31 MPa, compared with those of the non-retrofitted between 53.29 - 92.23 MPa, is relatively low compared to international standards. The investigation revealed that recycled wood wastes (sawdust) are a potential resource to produce economically viable ceiling tiles. The thermal and combustion properties have to be investigated just in the case of an uncontainable fire outbreak. [35] studied the physical and mechanical properties of aluminium dross added with bentonite. The brick sample of 106 μm had the highest volume shrinkage, 15% porosity, crushing strength of 940 KN/m^2, and peak bulk density of 1.9 g/c.c. Thermal, emission, and combustion properties were not investigated. This has, in a way, not solved fire propagation to the interior building from other fire sources in the building envelope. There are materials in the ceiling that propagate fire, leading to unpleasant incidents, especially plant origins such as cardboard, plywood, thatches, and particleboard. They possess fire properties that support flame spread. There are building ceilings with polymer composites and asbestos types. Asbestos has characteristics of heat insulation, flexibility, durability, and non-flammability. It is widely used as an anti-friction agent, including anti-slip, asbestos board used as a ceiling material or wall material, asbestos compression plate used for heat radiation, and asbestos cement pipe. It has been used in many parts of daily life, such as commercial products such as cladding and packaging products [36]. They are good thermal insulators but with inimical

Fig. 1. Recycled waste from agro-industrial.

Fig. 2. Thermal insulators agro-industrial waste.

emission characteristics, emitting noxious substances that can suffocate or cause a lifetime ailment to victims such as asbestosis, as seen in the asbestos ceiling. Harmful emission at the fire in building ceilings is not desirable as it will clog the occupant's respiratory tract. Fire tragedy and the associated noxious smoke emission are significant scares in building ceiling design. According to [37] when these disasters occur, there is little time to escape, and fire can become uncontrollable in less than 30 s filling the area with thick smoke and heat. There is a long-time negative impact on victim's psychology and finances of uninsured buildings. The ceiling is widely used in building construction due to its aesthetics and shield from heat radiation through the roof [38].

Building ceiling composite has been the focus of importance in the building industry, where the aesthetics, weight, and low thermal conductivity were factored in by researchers [39, 40]. This research seeks to develop novel building ceilings by stage-wise investigation of produced dross ceiling composites.

The investigation of the thermal protection characteristics of ceiling materials compared to the heat transfer constituent is necessary to give insight to all building stakeholders on factors to consider in ceiling production from initiation to final stage, thereby yielding excellent and enviable building ceiling products. Technological advancement tends to influence the selection, manufacturing, and modification of ceiling materials. Technology has sped up the improvement in ceiling tiles and ceiling composites. There is the awareness to modify the materials taking into cognizance the flame-retardant properties. There must be the development of standards such that manufacturers are enforced to comply with so that the ceiling material is improved in thermal comfort, low heat release rate, and excellent flame-retardant property. This will, overall, curb fire outbreaks in buildings. The properties of ceiling materials have been improved upon in decades. End users are comfortable psychologically, mentally and can escape a fire outbreak caused by external factors due to the flame-retardant characteristics of the ceiling materials. This present study will examine the evolution of the ceiling and the factors responsible for developing new products. Such factors for consideration include the aesthetic, thermal comfort, thermal insulation properties, combustion properties, and emission characteristics, which tend to improve the overall product's style and safety. The technology involves introducing new methods and initiatives to solve social, economic, and environmental problems. It is an essential element of globalization [41]. A city with its future is sustainable due to the application of technological innovation [42]. Technological advancement made available options for the choice of ceiling materials. This is so due to various profiles, products, and styles of building ceilings.

Flame retardant materials

Flame retardants are chemicals introduced to materials to inhibit the propagation of flame or maintain and sustain flame inertia [43, 44]. They are also additives to thermoplastic materials [45]. These flame retardants help reduce the flammability of plastics that have replaced metal-based structures in automobiles, buildings, furniture, and electronics. Types of flame retardants are halogen organic compounds, magnesium or aluminium hydroxides. There are natural retardants that are eco-friendly such as Nano clay, carbon nanotubes, and phosphorus-based compounds. These material can be assessed for flammability by testing for ignitability, flame spread, heat release rate, after flame time, and afterglow/time. The more char formed from a material when subjected to combustion, the more influential the flame-retardant characteristics of the material [46–49]. For instance, materials are set on fire in a cone calorimeter to study the thermal gravimetric action. Also, material selection for the interior of aircraft is such that it should meet safety requirements in terms of heat release rate and smoke toxicity. They must be flame retardants such as carbon composites, aluminium reinforced composites, thermoplastics, glass-reinforced phenolic, etc. The introduction of organic filler was proven to enable epoxy systems' thermal and dimensional stability [50, 51]. The thermal behaviour of terephthalamide stabilized PVC was investigated using a cone calorimeter and thermogravimetric analyser and was recommended safe for construction application. PVC is degraded at the temperature of 285.56 °C [52]. Flame retardant paint surface treated on combustible material has its limited function. It is strongly advised not to be used for a permanent structure. Flame spread rating for decorative materials should not exceed 75, and smoke spread rating should not exceed 100 [53]. A smoke detector is recommended to be installed in ceilings in public structures. If a ceiling is not accessible, aside sprinkler is advised. Standard ceiling tile is recommended to be of the dimension 600 mm by 600 mm tile; this will enable the ceiling to be reachable as it can be detachable [54, 55]. In separate standard documentation, the ceiling must be soundproof and fire-resistant. It shall also be positioned in panels. In health centres, the design should be cleanable and nondegradable. It should be able to support dead loads [56]. The use of timber ceilings for schools is advised to be discouraged due to its explosive nature. Ceiling finishes should ensure light reflection, and an acoustic tile ceiling is recommended for classrooms [57]. It is essential to develop a ceiling that has an appreciable measure of flame retardant.

Review on aluminium dross as a viable additive material in composite

Aluminium dross is an industrial waste during aluminium processing and casting [58,59]. The formation of aluminium dross implies the losses in aluminium, which manufacturers aim at reducing to a minimal level [60]. Composite with aluminium dross has diverse areas of engineering applications. Pratumma et al. [61] combined aluminium dross with ADC12 and Aluminium 6063 to develop plant fertilizer. The elemental composition revealed the absence of harmful heavy metals. Alumina was the main composition in the dross by more than 50%. The percentage composition of aluminium dross, as shown in Figure 2, shows the essential elements such as silicon, calcium, potassium, magnesium, sodium, and aluminium that enable the parent compound to be compatible with the product such as cement. Harmful compounds such as ammonium compounds and H_2S, emitted by dross when in contact with water, can be suppressed when the dross is transformed into other products. Containing these environmentally hazardous chemicals was achieved. This is done by stabilizing aluminium dross in liquor, thereby reducing the evolution of ammonia drastically. Aluminium dross has been successfully combined with cement, thus reducing cement consumption in building structures such as mixing different ratios of aluminium dross, aluminium sludge, and aluminium sinister to produce calcium aluminate cement. Such calcium-aluminate cement was used to fabricate fire-retardant brick. Aluminium dross was used as a substitute refractory material by David and Kopac [62]. Other applications of aluminium dross are raw materials for ceramic, semiconductor, metallurgy, and cement [58]. Cement is used as a binder to sand or in a sand combination with granite. Its compatibility with aluminium dross is made possible because of similar compounds in both such as CaO, SiO_2, and Al_2O_3 [63]. Cement is fire resistant due to its composition. Alteration of its structure by adding nano alumina (Al_2O_3) can improve its fire resistance up to 800 °C. The composition of calcined limestone cement was investigated by Avet et al. [64]. The findings of [65, 66] confirmed that the addition of nano alumina particles did not modify the primary hydration yields of the cement adhesive after four weeks of hydration. Mercury intrusion porosimetry (MIP) revealed the decrease in porosity as a dosage of nano alumina was augmented, which significantly influenced the compressive strength, which further corroborates the influence of additive to a matrix such as the addition of fly ash to activated slag cement [67]. Comparative observation revealed that calcium silicate hydrate (C-S-H) is the main binding phase in alkali-activated slag (AAS) cement paste. Onyeaju et al. [68] added that the main hydration products of low calcium fly ash on hardened low energy super sulphated cement paste were ettringite/monosulfate (AFt/AFm) and Calcium Aluminium Silicate Hydrate (C−A−S−H).

Authors from literature employed different agricultural wastes using binders such as epoxy resin and cement for the development of building ceilings They investigated the thermal conductivity, thermal absorptivity, thermal resistivity and specific heat capacity of the ceiling tiles endorsing them as excellent thermal insulators [68–71]. However, the combustion and emission behaviours were not studied. In an emission study by Bourguignon [72], it is shown that numerous air pollutants add to climate change while some impede solar radiation. There is a national objective to reduce six air pollutants (SO_2, non-metal volatile organic compounds, NH_3, particulate matter 2.5 andCH_4) within the years 2020 and 2030.

This study aims to develop a sustainable emission-noxious negligible fire-retardant eco-friendly building ceiling from locally sourced materials available in the environment.

Materials and methods

The materials employed for this research are aluminium dross, an industrial waste that serves as the base material, cement, which functions as the binder. Carbon graphite serves as the flame retardant. Similarly, the reinforcement material is the oil beanstalk. The starting materials were selected due to excellent intrinsic bonding characteristics such as calcium, magnesium, silicon, negligible noxious elements, and significant flame retardant properties of the binder and base materials. The materials employed for the ceiling tile production is shown in Table 1. The subscript of the nomenclature depicts the percentage composition. These were pulverized to 90 μm using the grinding mill and sieve shaker. The Mould process was carried out manually for the composite casting at various percentage mixtures. The samples were moistened and left to dry at room temperature for five days to ensure proper bonding. This process helps maximize the developed samples' mechanical properties. The developed samples at 150 × 150 × 10 mm are shown in Fig. 3. The flowchart in Fig. 4 shows the production process from the starting material to the post-curing of the developed ceiling composites. The developed ceiling composites carried out mechanical, thermal, combustion, emission, and morphological characterizations.

The Thermolyne 6000 oven shown in Fig. 5 was employed to imitate an actual fire scenario with a quasi-sealed compartment, having a 12.5 mm opening only. This opening is a pictorial view of a singular exit point of escape in a room envelope where the windows and doors are closed, and there is a minimal escape of emissions from doors and windows. The maximum temperature that the equipment can attain is 950 °C; however, it was pre-set to 500 °C to allow for additional equipment's maximum temperature tolerance and supposed fire temperature incidences capturing humans and properties [74]. Fig. 6 shows the temperature response of humans and properties to temperature rise, which justifies the choice of the pre-set temperature of 500 °C. The emission analyser was calibrated, and the probe was inserted into the 12.5 mm orifice of the Thermolyne 6000 furnace to detect harmful gasses emitted from the oven compartment, which is by inference the building envelope. The gasses to be trapped by the analyser are CO, NO/NO_x, SO_2, CO_2, and O_2. The extent of detection will allow for a reasonable conclusion on how safe or not the material will be during its service life. Fig. 5 also shows the set-up for the combustion and emission connection of the developed ceiling composite test combining the Thermolyne 6000 having a maximum temperature of 950 °C and E5500 Portable Industrial Flue Gas & Emissions analyser.

The specific heat capacity experiment was conducted by using the copper calorimeter by the method of mixture. The setup for the specific heat capacity of solid by mixture method is presented by Dirisu et al. [75]. The variations in specific heat values are a function of temperature, which will further project the behaviour of ceiling samples under temperature increase from sun or fire incidences. These values will as reasonably deduce the desirability of the composite samples in building applications. The setup for the thermal conductivity experiment using an automated Lee's Disc apparatus is presented by Philip and Fagbenle [76] to obtain temperature differences. The temperature values were used with the specific heat capacities to compute the thermal conductivities of the composite samples. The calorific value test determines the material's heat of combustion, which is the energy contained through the heat given off during complete combustion. Cal 3k combustion calorimeter is the equipment employed, and the procedures are presented by Dirisu et al. [77].

Result and discussions

The results of the three developed ceiling composites are presented in this section. The study is driven by the quest to develop a flame retardant aluminium dross composite that can be employed in building ceilings to curb flame spread at the instance of fire and to utilize the indiscriminate dumping of aluminium dross in the environment.

Table 1
Materials for ceiling tile composite production

Sample	Nomenclature	Al Dross (base Material) (wt%)	Binder (wt%) (Cmt)	Flame retardant (G)	Additive (wt%) (OBS)
1	$_{0.6}$**Aldr$_{0.3}$Cmt$_{0.05}$G$_{0.05}$OBS**	60	30	5	5
2	$_{0.6}$**Aldr$_{0.32}$Cmt$_{0.05}$G$_{0.03}$OBS**	60	32	5	3
3	$_{0.6}$**Aldr$_{0.34}$Cmt$_{0.05}$G$_{0.01}$OBS**	60	34	5	1

Fig 3. Developed ceiling composite samples.

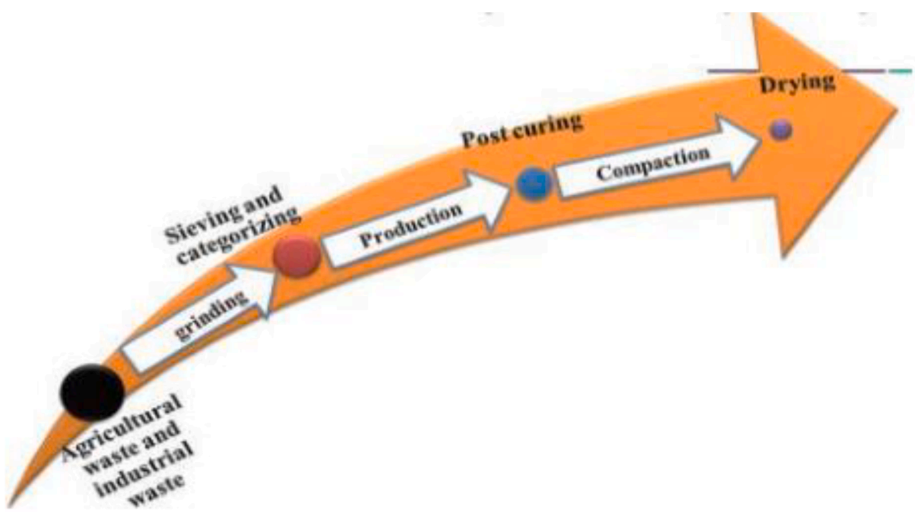

Fig. 4. The flow chart for the production and curing of developed aluminium dross ceiling composite.

Comparison of specific heat capacity of developed ceilings and existing ceiling

Fig. 7 presents the specific heat capacity of the developed samples and existing ceiling samples. The highest is sample 1 at 3900 J/kg K, which requires a high amount of energy to raise or lower its temperature. Substances with a high specific heat capacity are suitable as a building material as more energy is needed to heat the material, thus delaying flame spread at the instance of fire [78]. This sample both heat and cool slowly compared to other samples such as sample 2 with a value of 920 J/kg K. This further predicts the thermal absorptivity as it is expected to have high value due to high SHC value. The differences in SHC values account for variation in the bond nature of the individual material making up the composite sample. The specific heat capacities (SHC) of the samples are high compared to existing ceilings such as polyvinyl chloride (PVC) 1571 J/kgK [70], Plaster of Paris (POP) 1468 J/kgK [79], cardboard 2366 J/kgK [79], and asbestos 842 J/kgK [79]. They are within the range of acceptable SHC for building ceilings.

Comparison of thermal conductivities of developed and existing ceiling samples

Fig. 8 presents the thermal conductivities of the developed building ceiling composites. A low thermal conductivity is sought out amongst the developed samples as it is most suitable in building ceiling applications, especially in tropical regions. Graphite material or carbon particles is an excellent thermal conductivity reducer when added to as a composite enhancer, according to [73,80]. Fig. 8 also shows that the thermal conductivity of the developed composite ceiling material is generally low compared to the existing ceiling samples. Sample 2 possesses the lowest value of thermal conductivity of the developed composite ceiling. This range of values closely corresponds to concrete slab and timber as attested by Atbir et al. [81]. Undoubtedly, low thermal density often influences components with low thermal conductivity, as

Fig. 5. Portable emission analyser and 950 °C thermolyne 6000 Oven.

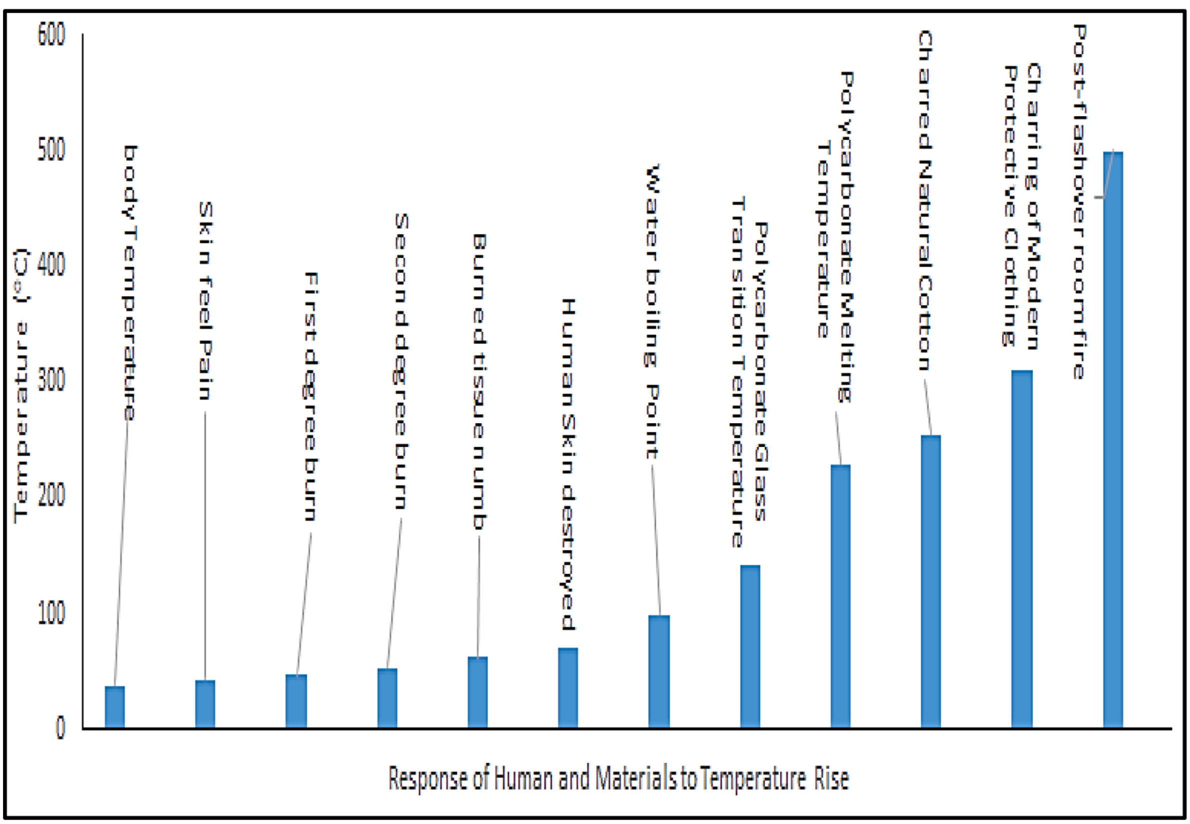

Fig. 6. Human and material response to temperature [74].

observed in this study, which agrees with [82]. The closeness of the atomic structure of the material framework of the ceiling samples also accounts for the low thermal conductivity, which is desirable in the building structure application. The reluctance in heat transmittance and combustion is expected behaviour of these samples.

Comparison of thermal diffusivity of developed ceilings and existing ceiling tiles

From Fig. 9, PVC exhibited the highest thermal diffusivity of 4.5×10^{-8} m^2/s, an indication of high thermal conductivity compared to the three developed samples. This will account for its faster combustion

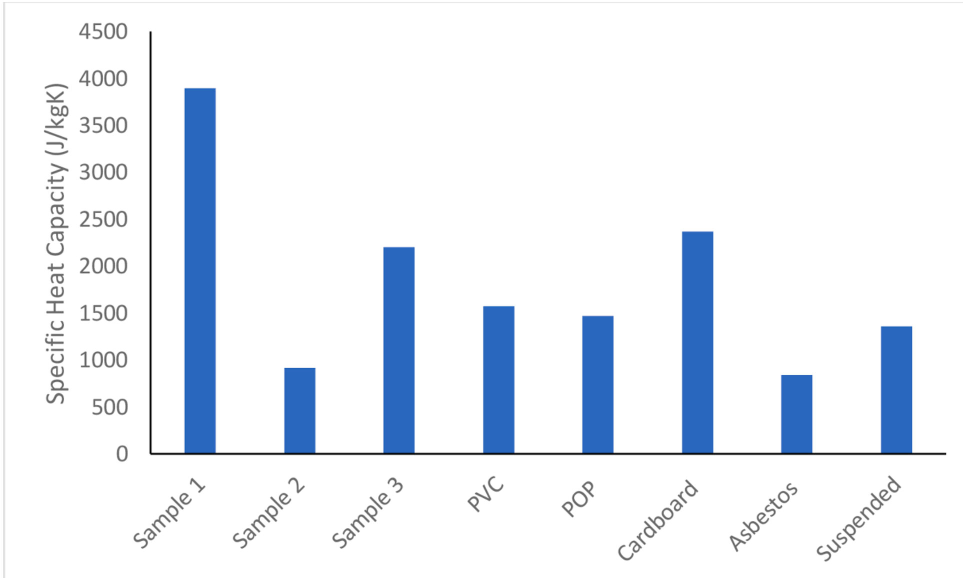

Fig. 7. Specific heat capacity of developed samples and existing ceiling Samples.

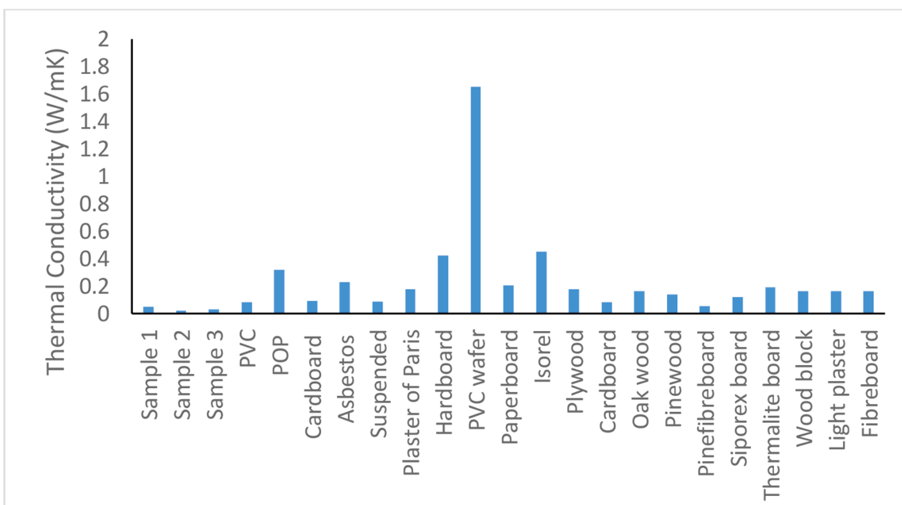

Fig. 8. Thermal conductivity of developed and existing ceiling samples.

compared to the developed ceilings, as attested by Pupeschi et al. [83]. The lowest thermal diffusivity is seen with sample 1 at 0.84 × 10^{-8} m^2/s. Brick, which shares part composition with developed ceilings, has thermal diffusivity of 0.52 × 10^{-8} m^2/s, which slightly differs from the aluminium dross ceiling composites

Calorific value of starting materials and developed ceiling composites

Fig. 10 shows the calorific report of additives, binders, and developed ceiling composites. Different starting materials extracted from [80, 84, 85] are presented in comparison to the materials used for this research. The calorific value of coconut shells conducted with a combustion calorimeter is recorded as 18.60 MJ/kg. The heating value slightly varies from literature such as 18.46 MJ/kg [86]; 23.68 MJ/kg [87]; 20.92 MJ/kg [88]; 20.49 MJ/kg [89]; 30.4 MJ/kg [90]; 17.39 MJ/kg [91]. The variation in calorific values can be linked to the global positioning system (GPS) location where the additive was obtained and probable neglect in calibrating the equipment before performing the research. Oil beanstalk is the curvy exocarp that houses the oil bean seed. The heating value is shown to be 17.80 MJ/kg. [92] showed that the heating value of oil bean seed is 577.04 kcal/100 *g* ≈ 24.16 MJ/kg. Cement, aluminium dross, and developed ceiling composites were non-combustible due to virtually perfect insulation elements that are combustion retardant. The fire-retardant nature of the perfect insulator, such as cement, and aluminium dross, suppress the combustion tendency of coconut shell and oil beanstalk. These ceiling composites in the overall roofing structure serve as a fire suppressant/inhibitor, preventing its overall spread. The non-combustibility behaviour of the binders and developed ceiling composites is due to a stable balance of bond pairs with highly attractive force, as affirmed by Pi et al. [93].

Comparison of concentration of gas emission and temperature of emission @0.01 kg the three developed building ceilings samples

Sample 1: $_{0.6}Aldr_{0.3}Cmt_{0.05}G_{0.05}OBS$

From Table 2, at a pre-set temperature of 500 °C in the muffler furnace, it took 24 min to reach maximum temperature. The zero value at each temperature rise indicates null emission, which implies the safety of the material at that temperature rise. Effervescence evolved at 11 min for NO at 3 ppm, 373 °C, and at 12 min for CO_2 at 0.2 ppm, 386

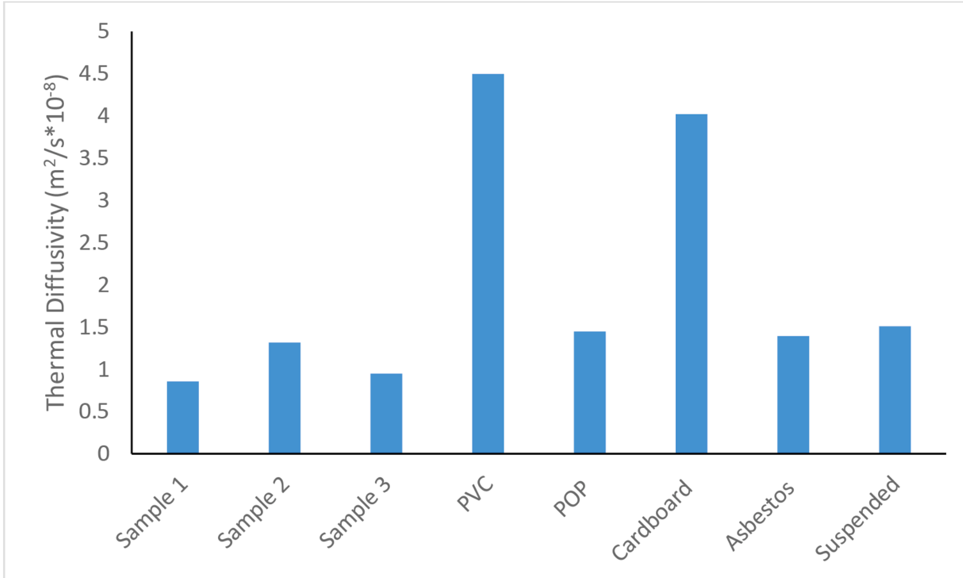

Fig. 9. Thermal diffusivity of developed and existing ceiling samples.

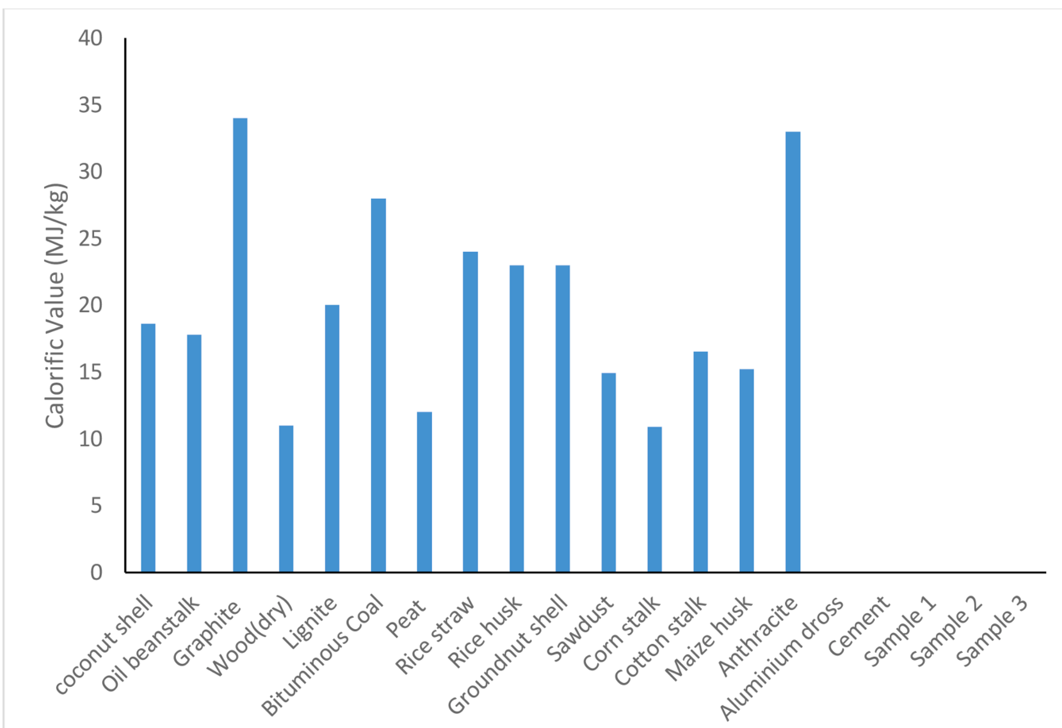

Fig. 10. Calorific value of starting materials and developed ceilings.

°C. However, SO_2 remained at 0 ppm throughout the combustion process. The values of CO_2 were significantly low, having the highest value recorded at 0.5 ppm. The highest CO value, 2265 ppm occurred at time 19 s at 456 °C, which is the stage of actual fire incidence; this is when the CO_2 is constant at 0.5 ppm and O_2 is constant at 19.8 ppm. Reduction in O_2 at 19.8 ppm at time (18–24) minutes enabled CO_2 to be maximum and consistent at this range while NO/NO_x picked up significantly. Values of NO and NO_x came to a peak at 49 ppm at 500 °C, representing threshold fire incidence. A wholly enclosed apartment during a fire outbreak will reduce the O_2 level causing the significant rise and diffusion of CO_2 and nitrogen compounds. SO_2 is not detected during the duration of burning connected to the elemental nature of this understudied ceiling composite sample1. The noxious nitrogen gases increase as the temperature and time increase, which shows that its diffusion is temperature-dependent. Fig. 9 shows the Human and material responses to temperature rise.

At room temperature at 25 °C, null values of emissions were detected. It became significant at 53 °C gas temperature and 233 °C temperature of the sample, which gives 33 ppm of CO and invalid values for other harmful gasses. The temperature at 230 °C, according to Drysdale [74], is the melting temperature of polycarbonate, which indicates that the PVC ceiling, which belongs to this category, begins to disintegrate at this point. Hence the sample can withstand elevated temperature with minimal mass loss. Also, it is safe for the material to be used as a ceiling

Table 2
Data on the concentration of gas emission during combustion, Sample 1

Time (min)	T_g (°C)	Temp. (°C)	CO (ppm)	O_2 (ppm)	CO_2 (ppm)	NO (ppm)	NO_X (ppm)	NO_2 (ppm)	SO_2 (ppm)
1	53	233	33	20.8	0	0	0	0	0
2	92	273	37	20.8	0	0	0	0	0
3	128	287	40	20.8	0	0	0	0	0
4	142	294	41	20.8	0	0	0	0	0
5	170	305	46	20.8	0	0	0	0	0
6	201	317	59	20.7	0	0	0	0	0
7	236	331	87	20.7	0	0	0	0	0
8	258	341	178	20.6	0	0	0	0	0
9	282	352	324	20.5	0	0	0	0	0
10	305	363	603	20.5	0	0	0	0	0
11	329	373	877	20.4	0	3	3	0	0
12	356	386	1211	20.3	0.2	3	3	0	0
13	374	395	1213	20.4	0.2	3	3	0	0
14	391	406	1333	20.3	0.2	4	4	0	0
15	407	416	1458	20.2	0.3	4	4	0	0
16	423	427	1798	20.0	0.4	6	6	0	0
17	437	436	1201	19.9	0.4	7	7	0	0
18	453	446	1217	19.8	0.5	10	10	0	0
19	465	456	2265	19.8	0.5	13	13	0	0
20	479	465	2212	19.8	0.5	16	16	0	0
21	494	477	2120	19.8	0.5	23	23	0	0
22	503	484	2054	19.8	0.5	30	30	0	0
23	515	494	1951	19.8	0.5	40	40	0	0
24	527	500	1828	19.8	0.5	49	49	0	0

Table 3
Data on the concentration of gas emission during combustion for ceiling, Sample 2

Time (min)	Temp. (°C)	Tg (°C)	CO (ppm)	O_2 (ppm)	CO_2 (ppm)	NO (ppm)	NO_X (ppm)	NO_2 (ppm)	SO_2 (ppm)
1	69	33	9	20.8	0.1	0	0	0	0
2	77	37	14	20.8	0.0	0	0	0	0
3	85	44	20	20.8	0.0	0	0	0	0
4	96	51	25	20.8	0.0	0	0	0	0
5	106	58	29	20.8	0.0	0	0	0	0
6	117	67	33	20.8	0.1	0	0	0	0
7	127	75	35	20.8	0.1	0	0	0	0
8	138	83	40	20.8	0.1	0	0	0	0
9	150	92	41	20.8	0.1	0	0	0	0
10	162	100	45	20.8	0.0	0	0	0	0
11	173	110	47	20.8	0.1	0	0	0	0
12	184	120	49	20.8	0.1	0	0	0	0
13	196	133	52	20.8	0.1	0	0	0	0
14	207	148	55	20.8	0.1	0	0	0	0
15	219	163	56	20.8	0.1	0	0	0	0
16	231	178	60	20.8	0.1	0	0	0	0
17	242	194	68	20.8	0.1	0	0	0	0
18	253	211	83	20.8	0.1	0	0	0	0
19	264	226	119	20.8	0.2	0	0	0	0
20	275	241	185	20.7	0.2	0	0	0	0
21	287	257	299	20.6	0.2	0	0	0	0
22	298	271	520	20.6	0.4	0	0	0	0
23	309	284	828	20.5	0.4	2	2	0	0
24	320	299	1239	20.4	0.6	2	2	0	0
25	330	319	1701	20.4	0.6	4	4	0	0
26	341	338	2405	20.2	0.8	7	7	0	0
27	352	355	2657	20.1	0.8	8	8	0	0
28	362	371	2430	20.2	0.8	7	7	0	0
29	373	384	2324	20.3	0.8	6	6	0	0
30	383	397	2251	20.3	0.7	6	6	0	0
31	393	410	2179	20.3	0.7	6	6	0	0
32	404	423	2157	20.3	0.7	5	5	0	0
33	414	436	2209	20.2	0.9	6	6	0	0
34	424	449	2255	20.1	0.9	7	7	0	0
35	433	461	2296	20.0	1.0	9	9	0	0
36	444	475	2339	20.0	1.0	12	12	0	0
37	454	489	2393	19.9	1.2	16	16	0	0
38	463	501	2352	20.0	1.1	20	20	0	0
39	473	513	2249	20.0	1.1	27	27	0	0
40	483	525	2086	20.0	1.1	34	34	0	0
41	492	535	1903	20.0	1.1	43	43	0	0
42	500	547	1701	20.0	1.0	53	53	0	0

at room temperature, which is adjudged to be ≤ 27 °C.

At 100 °C, which is the boiling point of water, sample 3 showed a negligible value of SO_2 and sample 14 at above 250 °C. In contrast, no sample detected SO_2 at minimum ppm, which indicates a safe air quality when these samples are used at both room temperatures and elevated temperatures.

At the instance of fire at an elevated temperature below 300 °C, CO gave a minimum of 50 ppm; hence emissions, if solely from the building ceiling, are not capable of causing a hazard. Room temperature will give null emissions for most of the developed ceiling composites.

Sample 2: $_{0.6}Aldr_{0.32}Cmt_{0.05}G_{0.03}OBS$

Developed 0.6Aldr0.32Cmt0.05G0.03OBS took 42 min to attain the pre-set temperature of 500 °C, as shown in Table 3. The inherent thermal inertia is responsible for this long-time extension compared to sample 1. Therefore, there is reluctance in heat dissipation. The variation in material percentage mixture is also a causative feature. The peak value of CO at 2657 ppm came to the fore at 27 min. At this point, the concentration mass transfer of CO is maximum and undulates before and after this value due to collision with other molecules and ripple temperature. The nitrogen compound was at zero levels for up to 22 min. The reason will be due to the combustion source and the probable presence of nitrogen and oxygen in the elemental accumulation of this ceiling sample. NO/NO_x increases due to a corresponding temperature rise. It came to a maximum of 53 ppm at a maximum temperature of 500 °C. It is temperature-dependent. Maximum O_2, 20.8 ppm establishes minimum CO_2, 0.1 ppm. The presence of CO reduces the survival of occupants due to the low oxygen level. Low O_2 permits other noxious gases such as NO/NO_x, CO_2, which contribute to discomfort at the fire outbreak. Emission has significantly drastically reduced, and air quality has improved over the last four decades due to close monitoring by international bodies such as World Health Organization (WHO) and European Union (EU), as confirmed by Winkler et al. [94].

Sample 3: $_{0.6}Aldr_{0.34}Cmt_{0.05}G_{0.01}OBS$

From Table 4, 500 °C is reached at 37 min. 300 °C is the temperature to start up the momentum of CO gas at 54 ppm. The reluctance to this point is connected to the bond force of the atomic structure of the ceiling composite. However, SO_2 is detected at a maximum of 3 ppm and discontinued when CO started. SO_2 presence is linked to visible flame rich in O_2 and in the absence of CO. NO/NO_x is maximum at maximum temperature, at minimum O_2, and maximum CO_2.

Table 5
Elemental composition of Sample 1

Element	Weight%	Atomic%
C K	19.26	27.70
O K	52.63	56.83
Na K	0.83	0.62
Mg K	0.45	0.32
Al K	12.70	8.13
Si K	1.27	0.78
S K	0.33	0.18
Cl K	1.49	0.73
K	0.36	0.16
Ca K	10.33	4.45
Fe K	0.37	0.11
Totals	100.00	

Table 4
Data on the concentration of gas emission during combustion for ceiling, Sample 3

Time (min)	Temp. (°C)	Tg (°C)	CO (ppm)	O_2 (ppm)	CO_2 (ppm)	NO (ppm)	NO_X (ppm)	NO_2 (ppm)	SO_2 (ppm)
1	103	47	0	20.7	0.3	0	0	0	3
2	130	55	0	20.7	0.3	0	0	0	3
3	143	67	0	20.6	0.2	0	0	0	3
4	155	79	0	20.7	0.2	0	0	0	3
5	167	91	0	20.7	0.2	0	0	0	3
6	179	104	0	20.6	0.3	0	0	0	3
7	190	117	0	20.7	0.2	0	0	0	2
8	201	129	0	20.7	0.2	0	0	0	3
9	212	144	0	20.7	0.2	0	0	0	3
10	224	160	0	20.7	0.2	0	0	0	2
11	235	176	0	20.7	0.2	0	0	0	2
12	246	192	0	20.7	0.3	0	0	0	2
13	258	209	0	20.7	0.3	0	0	0	2
14	269	224	0	20.7	0.3	0	0	0	2
15	279	240	0	20.6	0.3	0	0	0	2
16	290	256	0	20.6	0.3	0	0	0	2
17	300	270	54	20.5	0.3	2	2	0	0
18	312	283	191	20.5	0.5	2	2	0	0
19	322	297	348	20.4	0.5	3	3	0	0
20	333	313	558	20.4	0.6	4	4	0	0
21	344	329	809	20.3	0.6	5	5	0	0
22	354	345	1056	20.3	0.8	6	6	0	0
23	364	360	1196	20.2	0.8	6	6	0	0
24	374	374	1320	20.2	0.9	6	6	0	0
25	384	386	1305	20.1	0.9	5	5	0	0
26	395	399	1250	20.1	0.8	5	5	0	0
27	405	412	1236	20.1	1.0	5	5	0	0
28	415	424	1308	20.0	1.0	5	5	0	0
29	425	437	1423	19.9	1.2	6	6	0	0
30	435	450	1525	19.8	1.3	8	8	0	0
31	445	462	1564	19.7	1.4	10	10	0	0
32	454	476	1616	19.7	1.4	13	13	0	0
33	464	489	1699	19.7	1.5	16	16	0	0
34	473	501	1740	19.7	1.5	20	20	0	0
35	483	511	1712	19.7	1.5	27	27	0	0
36	492	521	1608	19.7	1.4	34	34	0	0
37	500	533	1444	19.8	1.4	44	44	0	0

SEM/EDS analysis of aluminium dross composite, sample 1–3

Tables 5-7 present the elemental composition of sample 1–3 K-shell to inspect the presence of both noxious elements and binding elements. The percentage weight reveals the extent of either flame affinity or flame retardance at the instance of combustion. The microstructural characteristics are represented by the micrograph and images of the samples.

SEM/EDS analysis of aluminium dross composite sample 1

The elemental composition of sample 1 is shown in Table 5 and the SEM/EDS in Fig. 11. The elements present are iron, calcium, potassium, chlorine, sulphur, silicone, aluminium, magnesium, sodium, oxygen, and carbon. The "K" term beside the elements indicates the K shell. Aluminium, oxygen, and calcium are evidence of the compound captured by XRD and revealed silicate and aluminium dross. The element carbon shows the presence of carbon graphite. The interaction of carbon at insufficient oxygen may release carbon (II) oxide. Trace elements such as sulphur are expected during combustion even at the minimal percentage and due to the coating of the material before the EDS analysis. Its emission is a function of the fire source and is responsible for the degree of scorches experienced by fire victims. However, it is not inherent in the sample as revealed by the XRD composition, which shows that a perfect flame retardant ceiling composite requires other frame structures to contribute to the overall safety of occupants to inhibit fire spread and noxious emissions.

SEM/EDS analysis of aluminium dross Sample 2

Fig. 12 shows the dispersed aluminium particles across the composite in the form of flakes. This dispersal will strengthen the bond amongst the material and improve the mechanical property of the composite. Voids are insignificant here due to good surface finishing. The high value of calcium from the EDS will account for an excellent bonding amongst base material, binder, and reinforcement. The dark grey colour indicates that the entire environment is hydrated, showing water mix cum cement and aluminium dross. The invisible presence of sulphur in Table 6 is due to the reinforcement material, which is likely to

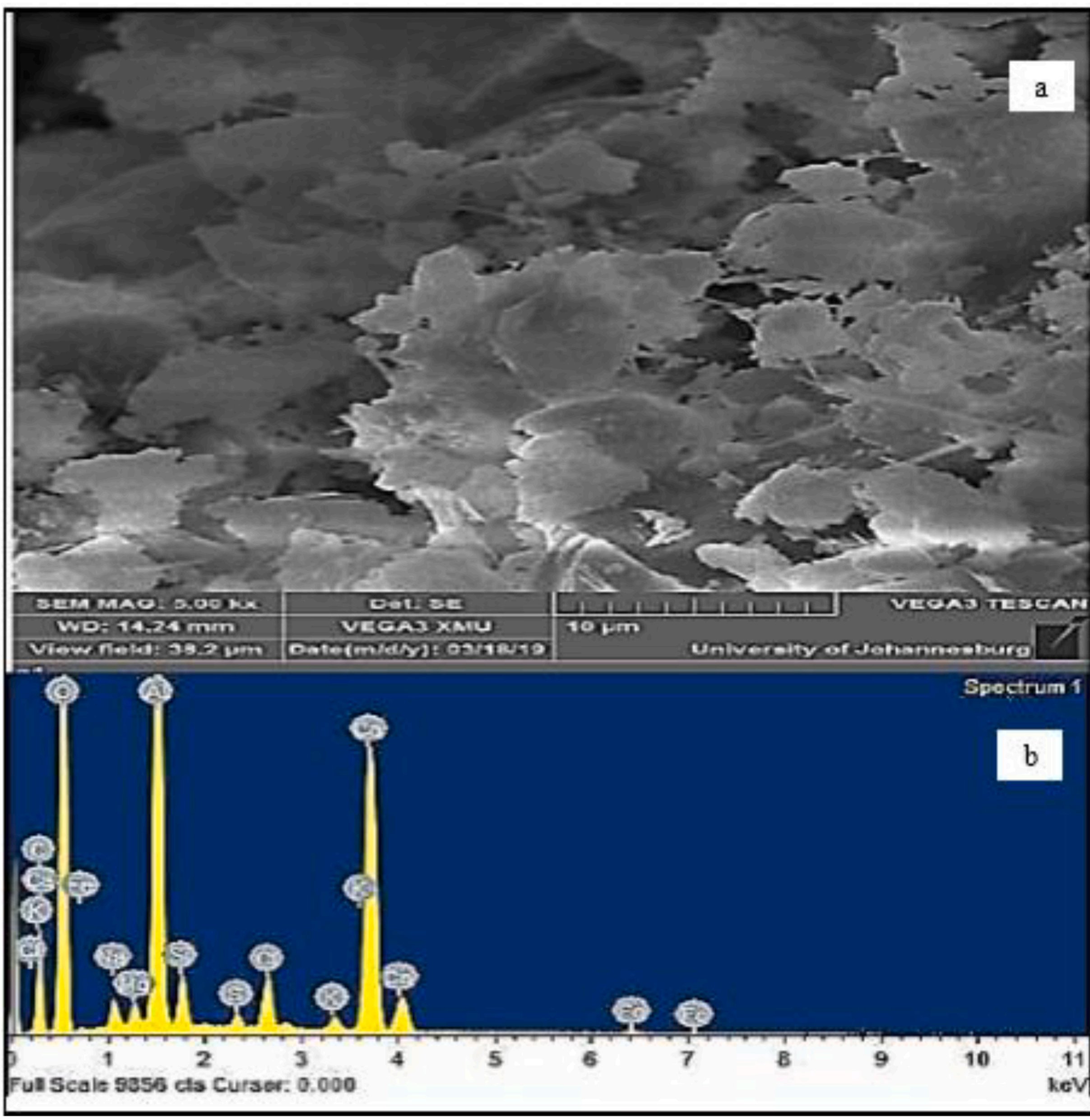

Fig. 11. (a)Micrograph of Sample 1 (b) Image of Sample 1.

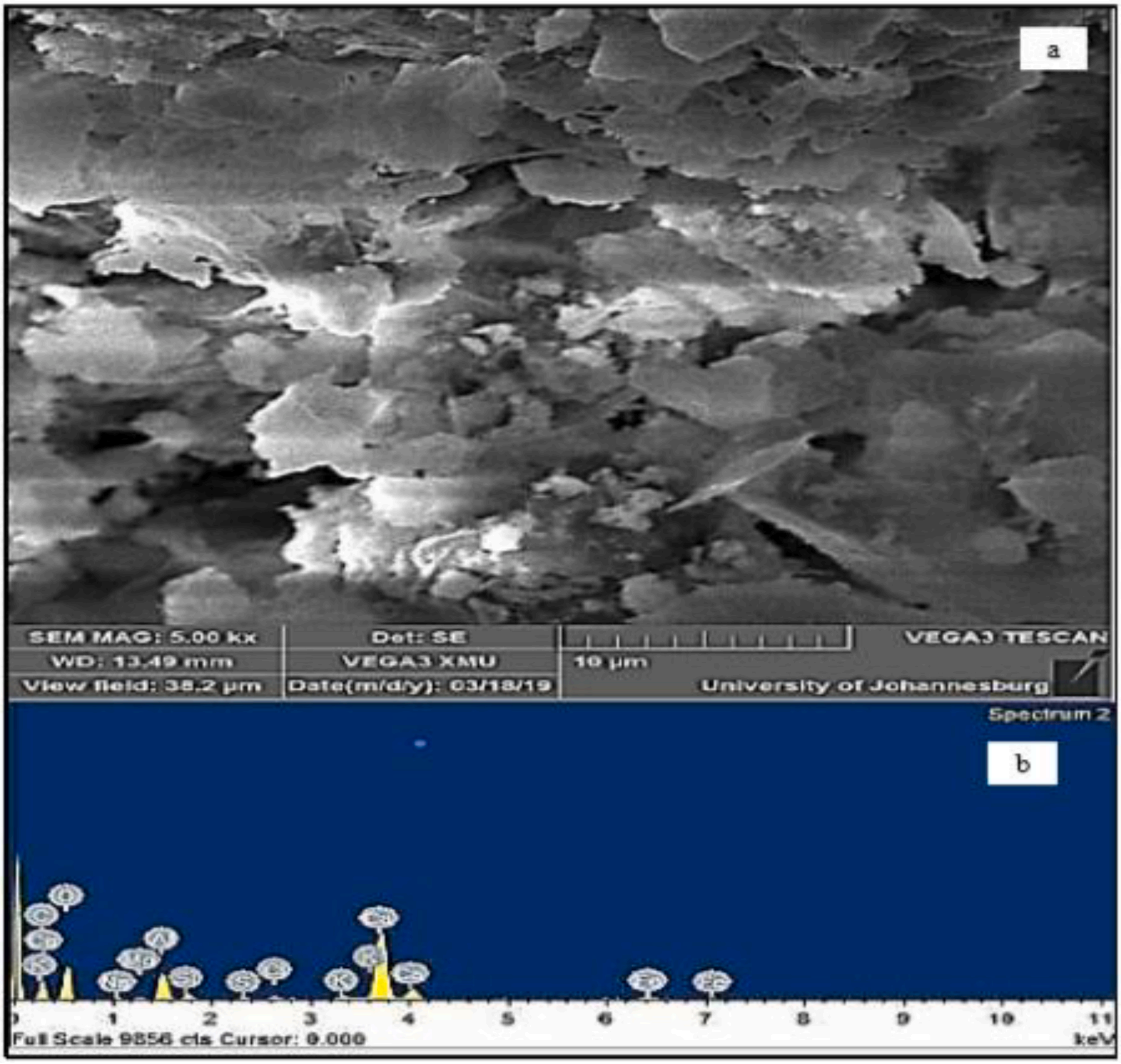

Fig. 12. (a)Micrograph of Sample 2 (b) Image of Sample 2.

Table 6
Elemental Analysis of Sample 2

Element	Weight%	Atomic%
C K	24.83	36.53
O K	43.75	48.33
Na K	0.26	0.20
Mg K	0.36	0.27
Al K	4.83	3.16
Si K	1.20	0.75
S K	0.42	0.23
Cl K	0.49	0.25
K	0.54	0.24
Ca K	21.37	9.42
Fe K	1.94	0.62
Totals	100.00	

Table 7
Elemental analysis of Sample 3

Element	Weight%	Atomic%
C K	13.76	21.18
O K	51.87	59.94
Na K	0.60	0.48
Mg K	0.57	0.43
Al K	9.87	6.77
Si K	2.12	1.40
S K	0.36	0.21
Cl K	0.51	0.27
K	0.37	0.18
Ca K	19.49	8.99
Fe K	0.47	0.15
Totals	100.00	

effervesce during combustion, reducing the weight at the instance of temperature rise.

SEM/EDS analysis of aluminium dross composite sample 3

A reduction in the percentage of sulphur is observed in sample 3 compared to sample 2 elemental composition. In Table 7, the percentage mixture of the macro material influences the elemental composition of the microstructure. Brittleness is reduced due to the rich presence of calcium at a high percentage, which dominates other elements after oxygen. Its presence in cement and aluminium dross mixture accounts

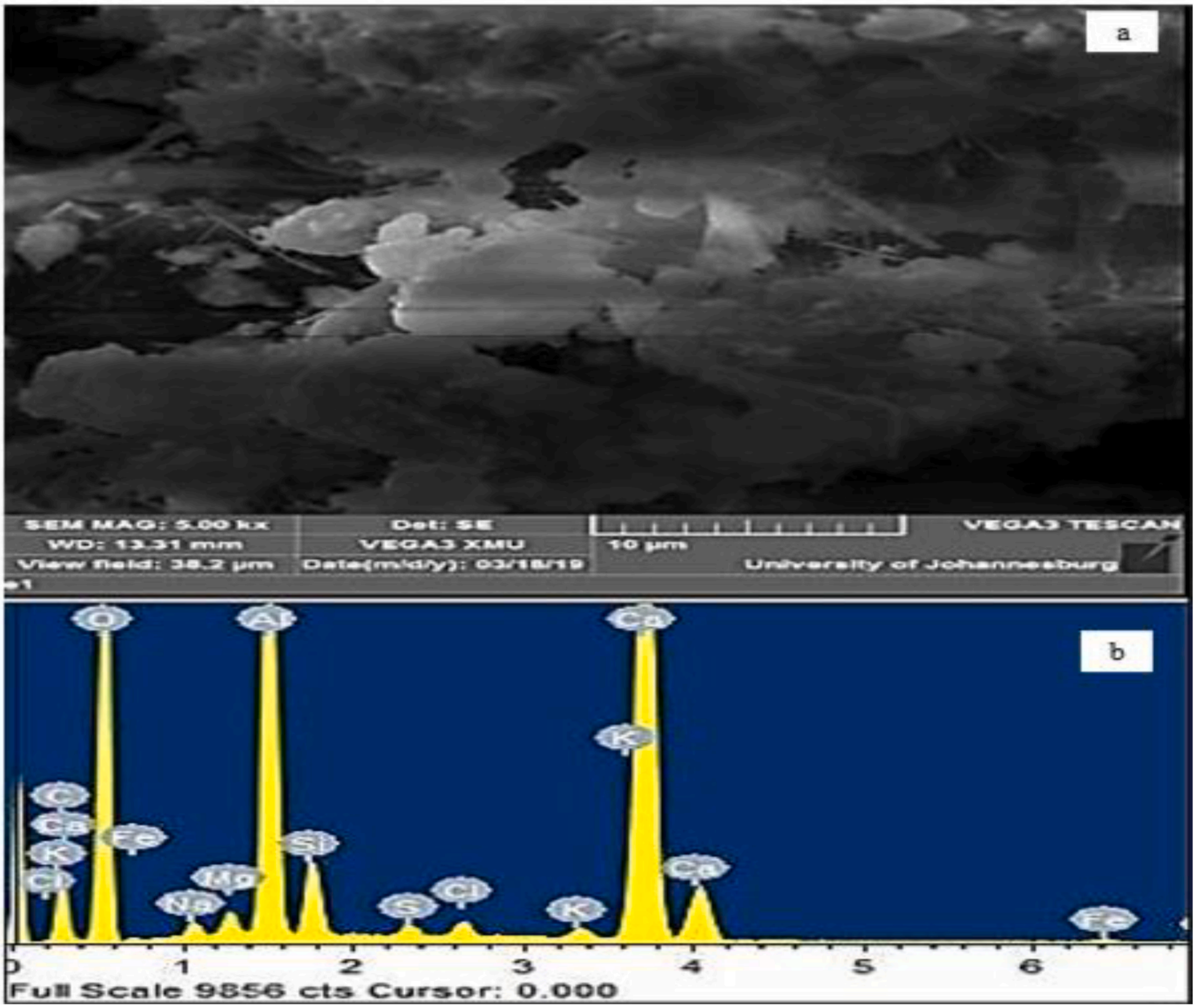

Fig. 13. (a) Micrograph of Sample 3 (b) Image of Sample 3.

for a high percentage of calcium. Pores and voids are observed in SEM in Fig. 13. Cracks can propagate at this point, and the material begins to yield when subjected to a crushing test. Aluminium is sparsely dispersed, as shown in tiny, shining white spots. The composite is amorphous and dulled grey, which indicates the mixture of the material with water.

Conclusion

This research establishes the effectiveness of the developed ceiling composite materials in addressing building challenges due to thermal discomfort and alarming fire outbreaks during service life. These developed building ceiling composites help contend the menace of observed susceptibility to fire, emission of volatile organic compounds, and high heat fluxes. The developed building ceiling composites are essential in resolving the requirement of low heat conduction, negligible calorific values, eco-friendly nature, low production cost, and employment creation.

The developed novel building ceiling composite is a significant breakthrough in the building sector. The composite has appreciable high thermal insulation properties and integrity in morphology, combustion, and emission perspectives. The characterization result of the developed building ceiling composite is sufficiently able to proffer a solution to practical challenges of thermal, fire outbreak, and emission hazards in the existing building ceiling in markets.

The base materials and binders exhibit reluctance to combust, which is a desirable feature in building applications. The additives employed improved the bonding effect with the base material and reduced brittleness significantly. The failure to combust by the base and binder materials attest to their flame-retardant nature, which is reflected in the building ceiling composite performance. The presence of flame reluctant compounds during morphology characterization shows retardancy of the developed composite to fire.

The aim of this study was attained as the starting materials are eco-friendly and quasi-natural in selection with the absence of polymer products that were condemned for their flame sustenance.

From this study, it can be concluded that:

- Cement becomes a primary binder in building composite ceiling development. The compounds present in cement were prominent when subjected to morphology examination by advanced electron microscopy.
- Carbon graphite is a desired flame retardant material and a thermal insulation additive supporting oil beanstalk.
- There are low values in thermal conductivity of the developed building ceiling samples and lowest amongst the ceiling materials. Sample 2 has the lowest value, much $<$ 0.0802 W/mK, which is a desirable property in ceiling application.

- Low thermal diffusivity is required to suppress flame propagation. This is exhibited by sample 1, with a value of 0.85×10^{-8} m^2/s as the lowest amongst developed ceiling samples.
- Cement and aluminium dross are perfect insulators as they do not combust in the combustion testing process. All samples were non-combustible due to the dominance of the perfect insulators suppressing the additives.
- All developed building ceiling composite samples are within acceptable ranges of low SO_2 level and CO_2.
- All samples are flame-retardant are established by the combustion calorimeter. Their thermal properties, material chemistry, and material mixtures are responsible for this performance.
- The possibility of water penetration exists amongst all samples as the composition supports porosity. This is common amongst asbestos ceiling and plant-based ceiling tiles such as particleboard, cardboard, plywood as they will dissolve when exposed to water for an extended period. Polyvinylchloride ceiling composites proved contrary due to the sealed surface by polymers and hardeners.
- All the building ceiling composite samples are free of volatile organic compounds, lead, and little accidental low sulphur, as revealed in the elemental and morphological analyses.
- All samples are suitable ceiling products in terms of morphology integrity, thermal, and emission deduction.
- CO_2 does not pose a threat to sample 1 due to low emission values. Sample 1 is free of SO_2 noxious emission as the values are zero and safe. The sample is safe for use as emissions were negligible at room and slightly above room temperature. A longer time for attaining 500 °C is observed at sample 2 compared to sample 1, which indicates more flame retardancy in the latter than the former. At high ambient temperature, usually at 34 °C [95], mainly from the surrounding tropical region, CO emissions will be detected at minimal ppm. This sample reveals values for CO at 9 ppm at 33 °C; NO/NOx and SO_2 are at 0 ppm. A reduction in oxygen level causes a rise in the CO level.
- SO_2 is safest in the overall emission as it is not detected for the first two samples and is negligible for the third sample. Sample 3 is the safest amongst the ceiling composites as emission started at a temperature well above room temperature, and CO was not detected except at a high temperature of 256 °C.
- Sample 3, $_{0.6}Aldr_{0.34}Cmt_{0.05}G_{0.01}OBS$**;** Sample 2, $_{0.6}Aldr_{0.32}Cmt_{0.05}$-$G_{0.03}OBS$ and sample 1, 0.6Aldr0.3Cmt0.05G0.05OBS are in the order in terms of safe emission characteristics while sample 2 ranks best in terms of flame retardancy.

Based on the outcome of this study, it is recommended that further research work should be carried out in the following areas:

- Replacing cement binder with an eco-friendly epoxy binder and characterize the composite produced.
- Varying the composition of aluminium dross and additive at different particle sizes and test the properties.
- Study of the heat flux gained by the developed building ceiling composite using a building model.
- Investigation the possible limitation of the water absorption as it relates to the binder used for the ceiling application.

Conflict of Interest

The research article titled "Thermal-Emission Assessment of Building Ceilings from Agro-Industrial Wastes" is being submitted for publication in Fuel Communications. The authors, Joseph O. Dirisu, Sunday O. Oyedepo, Ojo Sunday I. Fayomi, Olufunmilayo O. Joseph, Esther T. Akinlabi, Philip O. Babalola, Nduka E. Udoye, Oluseyi O. Ajayi, Abraham K. Aworinde, Solomon O. Banjo, Olusegun K.M certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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