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SOUND ABSORPTION PERFORMANCE OF FIBRE-REINFORCED CEMENT-BASED ROOFING COMPOSITES: A COMPARATIVE STUDY WITH CONVENTIONAL ROOFING MATERIALS

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Abstract
This paper examined he sound absorption characteristic of fibre-based composites using fibre reinforced cement, agricultural and recycled wastes such as cornhusk fibre, pineapple leaf fibre, plastic fibre and sawdust and compares them with the conventional roofing materials such as metal sheets, aluminium sheets and asbestos roofing. A Sound Level Meter (SLM) was used to carry out experimental evaluation with a small radio acting as a noise source with a distance of approximately, 3 1/2 (76.2 mm). Background noise was between 39.2- and 52.8-dB A and the data were taken with 10-second intervals. The thickness of materials affected sound absorption and this made it possible to compare them. Findings indicated that composite tiles are more effective in acoustic insulation as compared to other traditional materials such as iron and aluminium sheets because they have differences in terms of thickness, type of material and volume. Fibre-reinforced composite (FRC) was shown to have better acoustic performance, which was due to porosity, fibre distribution and internal friction mechanisms. The maximum reading was 85.3 dB A at the origin, and the minimum reading was 64.2 dB A in the case of sawdust- fibre-reinforced tiles (SDFRT). The sheet metal used recorded 78.1 dB A. Fibre reinforced composites particularly those based on sawdust exhibited consistent broadband absorption whereas conventional materials reflected majority of sound energy. These composites are environmentally friendly, economical and can be used in acoustical insulation.

Keyword: Sound, Absorption, Fibre-based, Insulation, roofing.

INTRODUCTION

Noise pollution has emerged as a severe environmental issue that has impacted on human beings and comfort (Lukáš & Robert 2016). The construction industry is critical in the reduction of noise by choice of materials. Noise traveling through the roof system is frequently not receiving much attention (Mahn & Pearse, 2010). Traditional roofing materials, including metal and aluminium sheets are very reflective and offer low insulation of sound. Although corrugated iron sheets are inclined to rust, can be quite noisy during the rain (Olorunnisola & Adeniji, 2019). Recent studies are interested in the natural fibre-reinforced composite as the sustainable acoustic material because of the porous microstructure and the ability to dissipate energy (Sari et al., 2017). Corrugated iron and Cement-bonded composites (CBCs) are the key roofing materials in Nigeria, which has an engineered construction material, some agro-industrial wastes can be employed as a partial substitute of cement, and also others may be employed as fibre reinforcement. The fibrous materials that can be used in cement-bonded composite roofing and making ceiling tiles in Nigeria include bamboo (Bambusa vulgaris), rattan cane, sugar cane bagasse (Saccharum officinarum), raffia palm (Raphia africana), luffa (luffa cylindrica), Cissus populnea, and coconut husk (Cocos nucifera Linn) among others (Olorunnisola & Adeniji, 2019). Wastes such as corn husk, pineapple leaves, sawdust etc. are made in

large quantities in agriculture. It is said that approximately 998 million tonnes of agricultural waste is generated annually (Obi et al., 2016 and Singh, 2022). They provide greener options, promising acoustic qualities, should they be tapped and developed into fibre and utilised as part of cementitious underpinning on the one hand. The natural fibres are increasingly receiving consideration in the construction industry over the synthetic fibres due to the fact that they are renewable, abundant in terms of availability at a low cost, stiffness and the positive indication in other applications. Coconut fibres were reported to possess good qualities that can be applied in construction industry as drainage, filtration, and reinforcement. Most buildings are now using synthetic fibre like the glass fibre and mineral fibre as sound proof materials; the increasing health hazard of these synthetic fibres has prompted the need to seek a material having minimal or no hazard to the health of the human beings. Research of acoustic absorption properties of fibrous materials came to the conclusion that the resistivity to airflow is a crucial aspect in the context of acoustic behaviour of fibrous assemblies (Gideon et al., 2018). The natural fibre-based acoustic panels are also less harmful to the health of human beings and more environmentally friendly compared to the synthetic fibre-based acoustic panels (Mamtaz & Fouladi, 2016).

OBJECTIVE

The study aims at the exploration of the Sound Absorption Properties of Fibre-Reinforced Cement-Based Composites of some natural and plastic-based fibres (cornhusks, pineapple, sawdust and plastic-pellets) on the basis of the traditional roofing materials.

MATERIALS AND METHODS

Materials

It was a local study, as the materials used were obtained in Ibadan North Local Government Area, Nigeria. The lignocellulosic material used was cornhusks (CH), pineapple leaves (PL), and sawdust, whereas the plastic waste material was obtained as discarded compact discs (CDs). The open-air drying was done on all fibrous agricultural materials, except plastic, to eliminate the available moisture content. The sawdust was placed in water before it was dried, over a period of three (3) days, to help in a partial reduction of lignin and increase the properties of interfacial bonding. The dry cornhusks and pineapple leaves were then dried and milled and sifted using a 0.850 mm mesh to provide the even distribution of the particles. Determination of moisture content of the processed fibres was done in the Multidisciplinary Central Research Laboratory (MCRL), University of Ibadan using standard procedures. The plastic waste (CDs) was mechanically reduced to pellets, and sieved to obtain uniform gradation, see *figure 1*.

Fine aggregate (stone dust), which was the result of mechanical disintegration of igneous rock, was collected at a quarry site in Ibadan and then sieved before being used. Grade 42.5 Ordinary Portland Cement (OPC), which is marketed in 50 kg bags, was purchased in a cement depot in Bodija in Ibadan. All mixing operations were performed using potable water of a rather neutral pH (c.7).



Corn-husk fibre



Pineapple-Fibre



Saw-dust



Plastic-pellets

Figure 1: Showing the various fibres used in this study

Mix Proportions and Experimental Design

The composite mix design was put at a mass composition of cement: sand: water 1:3:0.6 to ensure that this ratio stayed constant during the whole experimental program. The fibre content was adjusted in the range of 1 percent and 5 percent of cement weight to determine its impact on the sound absorption property (acoustics) of composite tiles made.

The study design was based on an analysis of variance (ANOVA) design comprising of three (3) replicates per condition using a factorial design, where three (3) treatment conditions are used and five (5) replications were done in each condition (Omoniyi & Arosoye, 2020).

Composite Preparation

Cement and fine aggregate were initially mixed in fine amounts, and mixed until a high degree of homogeneity was obtained. Gradually water was added and mixing was then continued so as to form a homogenous cementitious mix of around four minutes. Subsequently, the fibres were added and blended in a gentle manner to allow homogenous distribution without damaging the fibres as much as possible (Gideon et al., 2018). The mix was poured into profile moulds supported on a vibrating table, contact with which was inhibited by the support of interface sheets. The process of mechanical vibration was done over 20 seconds to remove entrapped air and reduce the level of void content to improve compaction and structural integrity, see *figure 2*. The compacted slurry was then levelled with the help of a hand trowel on the surface (Omoniyi & Arosoye, 2020).



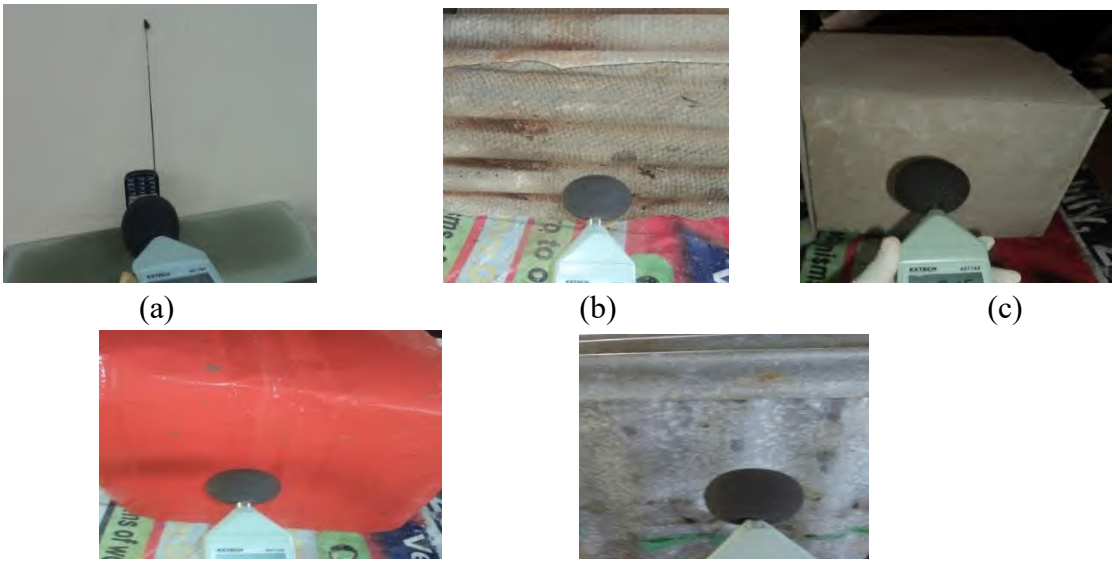
Figure 2: Composites Preparation

Curing Process

The specimens in the form of moulds were covered with polyethylene sheets and left to dry in controlled ambient conditions before the 24 hours elapsed to enable them to settle initially. The composite tiles were then demoulded and put in water where they were left to cure in 28 days in accordance with established procedures (Omoniyi & Akinyemi, 2012 and Omoniyi & Arosoye, 2020).

The Sound Absorption Property Test

The sound absorption properties of composite tiles were compared with the existing materials such as iron and aluminium sheet metals and the results were observed. The Sound level meter (*SLM*) was used to evaluate this property. The various materials used for this study were arranged to form a box inside which a small radio was put. The volume of the radio was adjusted to maximum, mid and low level respectively. The distance allowed between the tested materials and the *SLM* was about 31/2 (76.2mm) as shown in *figure 3*. The background noise recorded ranges from 39.2 to 52.8 dB A. The values of noise measured by the *SLM* were recorded at 10 seconds interval accordingly. The sound absorption properties of these materials were affected by their individual thickness as observed and comparison was made. The method adopted here is the Florida roof tiles acoustic property.



(a) (b) (c)

(d) (e)

Figure 3: Sound Absorption Test Radio (Control), (b) Asbestos, (c) Fibre-based composites, (d) Aluminum Sheet Metal and (e) Iron Sheet Metal

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RESULTS AND DISCUSSION

Results of Sound Absorption Properties of Some Roof Materials

The results showed that composites tiles were suitable acoustic insulation in comparison to the conventional materials such as iron sheet metal and aluminum sheet metals. This was possible due to the variation in their thicknesses, types and volume of materials used for their production. *Figure 4* showed that sheets produced from metal had the highest sound conductivity, followed by aluminum sheets while asbestos and composites tiles have the lowest sound conductivity respectively. The composite acoustic absorption performance was possible as a result of how well the fibres inside the composites was arranged. If the fibres are laid out in a regular, orderly pattern, the material barely absorbs any sound; its absorption coefficient is almost zero. But when the fibres are arranged randomly, the material becomes much better at absorbing sound, resulting in amuch higher absorption coefficient (Sari et al., 2017).

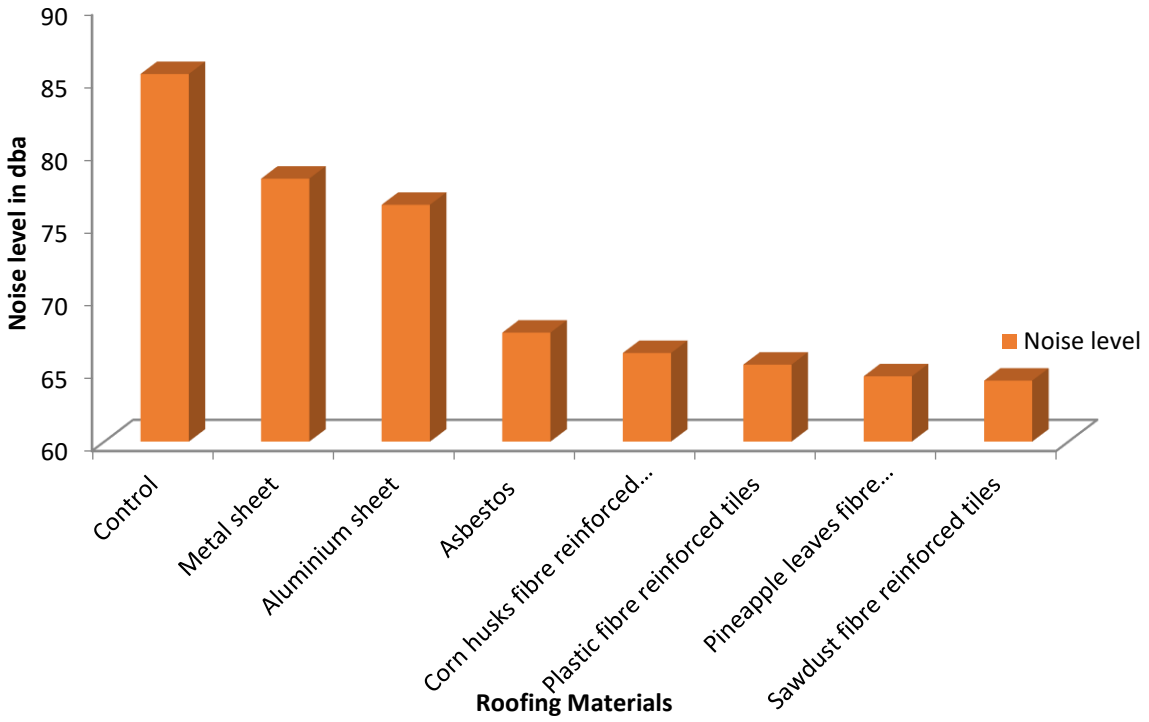


Figure 4: The Sound Absorption Properties of Roof Materials at Definite Volume.

Influence of Fibre-Content

Increased fibre composition enhanced the absorption of sound because of improved pore connectivity and airflow resistivity.

Comparison with standard Materials.

Traditional/standard roofing materials exhibited a low level of absorption due to their dense and non-porous structure, which resulted in acoustical reflectance and not attenuation.

CONCLUSION

Roofing composites made with fibre-reinforced-cement-based are found to be much better at absorbing sound as opposed to traditional roofing materials. The cornhusk and sawdust fibre composites are the

most promising and can be used in the acoustical insulation of the residential and industrial buildings. The utilization of the waste material in farming helps in ensuring sustainability and developing better performance in buildings.

RECOMMENDATIONS

1. Low-cost housing should take advantage of the adoption of noise control roofing materials.
2. Fibre composite studies: hybrid fibre composites should be further investigated.
3. Treatment and orientation of fibres within the matrix should be optimized.

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