

Development of Guinea Corn Husk-Cow Hair Hybrid Fibre Reinforced Cement Composite

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Abstract. This research work presents the application of guinea corn husk (GCH) and cow hair (CH) fibres as reinforcement in cement composite. The influence of the hybrid fibre volume on the flexural performance of the composite has been studied experimentally. The mechanical (flexural strength) and physical (density, water absorptivity, moisture content) characteristics of the GCH-CH hybrid fibre reinforced composite were evaluated. The highest flexural strength was 22.37MPa, exhibited by the composite reinforced with 15% (12.5% GCH & 2.5% CH) hybrid fibre. The density of the GCH-CH hybrid composite ranged from 1019 to 1963 kg/m³. The water absorptivity varied from 22.59 to 38.16% and the moisture content ranged from 3.32 to 11.28%. These limits are within the range in standard therefore, the performance of the composite satisfies the requirements of BS EN 12467 standard for ceiling board.

Key words: Guinea corn husk, cow hair, flexural strength, density, water absorptivity.

1. Introduction

Recently, researchers across the world have been working tirelessly to develop innovative and affordable engineering materials from renewable resources with good physical and mechanical properties (Ohijeagbon *et al.*, 2021). Initially, asbestos fibre was widely used in civil engineering construction for making building products like ceiling tiles, corrugated roofing sheets because it possesses good and desirable mechanical and physical properties (Khorami 2011). However, due to the carcinogenic health hazards associated with asbestos fibre, a great demand exists for suitable and better alternative or substitute (Lumingkewas 2015).

Natural organic fibres include those produced by plants and animals. They can be categorized according to their origin. All vegetable fibres are generally based on arrangements of cellulose and hemicellulose, often with lignin (Dungani *et al.*, 2016). However, the main structural component of plant fibre is cellulose (Lumingkewas 2015). Examples include guinea corn husk (GCH), cotton, linen, hemp jute, flax, ramie, and sisal etc. Previous findings have shown that high strengths and stiffness are obtainable from natural organic fibres and they are characterized by good performance (Dungani *et al.*, 2016). Also, fibres from animal origin are thread-like in nature for instance, hairs and threads (that is cocoon and spider thread). The hair thread is formed by keratin which is made up of protein containing high concentration of sulfur credited to the presence of amino acid cysteine (Valesco *et al.*, 2009). Principally, the main component of animal fibre is a protein called keratin (Alli *et al.*, 2021). Examples are sinews, spider silk, catgut and human or cow hair (CH). The hair fibre has good strength and high modulus of elasticity (Poole *et al.*, 2009). The aforementioned characteristics make plant and animal fibres suitable for use in composites with good structural requirements (Duggal, 2008; Pickering *et al.*, 2016).

Also, man-made fibres such as glass, carbon, Kevlar, polyethylene, polypropylene and steel have proven to be good replacements or alternatives for asbestos in the construction industry in terms of their mechanical and physical characteristics (Oladele *et al.*, 2009). However, due to the high cost of the aforementioned fibres in the developing countries, researchers are shifting their attentions to more promising, affordable and environmentally friendly alternatives, especially cellulosic and keratin-based natural organic fibres which are available in large quantities in many developing nations of the world (Sanjay *et al.*, 2016).

The incorporation of two or more fibres to reinforce cement composite is attracting more attention these days. Most importantly, fibres from different origin or orientation with distinct characteristics or properties can be utilized to complement the other fibre. According to Khorami (2011), the mechanical strengths obtained with cellulosic fibre reinforced composite are not sufficiently high that it could be adopted for various engineering applications and such need to be made stronger by incorporating another reinforcing fibre.

This research work was aimed at investigating the influence of guinea corn husk (GCH) and cow hair (CH) hybrid fibre as reinforcement in the cement composite.

Many research works have been carried-out on natural organic fibers as reinforcement in the development of construction materials but limited studies have been made in utilizing the two wastes used in this work as a hybrid fibre in one composite. Guinea corn husk (GCH) and cow hair (CH) are wastes from agricultural practices. Guinea corn Husk (GCH) is an agro-waste obtained from milling of guinea corn (*Sorghum vulgare*). Guinea corn is an essential food crop grown and largely produced in the savannah belt of Nigeria. Kaduna, Niger and Benue Rivers are some of the places where this crop is largely cultivated in Nigeria (Ndububa and Nurudeen, 2015). It has been reported that about 1.5 million tones of guinea corn is produced within the country on yearly basis which has potential to increase as the economy is diversified to agriculture (Akinloye *et al.*, 2014).

Agro-wastes have been studied and reported to have a greater potential for various application in composites (Sanjay *et al.*, 2016). This study presents the physical and mechanical properties of the GCH-CH hybrid fibre reinforced cement composite.

2. Materials and methods

2.1. Materials and Equipment

The fibre materials used for this research work were obtained from farm and abattoir in Ede, Nigeria. The fibre materials used for this research work were guinea corn husk and cow hair. Other materials were sodium hydroxide (NaOH) for treatment of GCH, wooden rectangular moulds, water, cellophane sheets and cement. They were all obtained in Ede town, Nigeria.

The equipment used in this research includes; Laboratory oven, digital weighing balance, measuring cylinder, beakers, hydraulic press, head pan, vibrating table, hand trowel and digital display WINCOM 190811 universal tensile machine with testing power 0-300kN having $\pm 1\%$ precision supplied by WINCOM company limited, China.

2.2. Methods

2.2.1. Treatment of fibre

The fibre utilized in this research work was treated before use. The cellulosic fibre (guinea corn husk) shown in figure 1 was treated with 0.2M NaOH solution. The GCH fibre was soaked in the NaOH solution for 24 hours to remove the lignin content. The fibre was thoroughly washed with tap water to remove any residual chemical on the fibre surface. Meanwhile the keratin fibre (cow hair) shown in figure 2 was washed with water to remove deleterious substances like dung, blood and impurities (Oladele *et al.*, 2015).



Fig. 1. Guinea corn husk



Fig. 2. Cow hair

2.2.2. Preparation of sample

The keratin fibre was cut into size range of 30-40mm in order to ensure even distribution of fibre in the composite and avoid balling problem. The GCH-CH fibres and cement were measured using the weighing balance based on the design mix. The mix proportions of the composite are shown in Table 1. The materials were manually and thoroughly mixed inside the pan with a water/cement ratio of 0.46 (Rahmanzadeh *et al.*, 2018). This was done until homogeneity was obtained. Afterwards, the mixture was poured into the wooden rectangular mould having a dimension of 300mm by 150mm with a thickness of 6mm. The sample was vibrated mechanically for few seconds to remove some void. Then the sample was compressed for 4 hours. Each sample was labelled and cured by wetting for twenty-four hours in the mould before it was removed. All the samples were cured in the laboratory atmosphere for twenty-eight days before carrying the physical and mechanical test on them. The experiment was carried out at room temperature of $22\pm 2^{\circ}\text{C}$.

Table 1. Mix proportion for the composite in volume

Sample	Cement (%)	Cow Hair (%)	Guinea Corn Husk (%)
VA	100	0	0
VB	90	5	5
VC	85	2.5	12.5
VD	85	7.5	7.5
VE	85	10	5
VF	85	12.5	2.5
VG	85	5	10
VH	80	15	5
VI	80	12.5	7.5
VJ	80	10	10
VK	80	7.5	12.5
VL	80	5	15
VM	75	10	15
VN	75	15	10
VO	75	5	20
VP	75	12.5	12.5

2.3.3. Testing of samples

The physical test carried out on the samples includes density, water absorptivity and moisture content respectively.

2.3.3.1. Density test

The density test was carried out according to BS EN 12467. The mass (Kg) per unit volume (m^3) each sample were measured. The following expression was used to obtain the density of the sample:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad (1)$$

2.3.3.2. Water absorptivity test

Water absorptivity test was carried out according to BS EN 12467. The percentage water absorptivity for each sample was also calculated using the relation:

$$\text{Water absorptivity} = \frac{\text{Weight of wet sample} - \text{Weight of oven dry sample}}{\text{Weight of oven dry sample}} \times 100 \quad (2)$$

2.3.3.3. Moisture content test

Moisture content was carried out according to BS EN 12467. The percentage of the moisture content was calculated using the following relation:

$$\text{Moisture Content} = \frac{\text{Initial mass of sample} - \text{Final mass of oven dry sample}}{\text{Final mass of oven dry sample}} \times 100 \quad (3)$$

2.3.3.4. Flexural test

Flexural test based on the three-point loading principle was carried out on the WINCOM Universal Testing Machine as shown in Figure 3. The sample size used was 300mm x 150mm x 6mm. This test was done in compliance with BS EN 12467.



Fig. 3. Flexural strength test for the composite according to BS EN 12467

According to BS EN 12467, the flexural strength was determined from the relation in equation 4:

$$\sigma = \frac{3PL}{2BH^2} \quad (4)$$

Where P is the breaking load (N), L is the span of the simple supports (mm), B is the width of the specimen (mm) and H is the thickness of the specimen (mm)

3. Results and discussion

3.1. Density

Figure 4 is the graphical representation of the density of the fibre composite. From the results obtained, VM reinforced with 25% (15% GCH & 10% CH) hybrid fibre has the lowest density of 1019 kg/m³. The highest density value of 1963 kg/m³ was exhibited by VA, the composite with 0% fibres after 28 days of curing. Relatively, the increase in the percentage volume of the fibres in the composite resulted in a decrease in density of the samples. The densities are within the range prescribed by BS EN 12467 standard for ceiling board.

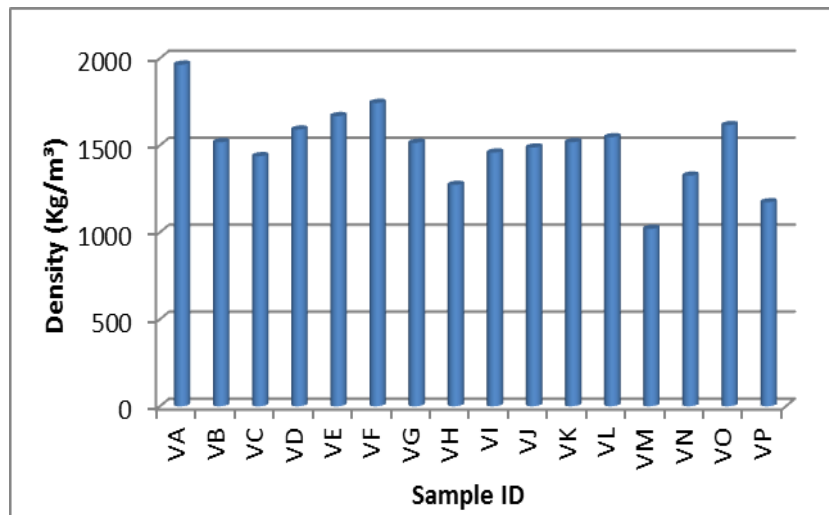


Fig. 4. Density of GCH-CH hybrid fibre reinforced composite

3.2. Water Absorptivity

Figure 5 is the graphical representation of the water absorptivity of the composite. From the results obtained, VB reinforced with 10% (5% GCH & 5% CH) fibre has the lowest percentage mean water absorptivity with a value of 22.59%. VM reinforced with 25% (15% GCH & 10%CH) absorbed the highest quantity of water with a value of 38.16%. It can be deduced from the graph

that VM with the highest percentage volume (25%) of fibre has the highest water absorptivity. This could be as a result of plant fibre's affinity for water.

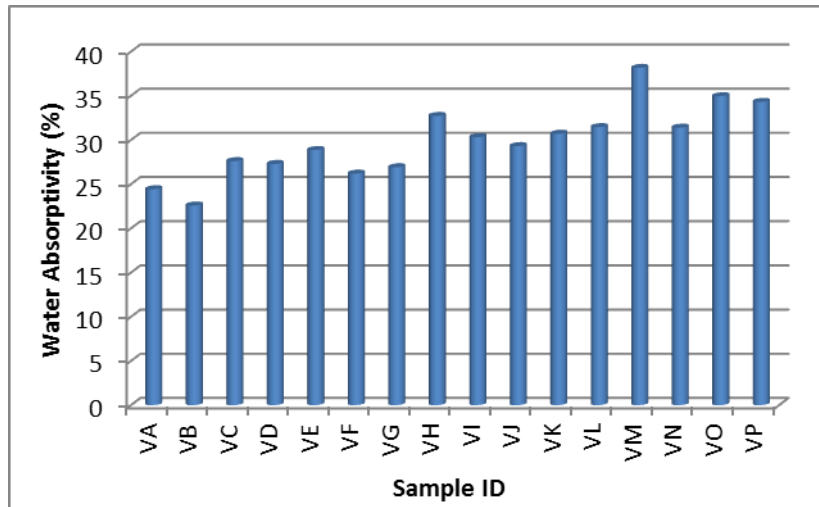


Fig. 5. Percentage water absorptivity of GCH-CH hybrid fibre reinforced composite

3.3. Moisture content

Figure 6 is the graphical representation of the moisture content of the composite after 28 days of curing. From the graph, it was indicated that VM reinforced with 25% (15% GCH & 10%CH) hybrid fibre gives the highest moisture content value of 11.28% and the lowest moisture content of 3.32% was exhibited by VF reinforced with 15% (2.5% GCH & 12.5% CH) hybrid fibre. The moisture content plays a vital role in the mechanical performance of the composite.

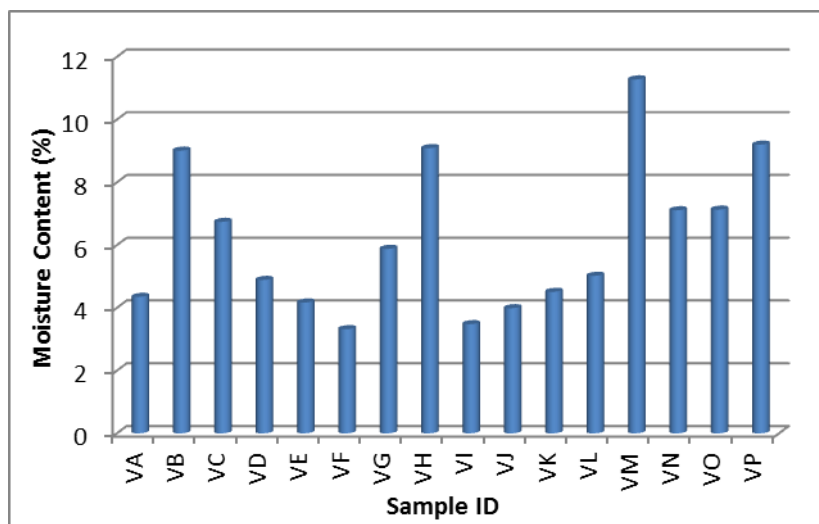


Fig. 6. Percentage moisture content of GCH-CH hybrid fibre reinforced composite

3.4. Flexural performance

The flexural behaviour of the composite is shown in Figure 7. This shows that the highest flexural strength belongs to VC reinforced with 15% (12.5% GCH & 2.5% CH) hybrid fibre which includes 12.5% of GCH and 2.5% of CH. The flexural strength of VA with 0% fibre reinforcement (control sample) is 21.44 MPa while that of VC and VG are 22.37 MPa and 22.05MPa respectively. It is obvious from the graph that VC and VG have greater flexural strength than VA (sample with no reinforcing fibre). Addition of 20% hybrid fibre led to a reduction in flexural strength when compared with the control sample, this could be as a result of decrease in the volume of the cement materials in the composite. According to Khorami (2011), decreasing the

cementitious material in the composite would decrease flexural strength. Further increase in the fibre content causes a decrease in the matrix-fibre interfacial bond within composite thereby resulting in a decrease in the flexural strength. However, most of the samples meet up with the minimum failure strength for four classes according to the BS EN12467. Except VF, VL and VO, other samples have flexural strength greater than 20MPa. Meanwhile, the minimum failure strength for the fifth or highest class is 22MPa according to the aforementioned code. It means that VC reinforced with 15% (12.5% GCH & 2.5% CH) and VG also reinforced with 15% (10% GCH & 5% CH) hybrid fibre satisfies and surpasses the minimum failure strength for all the classes.

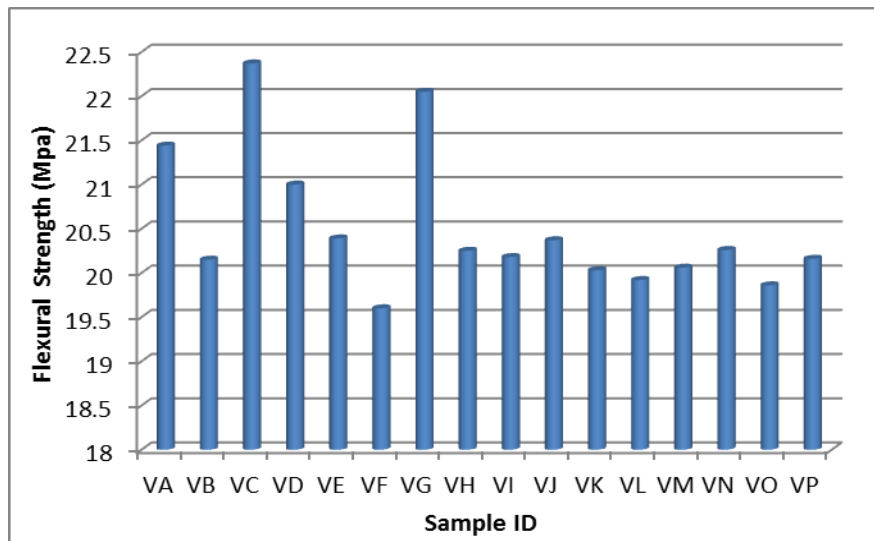


Fig. 7. Flexural behavior of GCH-CH hybrid fibre reinforced composite

4. Conclusion

The development of composite ceiling board from guinea corn husk (GCH), cow hair (CH) and cement has been conducted. This study also shows that the incorporation of the GCH-CH hybrid fibre improves the physico-mechanical properties of cement composite. The outcome of the findings shows that plant (guinea corn husk) and animal fibres (cow hair) obtained from waste can be judiciously utilized as reinforcement in fiber cementitious composites.

Furthermore, the study shows that the optimum composition of hybrid fiber in the board contains: 12.5% of guinea corn husk (GCH) fibre, 2.5% of cow hair (CH) fibre and 85% of cement. The corresponding flexural strength at the optimum composition of hybrid is 22.37MPa which surpasses the minimum standard in BS EN 12467. The density of the GCH-CH hybrid composite ranged from 1019 to 1963 kg/m³. The water absorptivity varied from 22.59 to 38.16% and the moisture content ranged from 3.32 to 11.28%.

Additionally, the flexural strength decreases with the increasing contents of the hybrid (GCH-CH) in the composite. The overall flexural strengths obtained are acceptable for ceiling applications according to BS EN 12467 specifications. The utilization of guinea corn husk and cow hair as hybrid reinforcement in cement composite is not only suitable but will cause a reduction in both air and environmental pollutions. The outcome of this research satisfies the goal of turning agricultural and industrial wastes into useful construction materials. Effective utilization of natural fibres in the development of innovative composite board will result in the manufacture of affordable products if embraced in the construction industry.

5. References

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