Thermomechanical characterization of Grewia bicolor bark mucilage reinforced mud bricks

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ABSTRACT

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| The use of local biomaterials in construction is becoming an imperative to save the planet and to reduce the cost of construction in sub-Saharan region. The aim of this research work is to study the effect of the mucilage of Grewia bicolor fiber on the properties of mud bricks. the mucilage from *Grewia bicolor* bark was used to stabilize raw earth bricks. Two formulations of samples are obtained. The first one is with 100% of soil and without mucilage. The second one the soil stabilized with mucilage at three different viscosities (25.30s, 20s and 10s). The output measurement are compressive and flexural strengths, as well as the thermal conductivity, thermal resistance and thermal effusivity of the composite material formulated. The results show an increase in compressive strength with the increase in viscosity of the mucilage. An increase in flexural strength when the viscosity of the mucilage is increased. A decrease in thermal conductivity when the viscosity of the mucilage is increased. An increase in thermal resistance when the viscosity of the mucilage is increased. Effusivity decreased with increasing of mucilage viscosity. These results show that the mucilage of *Grewia bicolor* can significantly improve the characteristics of mud bricks and this may have potential use in eco-construction for habitat. |

*Keywords: Grewia bicolor, mud brick, compressive strength, flexural strength, thermal conductivity, thermal resistance and thermal effusivity*

1. INTRODUCTION

To save the planet, we need to use local resources. In the housing sector, this means using eco-materials [1]. The first local building material used by mankind is, of course, earth, which has been used for years to build our homes. It is a material that is available and accessible everywhere on the planet [2]. In Africa, the south of the Sahara, there are many mud houses. However, when exposed to the elements, they remain fragile due to earth's sensitivity to water and its poor mechanical; [3]. This issue continues to preoccupy researchers.

Located in the heart of Africa, Chad It has a rainy season from May and October, with total rainfall of between 150 and 300mm per month and it exposed to the weathering [4]. Building materials and the energy consumed for heating and air conditioning are expensive. In order to make the most of local materials and help reducing construction costs in Chad, it is very important to use local materials.

Some researchers are showing renewed interest in those materials [5], [6], [7], [8], [9], [10], [11] as an alternative to expensive fossil fuels such as cement. The results of their work showed that earth, used as a matrix for composite materials with plant fibers as reinforcements, offers very interesting advantages in thermomechanical terms. They highlighted the good thermal inertia of raw earth bricks.

In order to develop the local materials for use in eco-construction in Chad, thermomechanical characterization of Fianga soil in the East Mayo Kebbi region and a Grewia Bicolor as a fiber are carried out in this research work.

1. LITERATURE REVIEW

The formulation of composites based on local materials for use in the construction of housing in the sub-Saharan zone with a view to improving its characteristics is still a concern for researchers, as it is still in the experimental stage. Several authors have demonstrated that the characteristics of soil materials in terms of mechanical, physical and chemical can be improved by incorporating fibers or aggregates in the formulation of raw earth bricks [11], [12], [13], [14 [15]. The addition of biological fibers and aggregates leads to a reduction in the bulk density of the raw earth brick. Increasing the fiber particle content leads to a decrease in the soil content and therefore a decrease in the dry density of the composite [16]. The work of Algin et al. [18] showed a decrease of about 29% in density for an addition of 40% by volume of cotton residues.

Abessolo et al. [18] observed a reduction in density of 0.96, 1.29 and 7.42% respectively for additions of 0.5, 0.75 and 1% in 5 cm Bambusa vulgaris fibres. Conversely, they observed an increase in porosity of 16, 20 and 32% respectively for the same levels of reinforcement and at the same length.

The Grewia bicolor is tropical plant and might be used as reinforcement for formulation of composite materials due to its mucilaginous properties. *Grevia bicolor* has remarkable strength and elasticity, these properties make it a multipurpose material leaves and bark of Grewia bicolor possess mucilaginous property and can be used as a binder [19]. Few works are done on the *Grewia bicolor* as a stabilizer in formulation of local composite materials.

1. **Materials et Methods**

**1.1. Materials**

The basic material used is the soil taken from the site in the village of Lengoua located in Fianga, Chad. The coordinates of the site are 9°56'1.06‘’ N, 15°7'59.99‘’ E. The soil is taken from its natural state at a depth of around 90 cm. This site is chosen on the basis of its availability and its appearance in matching with its use to compressed earth bricks. The granulometric curve of Fianga soil is presented in Figure 1 and the granulometric composition of the soil on table 1.



Figure 1: Granulometric curve of Fianga soil

**Table 1: Granulometric composition of the soil**:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **N°** | **Sample** | **Sand (%)** | **Loam (%)** | **Clay (%)** | **Nature of soil** |
| 1 | Fianga Lengoua1 | 48 | 16 | 36 | Sandy-clay-silty |

To prepare the test sample, the water from the Chadian Water Society (STE) available at Building and Civil Engineering Laboratory is used. The *Grewia bicolor* (GB) shrubs were collected from Fianga in the Mont Illi Department, in the village of Lagna with coordinates 9°.56‘.43.7’‘N, 15°.6’.13.85‘’E. The figure 2 Mucilage of *Grewia bicolor* bark. Grewia bicolor bark fibers and mucilage are extracted to stabilize the bricks.

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| a) *Grewia bicolor* bark fibers | b) Mucilage and fibers of GB barks |
| Figure 2: Mucilage of GB bark | |

The Grewia bicolor is tropical plant and is used as reinforcement for formulation of composite materials due to its mucilaginous properties similar.

**1.2. Methods**

To obtain the best conditions for mixing, the soil used is ground and dried. The soil is oven-dried for 24 hours at a temperature of 65°C. Material mixes (soil + fibers) are first made dry, then mixed with water using an electric mixer. The dry mixes are homogenized with the fibers for a few minutes. Mixing with water lasts three minutes. The composite material is placed in the mold directly after mixing and homogenization. A block of 3 molds measuring 4x4x16cm3 was used to produce the adobes for the mechanical tests, and another measuring 4x5x8cm3 for the thermal tests. Specimens are densified using a vibrating table. The coding of sample formulations is presented in Table 2.

Table 2: Coding of different formulations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Formulation** | **Sol (%)** | **Mucilage (Viscosity)** | **Codes** | **Meaning** |
| 1 | 100 | 0 | NSO | 100% soil, without mucilage |
| 2 | 100 | 25.30s | SMv1 | Mixing with a v1 viscosity of 25.30s |
| 3 | 100 | 20s | SMv2 | Mixing with a v2 viscosity of 20s |
| 4 | 100 | 10s | SMv3 | Mixing with a v3 viscosity of 10s |

The 3-point bending and compression tests were carried out in accordance with standards NF EN 12390 - 5, 2001 and NF EN 12390 - 3, 2003 respectively, at 28 days curing. Each test was carried out on three specimens of the same formulation.

3. RESULTS AND DISCUSSION

The results observed from the experiment are presented in this section.

**3.1. Effect of Grewia bicolor mucilage on the compressive strength of adobes**

Figure 3 shows the effect of varying the viscosity of *Grewia bicolor* mucilage on compressive strength.

Figure 3: Effect of varying the viscosity of GB mucilage on the compressive strength of adobe specimens.

The results from the figure 3 show an improvement in compressive strengths with mucilage compared to the formulation with 100% soil. The maximum is reached with a viscosity of 25.30s (5.74MPa). There was an increase in compressive strength with increasing mucilage viscosity. The results corroborate those obtained from the work of authors Marangoni et al., Togdjim Jonas et al., Abdallah Ban-nah et al. ([5], [6], [7] carried out with fibers as stabilizers.

**3.2. Effect of *Grewia bicolor* mucilage on the flexural strength of adobes**

Figure 4 shows the effect of varying mucilage viscosity on the flexural strength of adobe specimens.

Figure 4: Effect of varying the viscosity of mucilage on the flexural strength of adobe specimens

As with compressive strength, the results in the figure show an improvement in flexural strength with mucilage compared with the formulation with 100% soil without binder. The maximum is reached with a viscosity of 25.30s (2.88 MPa). These results are allied with those works from authors [8], [9], [10], [11].

An increase in flexural strength is observed as a function of increasing mucilage viscosity. The same trend was obtained from work carried out on adobes stabilized with plant fibers.

**3.3. Effect of *Grewia bicolor* mucilage on the thermal conductivity of adobes**

Figure 5 shows the effect of varying mucilage viscosity on the thermal conductivity of adobe specimens.

Figure 5: Effect of varying mucilage viscosity on the thermal conductivity of adobe specimens.

The results in the figure show a decrease in thermal conductivity with mucilage as the viscosity of the mucilage increases. The thermal conductivity varies from 0.69 to 0.60 W/mK. This result shows the same trend with adobes made from GB bark fibers. The same decrease was obtained from work carried out on raw earth bricks stabilized with plant fibers ([6], [7] [6], [7], [8], [9].

**3.4. Effect of *Grewia bicolor* mucilage on the thermal resistance of adobes**

Figure 6 shows the effect of varying the viscosity of *Grewia bicolor* mucilage on the thermal resistance of adobe specimens.

Figure 6: Effect of varying the viscosity of GB mucilage on the thermal resistance of adobe specimens

The results in the figure show an increase in thermal resistance as the viscosity of the mucilage increases. This increase ranges from 0.058 to 0.066 m2°C/W.

This result shows the same trend for adobes made from GB bark fibers. Authors [5] [6], [7] [6], [7], [8], [9] obtained similar results with plant fibers and other biobased aggregates.

**3.5. Effect of *Grewia bicolor* mucilage on the thermal effusivity of adobes**

Figure 7 presents the effect of varying mucilage viscosity on thermal effusivity of adobe specimens.

Figure 7: Effect of varying mucilage viscosity on thermal effusivity of adobe specimens

The results in the figure show a higher thermal effusivity obtained with the soil formulation without binder (100% soil). The formulations using mucilage have lower thermal effusivities than the soil without binder. Adobes with viscosities of 20s and 10s have the lowest thermal effusivities (0.60 W/S1/2m2/K) [6] [7], [9] [10].

**CONCLUSION**

The aim of this study was to investigate the effects of the viscosity of *Grewia bicolor* bark mucilage on the thermomechanical properties of mud bricks. In view of the results obtained from this work, the following can be concluded:

There is an improvement in the thermomechanical performance of mud bricks reinforced with *Grewia bicolor* mucilage. As viscosity increases, so does thermomechanical performance:

* The flexural strength of fiber-reinforced specimens increases as the viscosity of the *Grewia bicolor* mucilage increases.
* The compressive strength of fiber-reinforced specimens increases with increasing viscosity of *Grewia bicolor* mucilage.
* Thermal conductivity decreases with increasing viscosity of *Grewia bicolor* mucilage.
* Thermal resistance increases with increasing viscosity of *Grewia bicolor* mucilage.
* Thermal effusivity decreases with increasing viscosity of *Grewia bicolor* mucilage. Specimens made with mucilage viscosities of 20s and 10s have the lowest effusivities (0.60 W/S1/2m2/K).

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Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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