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Development and Characterization of Banana Fiber Reinforced Clay Composites for Construction Technology

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Abstract— Now a day's natural fiber reinforced polymer matrix composite is one of the highly developed alternative material that have been for many. Presently, due to indecisive conditions in the scarcity of resource of construction material, hard currency, unable to use available material and the cost of cement is a problem. This research aims to develop and characterize short banana fiber reinforced clay composite material to find applicable resource for construction industry.

Banana fiber reinforced clay composite material were developed having both treated and not treated fiber length of 5mm, 10mm, and 15mm and fiber weight percent ratio of 0:, 10, 20, and 30. Besides it considered clay matrixes weight percent ratio of 100%, 90%, 80%, and 70% enclose grain size of 0.2mm, 0.4mm, 0.6mm, 0.8mm using sieve filter. Then fabricating of the composite was using compression technique.

In this research developed composite were characterize with physical properties of water absorption, fire resistance, and mechanical properties of compression strength. Experimental results showed decrement on 0, 10 wt% and 20 wt%, however, which shows is optimal augmentation at 30wt% banana fiber to 70 wt% clay matrixes.

The utmost outcome of this research was obtain for mixture of optimal edagahamus clay, Hashenge clay and optimum quantity of banana fiber 20%, and the length of 15mm. the fiber reinforced clay exhibit fracture and surface shave breakage mode. The test result of compression strength is 35 MPa and the sample is treated by fired increaser into 39.5 MPa. the water absorption value is 3.52 g and the composite material resist fire up to 128 ℃ all the value are above the recommended value for structure work of construction technology to manufacture the structural product of clay reinforced solid brick.

Keywords— Banana fibers, Clay Matrix, Compression molding, Mechanical properties, Physical properties, Construction technology.

I. INTRODUCTION

Banana plant is one of the world's oldest cultivated plants in Africa that has been used for different human consumption which includes tropical and subtropical areas of the world generate about 70 million metric tons of bananas annually having only 20 of its 300 species. In general, banana plants engender 30 leaves, each measuring approximately 30–60 cm wide and 2 m long. All of these fibers of the banana leafs enclose a amalgamation of cellulose, hemicelluloses, and lignin, even though their relative amounts vary which is one species from the other different species of plants [1], [2]. Specifically while it have been characterize the mechanical properties of banana fiber vary in high even if in the same banana plant because of life cycle of the banana plant, area and of growing of banana plant, harvesting and extracting mechanism, way of transportation and packing banana fiber in span of time [1-5].

II. METHODOLOGY

2.1. Materials

Banana fiber

It have been collected from study area and used as short banana fiber length having length of 5mm, 10mm, and 15mm and fiber weight percent ratio of 0:, 10, 20, and 30. Besides both the varying fiber length and fiber weight percent ratio is treated with 1%, 2%, 3%, 4% NaOH, and not treated one [8-9].

Table 1: Physical prosperities of the banana fiber [7]

S.No	Properties	Range
1	Cellulose (%)	62.5-66.98
2	Hemicelluloses (%)	18-19
3	Lignin (%)	4.5-5.0
4	Moisture(%)	10-11
5	Density (g/cm^3)	1-1.5
6	Elongation at break	4.7-6.6
7	Young Modulus (GPa)	18.5-20.1
8	Micro filbrillar angle (deg)	11
9	Lumen Size (mm)	5

Clay Matrix

It have been collected from study area and used clay matrix by weight percent ratio of 100%, 90%, 80%, and 70% considering grain size of 2mm, 4mm,6mm,8mm using sieve filter .

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Table 2: Physical Properties and Mechanical Properties clay soil [10, 12, 13, 14, and 15]

S.No	Physical Properties	Mechanical Properties
1	Cation exchange capabilities	Hydraulic ,and gas conductivity
2	Plastic behavior when wet	Ion diffusion capacity
3	Catalytic abilities	Swelling potential
4	Swelling behavior	Compressibility
5	Low permeability	Rheological

Clay is fine mixtures of decomposed igneous rock minerals are very small particles, which are very active electrochemically. As stated in [18] the amount of clay increase in the soil the behavior of the soil is governed by the property of the clay. Furthermore in [19] describe chemically clay is the composition of hydrous alumina silicate plus other metallic ions and all clay minerals are very small, colloidal size (diameter less than 12μm). There are only two fundamental crystal sheets that are tetrahedral or silica and octahedral or alumina. The particular way of in, which these sheets are, stacked, together with different bonding and different metallic ions in the crystal lactic constitute the difference clay minerals. The tetrahedral sheet is a combination of silica tetrahedral unit, which consist of four oxygen atoms at the corners, Surrounding a single silica atom.

The octahedral sheet is a combination of octahedral units consisting of six oxygen or hydroxyls enclosing aluminum, magnesium, iron or other ion briefly described in reference [20]. In [19] explain about clay properties for use in manufacturing depends up on two physical properties. The first property is easy molded and shaped when it is wet and the second is when subjected to heat there is change of state to be hard. The second physical property affected by the chemical composition of the clay. The chemical composition of the clay is affected the physical properties the dehydration and agglomeration accomplished by shrinkage. The effect of impurities present in clay is to lower fusing point .Moreover other investigator explain in [24] the particle size distribution, chemical composition, and mineral composition of clayey materials have been reported to influence their ceramic properties and they are generally buff, gray, brown, or rust in colors due to the content of clay mineral.

Banana fiber reinforced clay composite

Composite were fabricating using compression molding technique considering fiber treatment of 1%, 2%, 3%, 4% NaOH, fiber length of 5mm, 10mm, and 15mm, weight fiber/matrix ratio of 0/100, 10/90,20/80, and 30/70, grain size of clay matrix's of 0.2mm, 0.4mm, 0.6mm, 0.8mm using sieve strain.

2.2. Methods

Sample Preparation and Characterization

Banana stem were collected from study area in Alamata, southern zone of Tigray [figure 1a]. Banana fiber was extracted from banana stem using hand scraping [figure 1b]. Banana fiber was treated with alkali treatment to remove lignin and other impurity then dried in the sun, bundled, [figure 1d] and cut using manual seizer device based on required fiber length [figure1e]. Besides it had been dispensed fiber weight ratio using Dispensing Touchless Sensor device which is the specified ratio [figure 1f].

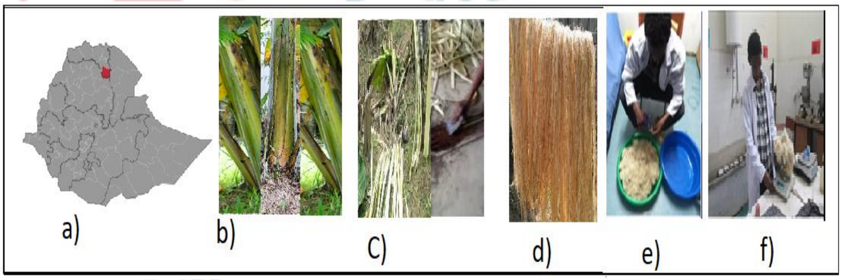

Figure 1: Study area: Alamata, South zone of Tigray

Clay soil was collected from the study area of Lake Hashing [figure2 a, b], Ethiopia. According the specified weight ratio of clay matrix it was dispensing based on grain size using sieve [figure 2c, d].

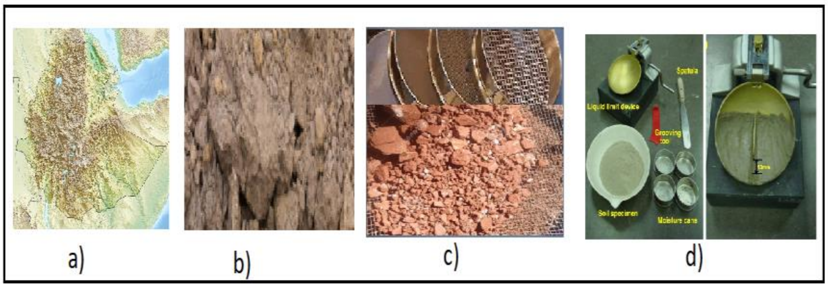

Figure 2: Study area: Hashenge, Tigray

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Banana fiber reinforced clay composite material was prepared in the following way for sample test to have looked the effect of fiber length, fiber to matrix weight ratio, alkali treatment, grain size .

2.2.2 Characterization of banana reinforced composite material

Physical properties

Moisture Absorption

Sample for Moisture Absorption were prepared according to the ASTM D5229. It is a gravimetric test method that monitors change over time of moisture content by measuring the total mass change of a coupon that is exposed to a specified environment [11].

Table 3: Parameters to Physical properties

Length	Weight ratio of	Alkali treatment of fiber		Clay matrixes
Banana Fiber	Banana fiber to matrix	Treated	Untreated	Gray size
5mm	0/100%	1%	0	0.2mm
10mm	10/90%	2%	0	0.4mm
15mm	20/80%	3%	0	0.6mm
	30/70%	4%	0	0.8mm

Fire resistance

Sample for Fire resistance test were prepared according to the ASTME119, Standard test method for fire test of building construction material [7].

Table 4: Parameters of Fire resistance

Length	Weight ratio of	Alkali treatment of fiber		Clay matrixes
Banana Fiber	Banana fiber to matrix	Treated	Untreated	Gray size
5mm	0/100%	1%		0.2mm
10mm	10/90%	2%		0.4mm
15mm	20/80%	3%		0.6mm
	30/70%	4%		0.8mm

Mechanical properties

Compression strength

Sample for compression residual strength properties test were prepared according to the **ASTM D7137** [12]**.** It is a testing standard designed to measure the compression residual strength properties of multidirectional polymer matrix composite laminated plates. Susceptibility to damage from concentrated out-of-plane forces is one of the major design concerns of advanced composite laminates.

Table 5: Parameters of Compression strength

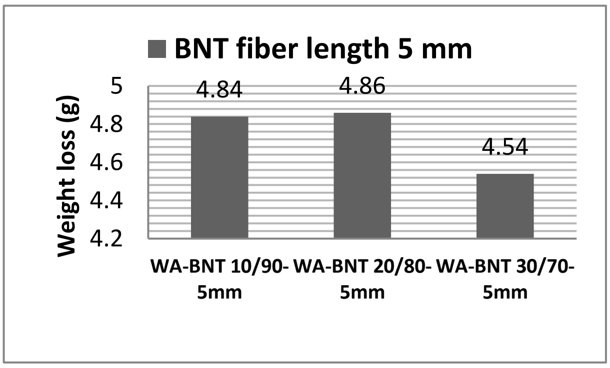
Length	Weight ratio of	Alkali treatment of fiber		Clay matrixes
Banana Fiber	Banana fiber to matrix	Treated	Untreated	Gray size
5mm	0/100%	1%	0%	0.2mm
10mm	10/90%	2%	0%	0.4mm
15mm	20/80%	3%	0%	0.6mm
	30/70%	4%	0%	0.8mm

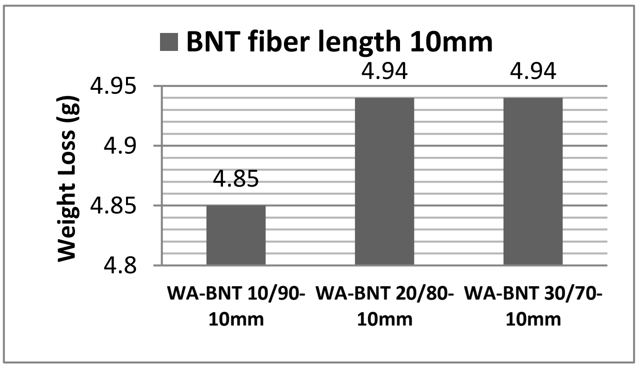
III. RESULTS AND DISCUSSION

3.1 Physical properties

Water absorption

For the ***Water absorption*** evaluation, 18 specimen groups were prepared for both treated and untreated fiber to clay ratio of 0/100 (5% banana fiber and 100% clay), 10/90 (10% banana fiber and 90% clay), and 20/80 (20% fiber and 80% clay) for each 5mm, 10mm, and 15 fiber length. Thus a total of 56 sample specimens (2 parameters which are treated and untreated ×3 parameters which are fiber to clay ratio ×3 parameters which are fiber length ×3 trial tests) were tested. The average ***Water absorption*** for the three trial tests are shown below:





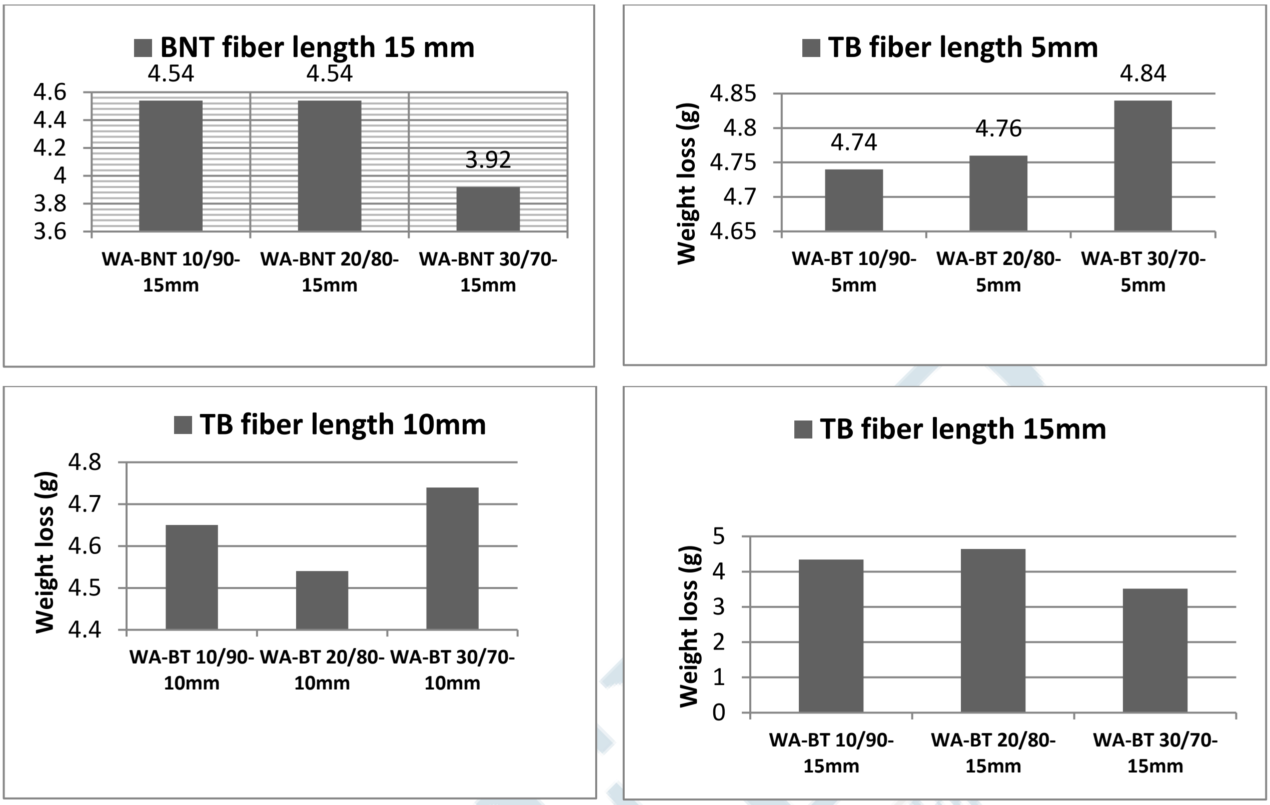
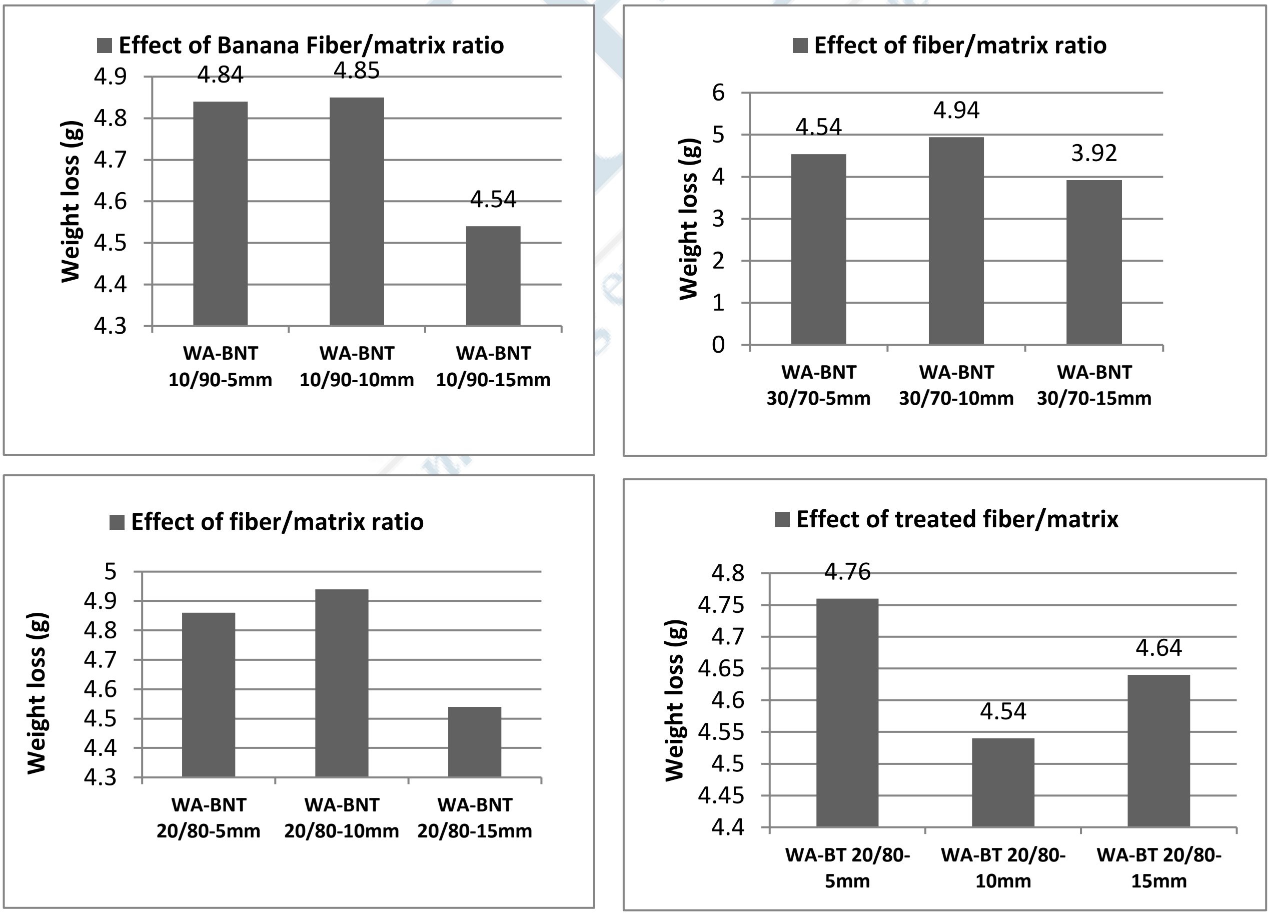


Figure 3: Effect of fiber/matrix ratio on the chemical resistance for BF/Clay Composite



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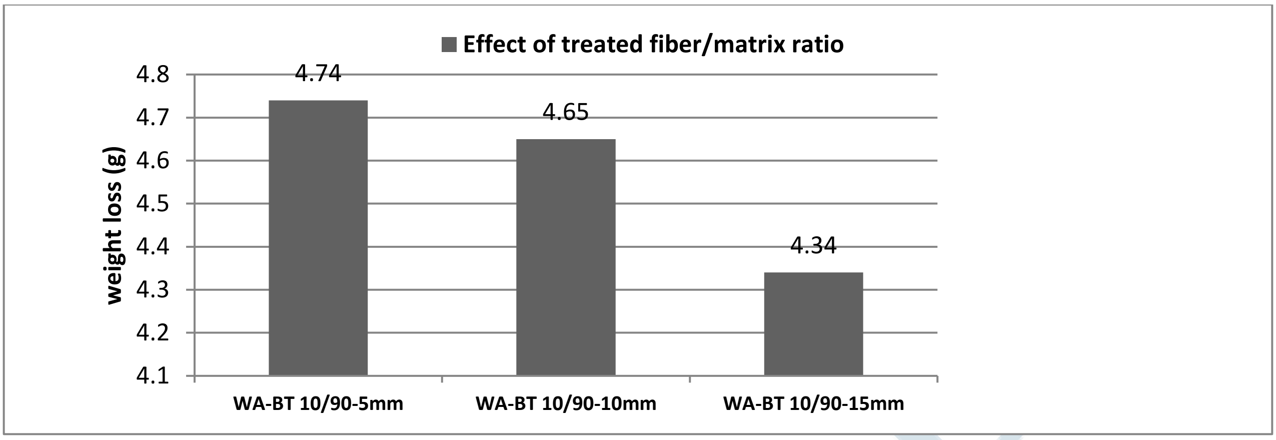

Figure 4: Effect of fiber length on the water absorption for BF/Clay Composite

Treating fibers especially alkali treatment removes lignin,hemicellulose and other impurities which are usually hydrophobic (water hating). After removal of these hydrophobic parts, the remaining cellulose is now able to take in more water. While treatment of fibers, surface of fiber tends to more rough then the untreated so it could be a one of the possible for more intake of water, and more thing high amount of cellulose leads to high intake of water which resulted minimum at water absorption un treated banana fiber of 30/70wt% -15mm (WA-BT 30/70-15mm), 3.92 gram and maximum at 4.94 gram weight loss.

The minimum weight loss implies more strength than the maximum weight loss of banana fiber reinforced clay composite in construction technology products such as soiled brick.

Fire resistance

For the fire resistance evaluation, 18 specimen groups were prepared for both treated and untreated fiber to clay ratio of 0/100 (5% banana fiber and 100% clay), 10/90 (10% banana fiber and 90% clay), and 20/80 (20% fiber and 80% clay) for each 5mm, 10mm, and 15 fiber length. Thus a total of 56 sample specimens (2 parameters which are treated and untreated ×3 parameters which are fiber to clay ratio ×3 parameters which are fiber length ×3 trial tests) were tested. The average fire resistance evaluation for the three trial tests are shown below

The maximum exposed temperature of the soiled composite sample brick rise on the 128°C for a single thermocouple and reduce to 53.98°C for the average of thermocouples, at the specified time period. The test panels showed the following maximum and average rise of temperature in figure 5.

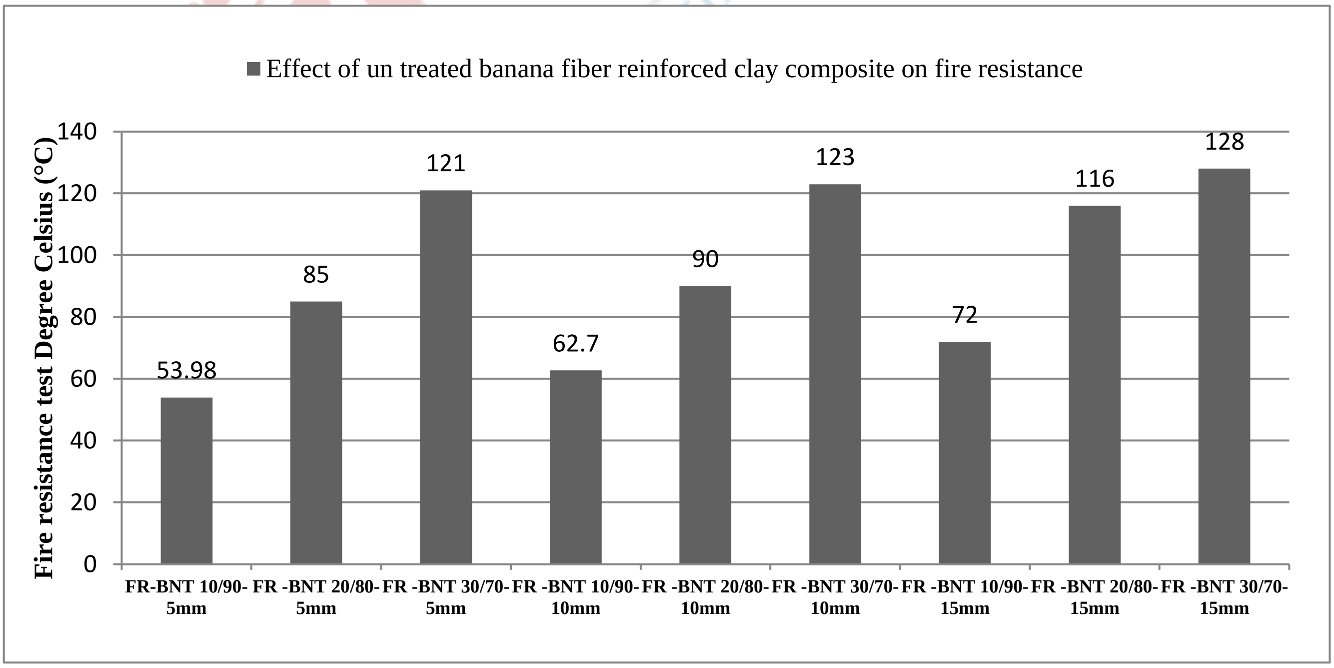

Figure 5: Effect of banana fiber reinforced clay composite on fire resistance

Very few short Banana fibers weight ratio to clay matrixes in solid brick may considerably reduce the amount of spelling in clay due to fire. Short banana fibers distribute and create channels through which the water vapor pressure built-up within the clay due to temperature rise is released. This release of the vapor pressure significantly reduces the spelling tendency of clay under fire conditions. As the weight ratio of short fiber increase the more strength do have because of high bond interaction between the banana fiber and clay matrix which resulted 128°C at 30/70 banana fiber to clay matrix ratio. However, As the weight ratio of short fiber decrease the less strength do have because of less bond interaction between the banana fiber and clay matrix which resulted 53.98°C at 10/90 banana fiber to clay matrix ratio.

3.2 Mechanical properties

Compression strength

For the Compressive strength evaluation, 18 specimen groups were prepared for both treated and untreated fiber to clay ratio of 0/100 (5% banana fiber and 100% clay), 10/90 (10% banana fiber and 90% clay), and 20/80 (20% fiber and 80% clay) for each 5mm, 10mm, and 15 fiber length. Thus a total of 56 sample specimens (2 parameters which are treated and untreated ×3 parameters which are fiber to clay ratio ×3 parameters which are fiber length ×3 trial tests) were tested. The average compressive strength evaluation for the three trial tests are shown below:

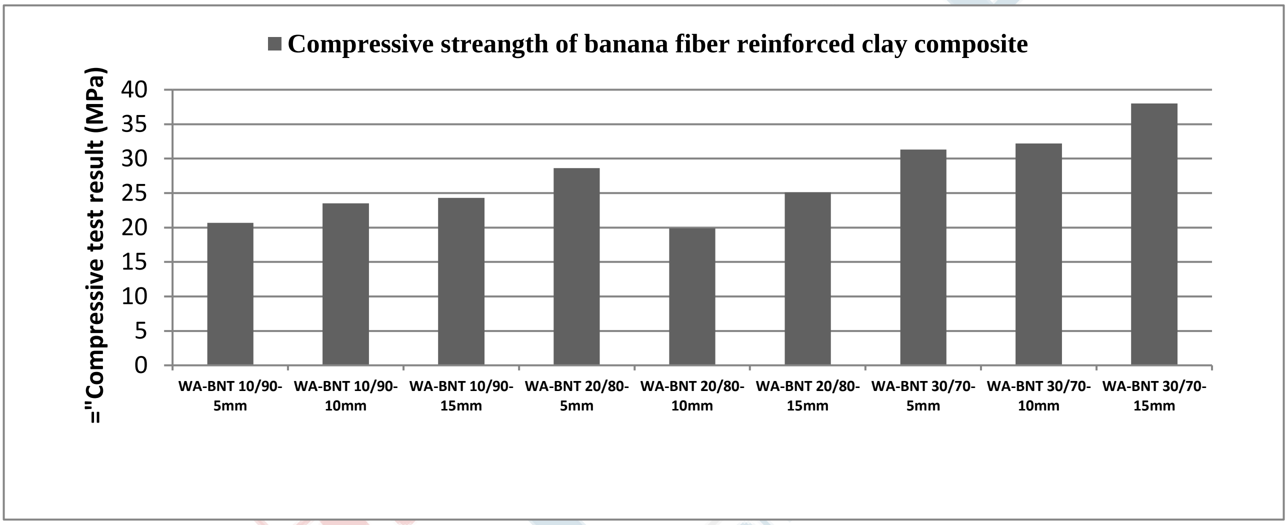

Figure 6: Effect of un treated banana fiber reinforced clay composite on compressive strength

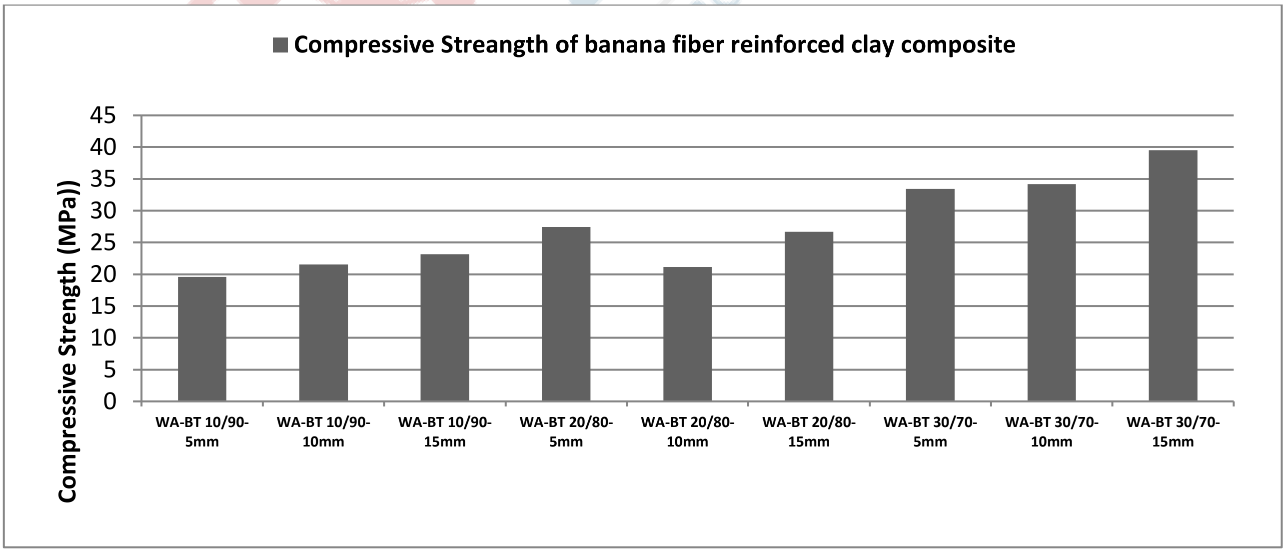

Figure 7: Effect of treated banana fiber reinforced clay composite on compressive strength

Increasing weight ratio of banana fiber decreases compressive strength. Nowadays with self-consolidating solid brick, it possible to decrease weight ratio of banana fiber to clay matrix significantly and gain increased strength, without compromising workability. It results approximately 35 MPa for untreated banana fiber reinforced clay composite, and for treated banana fiber reinforced clay composite 39.5 MPa.

IV. CONCLUSIONS

In conclusion, it can be stated that the adding of banana fiber clay reinforced composite material can produce composite products with water absorption value 3.52 gram of treated banana fiber, fiber resistance value of 128 °C, compressive strength values of approximately 39.5 MPa, which is adequate for Brick building applications.

V. RECOMMENDATIONS

Researchers can do for other application having the same fiber and clay matrixes which are further evaluation mechanical properties which is impact strength, flexural, physical properties which are chemical resistance, and other morphological characteristics like XRD.

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