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Physical Properties of Unfired and Compressed Same Clay Brick Composites Reinforced with Natural Fiber from Tanzania

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Abstract*— This study reports on the physical properties of unfired and compressed clay brick (UCCB) composite reinforced with coir or sisal fibers. The sedimentation test shows Same clay has 17.4%, 50%, and 32.6 % of fine, silt, coarse particles respectively. XRD result shows that raw Same clay is composed of kaolinite and quartz. The density of UCCB increases with increasing compressive pressure. Because of its low volume content, the fibers show no effect on water absorption coefficient on UCCB. The water absorption coefficient for UCCB reinforced with sisal and compressed at 4, 6, 8 MPa have the value of 3.81, 2.81, 2.33 Kg/m^2/min, respectively. Also, water absorption coefficient for UCCB reinforced with coir and compressed at 4, 6, 8 MPa have the value of 3.79, 2.79, 2.33 Kg/m^2/ min, respectively. Water absorption test shows water absorption coefficient for UCCB decreases with increasing compressive pressure. Therefore, UCCB composite is undesirable in traditional construction, because water absorption coefficient is greater than 2 Kg/m^2/min.

***Keywords*— Physical properties, unfired bricks, clay, Natural fibers, Water absorption**

I. INTRODUCTION

Clay bricks are the ceramic materials commonly used in construction sector [1]. Mud bricks had been used in the construction of shelters for thousands of years, and approximately 30% of the world's present population still live in earthen structures [2]. Clay brick had been used as the earliest building materials since ancient time and yet still used today. This is due to their simplicity, low cost, good thermal, acoustic properties, manufacturability and at the end of a building's life the clay material can easily be reused or resumed to the ground without any interference with the environment. The main deficiency of unfired earth bricks is susceptible to water. When water penetrates to the centre of the unfired bricks it reduces it durability [3],[4],[5].For low income people it is difficult to afford the cost of building materials due to increased cost of modern building materials. Tanzania is endowed with a clay deposit and natural fibers that can be utilized for production of UCCB. There is a potential of producing unfired clay bricks composite by reinforcing natural fibers. UCCB composite must meet the minimum value of water absorption coefficient in order to be utilize in building houses. The required value water absorption rate is 2 Kg/m2/min for bricks. Brick with greater value of water absorption is difficult to lay with traditional mortar [6]. The main purpose of this research is to investigate the physical properties of UCCB reinforced with sisal or coir natural fiber, if they can be used in building houses.

II. EXPERIMENTAL PROCEDURE

The materials used for production of UCCB were clay, sisal, coir and water. The clay used was obtained from Same district in Kilimanjaro region while sisal and coir were from Tanga region northern east of Tanzania. Sedimentation test was done by filling 1/3 Same clay to measuring cylinder and add 2/3 of water in it and shake it for 1min.Then after 1 minutes read the measurement for coarse particle, and after 5 minutes read again and record Silt particle. After waiting for half an hour read and record fine particle. XRD pattern for Same clay obtained with Rigaku, D.Max 2200 diffractometer operating at tube voltage and current 40kV and 40mA, respectively using monochromatic Cu-Kα radiation. Diffraction patterns were recorded by scanning from 10^0 to 80^0 (2θ) at a rate of 2^0/min. The water absorption test for UCCB was carried out by drying the specimen 0.845 Kg to constant weight at room temperature. Specimens were then placed in contact with 1 cm of water for 60 sec. The bricks were manually prepared by mixing the clay with 15 vol. % of water for 2 minutes. Then adding 1vol. %, 2vol. %, 3 vol. %, 4vol. %, and 5 vol. % of natural fiber trimmed 3cm length into the clay and water mixture and continue mixing for additional 3minutes. The dimension of UCCB is 15x 7.5x 5.0 cm reinforced with sisal or coir fiber. Then UCCB specimens were manually pressed at pressure of 4, 6, and 8 MPa.

a) b)

Figure 1: a) Coir fiber b) Sisal fiber

Table 1: Mix proportions of UCCB

Type of natural fiber	Mix	Dry clay(cm^3)	Fiber (vol. %)
Coir	NF	845	0
	C1	845	1
	C2	845	2
	C3	845	3
	C4	845	4
	C5	845	5
Sisal	S1	845	1
	S2	845	2
	S3	845	3
	S4	845	4
	S5	845	5

III. RESULT AND DISCUSSION

A. Particle size

Sedimentation test was carried out to determine the amount of fine (< 0.01 mm), silt(0.01 – 0.1 mm), and coarse(0.1 – 2 mm) particles present in the Same clay. The sedimentation test shows Same clay has 17.4%, 50%, 32.6 % of fine, silt, and coarse particles respectively. The sieve analysis for Same clay has fine and silt 69%, and coarse 31% particle size reported by Asson et al [7]. It has been reported that the good earth bricks can be made from soil containing 9% to 28% of fine particle size [8].

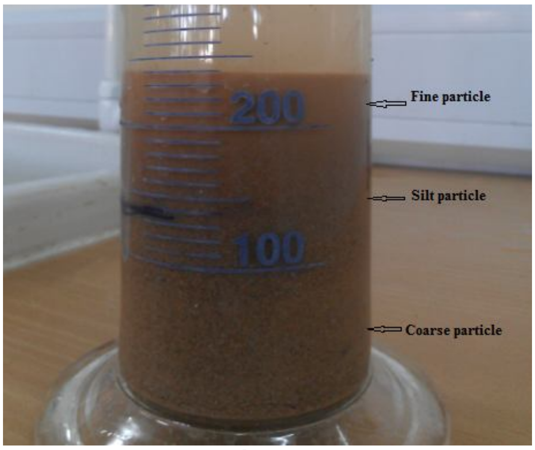

Fig. 2 Sedimentation test

B. Chemical composition

The chemical composition of Same clay has been reported by Hashimu et al [9] and result are summarized in the Table 2. It has been reported that Clay with composition of SiO_2 (45-75 %), and Al_2O_3 (10-35 %) and iron oxide (4-9 %) content are suitable for unfired bricks production[4, 10]. Therefore, the Same clay is suitable for production of UCCB.

Table 2: Chemical composition of Same Clay

Chemical composition [%]	
SiO_2	62.1
Al_2O_3	23.5
Fe_2O_3	2.62
TiO_2	1.554
CaO	0.02
MgO	0.09
Na_2O	0.02
K_2O	0.08
Ig loss	10.3

C. XRD analysis

Figure 3 shows the XRD pattern for raw Same clay at room temperature. XRD pattern shows that raw Same clay is composed of kaolinite and quartz at room temperature.

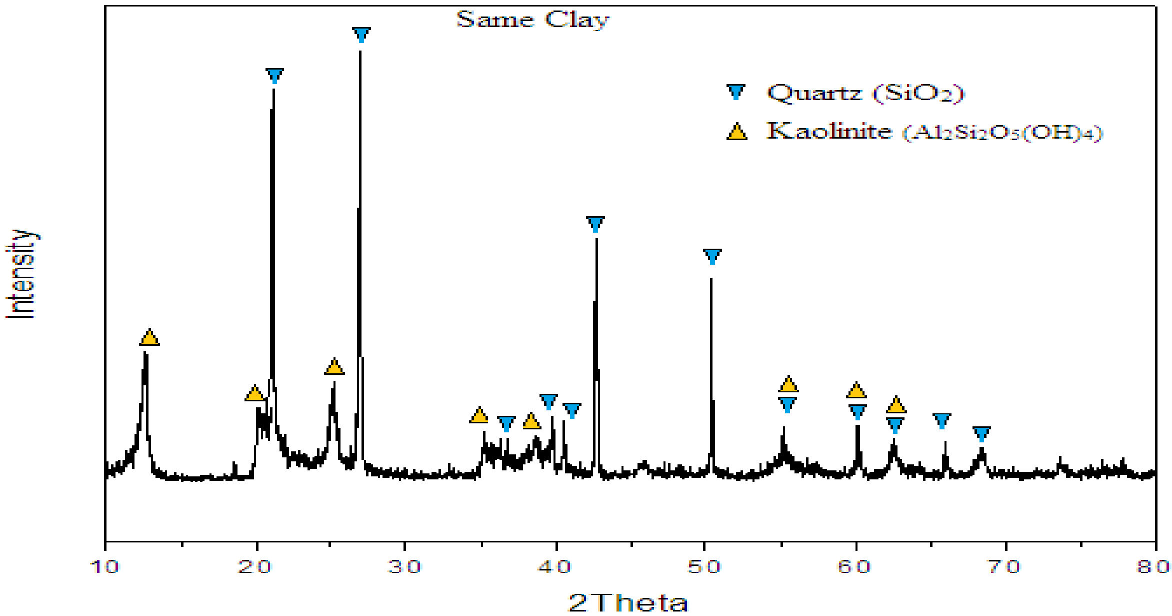

Fig. 3 XRD for raw Same Clay

D. Density

Fig. 4 shows density values for UCCB after 28 days of curing are presented. The density value UCCBC increases with increasing pressure. The UCCB pressed at 4 MPa with or without reinforced of sisal fiber has the lowest density value of 1.41g/cm^3. Also, UCCB pressed at 6 MPa with or without reinforced of sisal fiber has the density value of 1.59 g/cm^3.Whereas Fig. 4 at 8MPa indicate the higher value about 1.68 g/cm^3 for each UCCB with or without reinforcement of sisal fiber content. This is because the increase in pressure decreases the porosity, then the UCCB becomes dense.

Also, Fig. 4 shows a density values of UCCB with or without reinforced coir after 28 days of curing. The graph shown UCCB with or without reinforcement of coir fiber density value 1.41g/cm^3 pressed at 4 MPa. Whereas UCCB with or without reinforcement of coir pressed at 6, 8 MPa has density values of 1.59 g/cm^3, 1.71 g/cm^3. The density increases in UCCB due to amount of pressure applied on it. Increasing compressive pressure on UCCB reduces the pore. Slight increase in density with increase in fiber content is also observed.

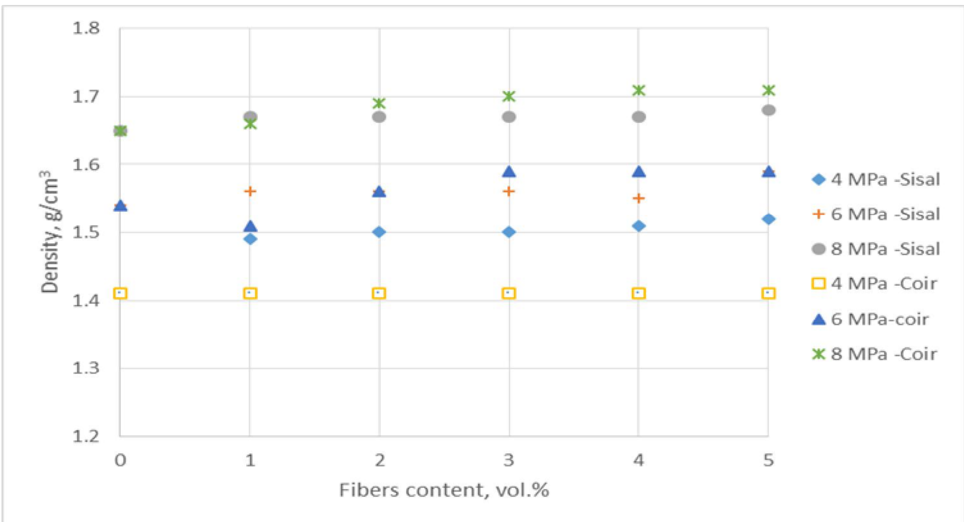

Fig. 4 Density of UCCB with or without reinforced sisal and coir fibers after 28 days of curing

E. Water absorption coefficient

Specific water absorption is determined from the quantity of water in relation to the area in contact[11].The water absorption coefficient can be calculated by using the following equation:

$$C_w = \frac{M_w - M_d}{A\sqrt{t}}$$

Where,
C_w-Water absorption coefficient (Kg/m^{2}min$^{0.5}$), M_w-Wet mass (Kg), M_d-Dry mass (Kg), A-Surface area (cm^2), and t-Time (min)

Fig. 5 shows water absorption of UCCB reinforced with sisal fibers after 28 days of curing. The result shows water absorption coefficient value of 3.81, 2.81, 2.33 Kg/m^2 /min, for UCCB with 0, 1, 2, 3, 4, and 5 vol. % of sisal compressed at 4, 6, and 8 MPa respectively. Similarly, the UCCB with 0, 1, 2, 3, 4, 5 vol. % of coir pressed at 4, 6, 8 MPa have water absorption coefficient value of 3.79, 2.79, and 2.33 Kg/m^2 /min respectively.

Fig. 5 shows that increase in pressure leads to decrease in water absorption. This is supported by Fig. 4 where there is increase in density as pressure increases. This indicates that when pressure increases on UCCB reinforced with sisal fiber it becomes less permeable. The higher permeability of UCCB causes the fast migrate of water inside the brick eventually led unfired clay brick composites to collapse.

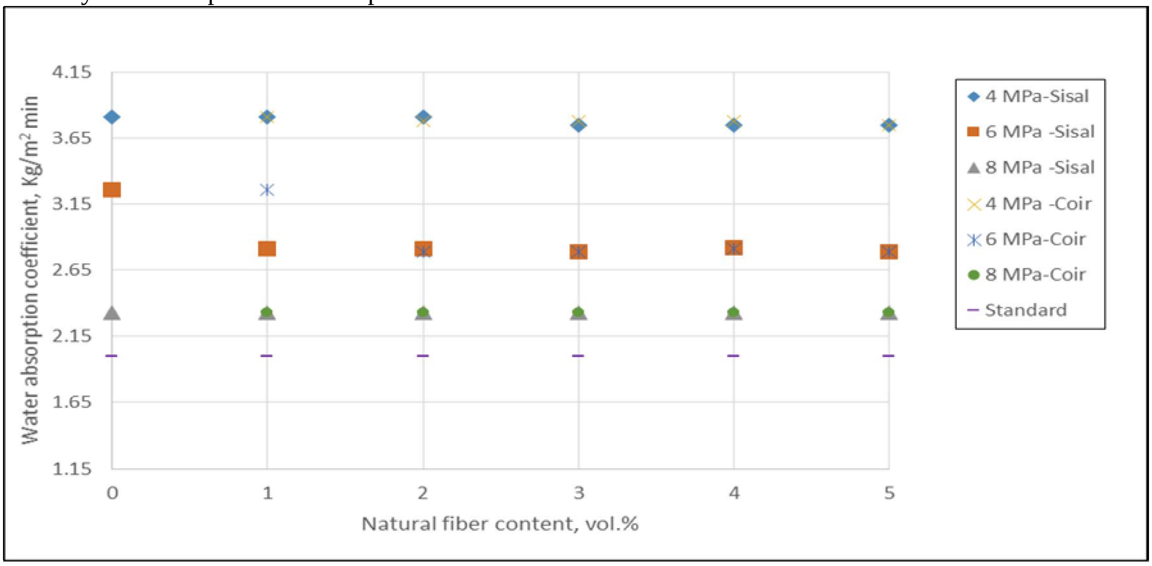

Fig. 5 Water absorption of UCCB reinforced with sisal and coir fibers after 28 days of curing

As compressive pressure and density increases on UCCB becomes dense and less permeable. There is slightly difference of sisal and coir content in water absorption coefficient because of its low volume in UCCB. of a brick rises from 2 Kg/m^2/min to 4 Kg/m^2/min then the strength of the wall will be reduced by 50% This means that bricks with large water absorption coefficient values will draw moisture from the mortar and reduce its effectiveness [6]. All UCCB samples tested in this research have displayed water absorption coefficient of larger than 2 Kg/m^2/min and, therefore, would be undesirable in traditional construction.

IV. CONCLUSIONS

The density of UCCB increases with increasing compression pressure. The sisal and coir fiber on UCCB density has slight low effect because of its low volume content. The water absorption coefficient for UCCB with or without reinforcement of sisal and coir fibers compressed at 4, 6, and 8 MPa decrease as compressive pressure increasing. This is due to the density of UCCB increases as compressive pressure increasing. Therefore, UCCB composite is undesirable in traditional construction because water absorption coefficient greater than 2 Kg/m^2/min.

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