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Splitting Tensile Strength, Physical and Durability Properties of Cement Stabilized Earth Block Reinforced with Treated and Untreated Pineapple Leaf Fibre

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Abstract

In the present study, the physical and mechanical strength of cement stabilized earth block reinforced with treated and untreated pineapple leaf fibre (T-PALF, N-PALF) have been studied. Three types of blocks were casted, firstly the block of dimensions 290*140*120mm were casted and these block were casted for abrasion test, secondly the cube blocks of dimensions 150*150*150mm were made and they were casted for water absorption and density test; thirdly were casted cylinder block of dimensions 200*100mm for Splitting tensile strength. It was found that, the water absorption of the blocks increase with increase of fibre content, the density decrease with fibre content. The fibre have increased the abrasion resistance and tensile strength of the blocks up to 3% of fibre content afterward it decreased. It was also observed that, the T-PALF had significantly improved the properties of the blocks comparing to those reinforced with N-PALF.

1. Introduction

All materials which have strength in compression has also strength in tension, these two properties of materials are always consider and one property can affect another. If a material is not homogeneous in its reinforcing matrix, tensile strength tends to be affected more than compressive in most cases.

For the most of time, tensile strength of brick masonry is assumed to be equivalent to zero (0). However, as the compressive strength, the tensile strength is also good to consider while designing especial work. For example the tensile strength of brick become important especially when the buildings wall are subjected to earthquake or if we have to avoid either reinforced concrete band or reinforcements due to corrosion prone zones, such as coastal areas, splash zones or for some especial works. Earth requires two properties to make it strong enough for building, compressive and tensile strength, masonry bricks suffer significantly of cracking and this may lead to significant damage for the wall when this is in contact with exterior agents (wing, lateral forces etc.). It may also suffer a lot of shear failure when it is subjected to earthquake event.

The failure of brickwork subject to axial compression is normally by vertical splitting due to horizontal tension (EN, 2003), The vertical splitting is the failure of the blocks under tensile stress so in the way to test the tensile strength, we can make splitting tensile strength test and furthermore according the works of many researchers indirect tensile splitting method produced a higher stress on the width than on the length of the bricks. In the present study indirect tensile splitting was adopted.

2. Material Acquisition and Experimental Set-up

2.1 Material Acquisition (Vodounon, Kanali, & Mwero, 2018)

The study was conducted at Jomo Kenyatta University of Agriculture and Technology (JKUAT) from February to June 2018. JKUAT is located in Juja township, 10 km West of Thika town and 45 km East of Nairobi, Kenya. The latitude, longitude and altitude of the location are 1.18ºS, 37ºE and 1460 m above sea level, respectively. Laterite soil and sand used for the study were procured from Juja and Nyeri, respectively. The soil was kept under polyetilene cover to ensure that it was neither too dry (by sun dry) nor too wet (by rain). In addition, Pozzolanic cement CEM IV/B 32.5R used in the study was formulated in accordance to the KS EAS 18-1:2001, which is adopted from the EN 197-1 European Standards. Finally, PALF which were the main material to be used for reinforcing the bricks were obtained from Hand Conifer Company Ltd, Mumbai, India.

2.2 Experimental Set-up

2.2.1 Determining the Physical and Chemical Properties of the Soil (Vodounon, Kanali, & Mwero, 2018)

The physical properties for the soil that were examined included moisture content, maximum dry density, Atterberg limits and soil size particle distribution. The moisture content was determined according to BS 1377: 1990. Dry density, Atterberg limits and the size distribution were analysed at JKUAT, as per to BS 1377-2: 1990 (BS 1377-2: 1990, 1990). On the other hand, the chemical composition of the soil assessed proportions of silicon oxide (SiO_2), aluminium oxide (Al_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sodium oxide (Na_2O), potassium oxide (K_2O), titanium oxide (TiO), manganese oxide (MnO), ferrous oxide (Fe_2O_3) and loss on ignition (LOI) which represents the mass of moisture and volatile material present in a sample. The volatile materials lost usually consist of 'combined water' and carbon dioxide from carbonates. These properties were analysed according to BS 1377-3:1990 (BS 1377-3:1990, 1990) at the laboratories of the Ministry of Mining and Petroleum, Government of Kenya.

2.2.2 Evaluating the Chemical Properties of the fibres

In order to assess the effect of alkali treatment on the fibre, 4% of NaOH solution was prepared by dissolving 80 g of NaOH in 2000 cm3 of distilled water afterward the fibre were immersed for a duration of one hour. The NaOH treatment is one of the best treatment used for natural fibres. It helps to increase the fibre surface roughness by chemically modifying and cleaning the fibre surface (bt Ahad et al., 2009).

2.2.3 Determining the Mechanical, physical and durability Properties of Cement Stabilized Reinforced Blocks

a) Mix Design

The material for making cement stabilized blocks reinforced with PALF were prepared as follows. First, Portland cement, sand and laterite soil were mixed in proportions of 3, 27 and 70% by mass, respectively, and water was added to form a paste of acceptable range of moisture content, where simple drop test was done according to the New Zealand Standard 4298 (1998) (N. 4298:1998, NZS 4298, 1998). This formed the first specimen. Another specimen comprising a mixture of 5, 25 and 70% of Portland cement, sand and laterite soil, respectively, was prepared in similar manner. For both specimen, T-PALF and N-PALF were added in proportions of 0 to 5% in steps of 1% by mass of cement. The length of fibres used in this study was on average 30 mm since it necessary the fibres be short and straight to enable a quick dispersal without clinging (Ismail & Yaacob, 2011). Hand shovel mixing was used to ensure that there is a good dispersion of the fibres in the cement to prevent balling up. Laterite soil and sand were added after mixing cement with the fibres. The mixing process took 10 minutes to ensure an even dispersion of all the materials. In this study the treated fibres for one hour and untreated were used.

After mixing, the materials were poured into three different moulds, firstly it was poured into cylinder mould of internal diameter 100mm and 200mm of length, and the compaction was made by using automatic compaction's machine as shown in Figure 1, this compaction was made in three layers with standard number of 25blows. The cylinder blocks were casted for tensile strength test. Secondly, the cube and prism blocks of dimension 150×150×150mm and 290×140×120mm respectively were casted using manual stabilized mould. The cube and prism blocks were subjected to density, abrasion test and water absorption tests. Thereafter, they were stored in the open air for 7 days afterward for 21 days for curing before being submitted to the different tests.

a) Mechanical test: tensile splitting test

The tensile splitting test were conducted in accordance with BS EN 12390-6(2009) (British Standards Institution BSI, 2009) after 28 days of curing. The load were applied continuously at a steady rate of 0.05 N/ mm^2/s up to failure of the brick, and tensile splitting strength recorded. Equation (1) was employed to calculate the splitting tensile strength (T in MPa) of cylindrical blocks. In the equation, P is the maximum applied load (N), d and L are diameter and length (in m) of the blocks, respectively.

$$T = \frac{2P}{\pi L d} \quad (1)$$

b) Durability test: Abrasion test

Each brick sample was weighed before the test was conducted. The sample was placed on a flat horizontal table-top secured against sliding as prescribed in AASHTO - T96, 2010. The top side of the sample was given 20 strokes of wire brush after which the sample was reweighed, and the depth of abrasion measured and recorded. The abrasion value (α) was computed by equation (2) in which ω_1 (weight before abrasion) and ω_2 (weight after abrasion).

$$\alpha\ (\%) = 100\left(\frac{\omega_1-\omega_2}{\omega_1}\right) \tag{2}$$

Figure 1. Making compressed stabilized cylindrical blocks

Figure 2. Splitting tensile strength set up

c) Physical properties tests

- The densities

The densities of the brick samples were determined at 28th days of curing. The test was carried out in accordance to Nigerian Industrial Standard (NIS 87, 2004). Equation (3) was utilized to compute the density (ρ) in which m and v are the mass and volume of the brick, respectively.

$$\rho = \frac{m}{V} \tag{3}$$

- Water absorption

Water absorption test were conducted as per the EN 771-1:2003 (E) Annex C procedures (EN, 2003). The bricks were placed in oven till they reach a steady state weight (W_1). Thereafter, the bricks were immersed in cold water for 24 hours to absorb water. They were then taken out of water, wiped and weigh again (W_2). The percentage water absorption (θ) was determined using equation (4).

$$\theta = 100\left(\frac{W_1-W_2}{W_1}\right) \tag{4}$$

3. Results and Discussion

3.1 Physical and Chemical Properties of the Soil (Vodounon, Kanali, & Mwero, 2018)

The results of the physical properties of the soil used in this study are shown in Table 1. The results show that the sand and clay proportions are each equal to 20%. This amount of clay is high for making good soil bricks according to Venkatarama Reddy, Lal, and Nanjunda Rao (2007). In order to reduce the clay dominance in the bricks some sand was added, because high clay content leads to excessive drying shrinkage, and it lessens durability and compressive strength (Venkatarama Reddy, Lal, & Nanjunda Rao, 2007).

Table 1. Physical properties of the soils

Properties	Values	Properties	Values
Proctor test:		Particle size distribution:	
Optimum moisture content (%)	31.1	Gravel (20 - 2 mm) (%)	2
Maximum dry density (kg/m^3)	1351	Sand (2 - 0.06 mm) (%)	20
Atterberg limits:		Silt (0.06 - 0.002 mm) (%)	58
Liquid limit, wL (%)	54	Clay (<0.002 mm) (%)	20
Plastic limit, wp (%)	28	pH:	7.31
Plasticity index	27	Soil classification (USCS):	CH

Table 2 shows the chemical composition of the soil, and it can be seen that the Silica Sesquioxides ratio (SiO_2/ [Al_2O_3+Fe_2O_3]) of the soil is equal to 1.5. This value is between 1.33 and 2.0 implying that the soil was indeed laterite soil, according to previous study (Pivatto, Duarte, Marcia, & Duarte, 2013). Laterite soil is the most suitable soil for making bricks because of its properties are not significantly affected by changes in its moisture. All these properties make the soil to be suitable for making bricks.

Table 2. Chemical composition of the soil

Chemical composition	Proportion (%)	Chemical composition	Proportion (%)
SiO_2	51.31	K_2O	1.7
Al_2O_3	22.26	TiO	1.25
CaO	1.33	MnO	0.34
MgO	0.06	Fe_2O_3	8.00
Na_2O	2.5	LOI	10.00

The particle size distribution of the soil corresponds to result of both dry sieving and hydrometer test (see Figure 3). It is observed that 58% of the soil passed through 0.06 mm sieve, indicating that the soil has a fine texture, according to ASTM. The fine texture of the soil confirms its high clay and silt content. Furthermore, it confirms why the soil has high liquid limit and plasticity index values which are not suitable for making soil bricks since this leads to excessive drying shrinkage, and low durability and compressive strength.

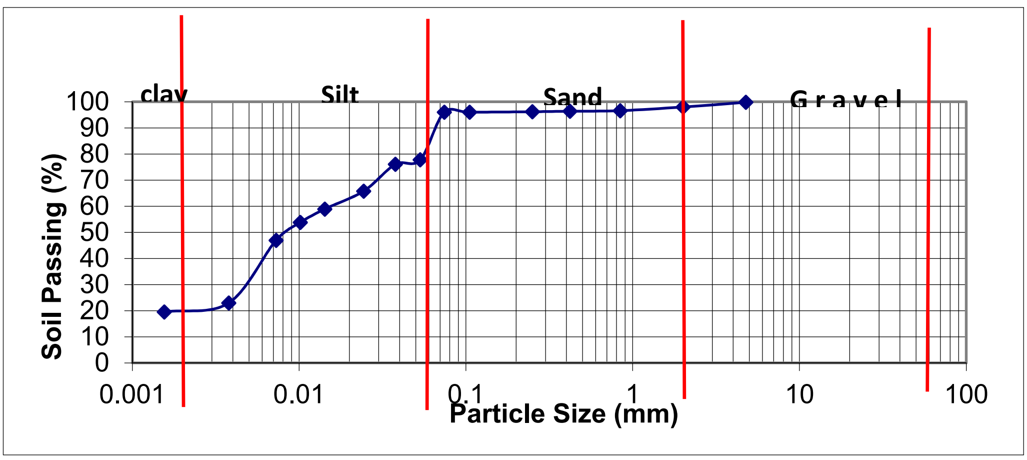


Figure 3. Particle size distribution of the soil used for the study

3.2 Chemical Properties of Pineapple Leaf Fibres

The results for the chemical properties of the pineapple leaf fibres are presented in Table 3 and they show that cellulose, hemicellulose and lignin decreased of with increase in duration of treatment of the fibres with sodium hydroxide. The small quantity of lignin present allowed the fibre and the soil matrix to have sufficient adherence (Oushabi et al., 2017).

The water absorption was carried out according to ASTM D2842 and the results shown that non-treated (N-PALF) and treated (T-PALF) pineapple leaf fibres had 84.4 and 80.5% moisture content, respectively. This indicates that sodium hydroxide had improved hydrophilic properties of the fibre, implying that reinforced blocks with treated pineapple leaf fibre would absorb less water.

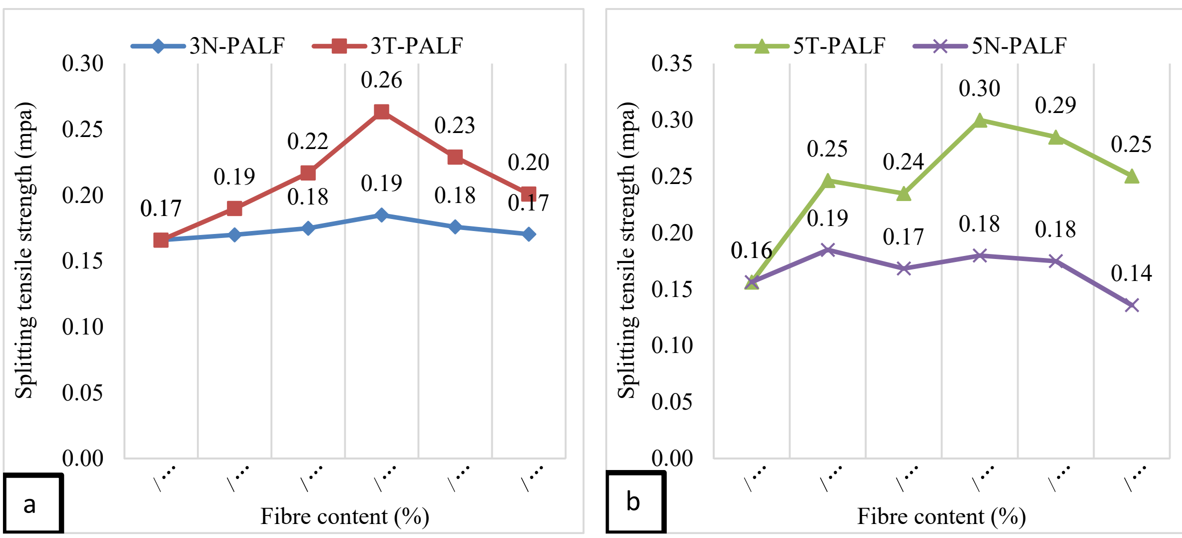
Table 1. Chemical composition of pineapple leave fibres for 4% treatment of sodium hydroxide

Duration of treatment (min)		Chemical composition (%)		
		Cellulose	Hemi-cellulose	Lignin
0	N-PALF	78.68	70.78	10.32
30	T-PALF	75.76	68.44	9.30
60	T-PALF	74.87	67.55	9.26
120	T-PALF	74.61	67.12	9.14
180	T-PALF	74.01	66.81	9.06

3.3 Splitting tensile strength test result of cement earth stabilized reinforced blocks

Splitting tensile strength was used to assess the tensile strength of brittle materials as mortar, because direct tensile test cannot be done on such types of materials. The summary of the splitting tensile strength test result is presented in Figures 4. The results show that the splitting tensile strength increased with increase of fibres content but after 3% fibre content it start decreased. The strength decreased because the high content of fibre in the blocks made a balling up which caused the blocks to loose strength. For both blocks stabilized with 3 and 5% of cement and reinforced with treated and untreated fibres, it was observed that the treated fibre had significantly improved the tensile strength when compared to those reinforced with untreated fibres. This is because the sodium hydroxide treatment increased the tensile strength of the fibres and this lead to the increase of the tensile strength of the blocks. In Figure 4.a), it is observed that with 3% of fibre content there was increase of 62.5% of blocks reinforced with treated fibre over the untreated one, while in Figure 4.b) with 5% of fibre content there was increase of 66.7 of blocks reinforced with treated fibre over the untreated one.

By looking at figure 5.a), it was observed that the unreinforced blocks has a divided into two pieces at failure stage, while in Fig 5. b) the fibre had made the reinforced block to be more ductile and more flexible and this property made the reinforced blocks to be more resistant.



3N-PALF means stabilized with 3% cement and reinforced with untreated fibre

Figure 4. Tensile strength of 3 and 5% cement stabilized blocks reinforced with T-PALF and N-PALF

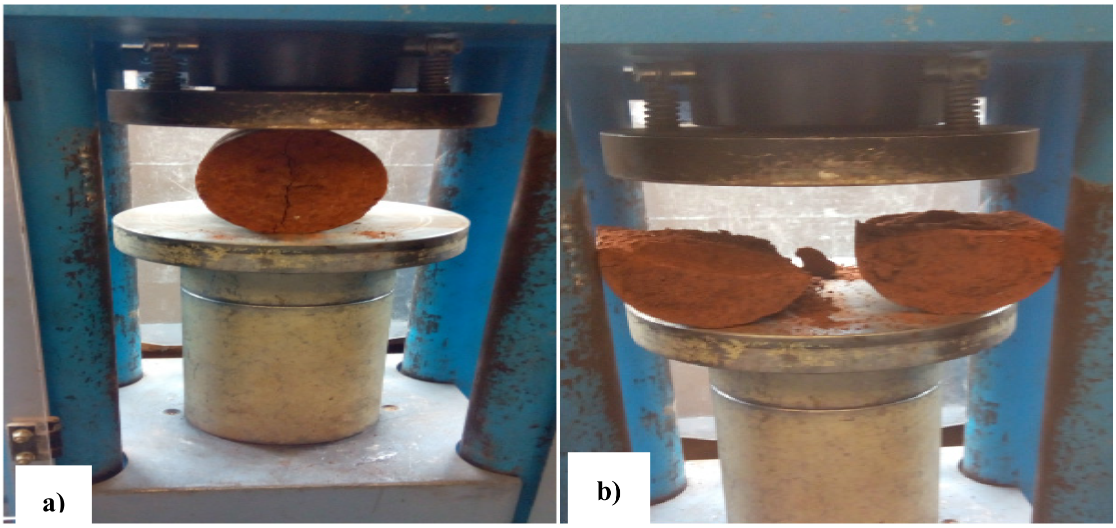


Figure 5. splitting tensile strength experiment of a) reinforced and b) unreinforced blocks

3.4 Physical properties of cement earth stabilized reinforced blocks

3.4.1 Density test

The results in Figure 6 show that the dry density of the blocks ranged between 1827.3 and 2074.0 kg/m^3. It is also observed that the densities of blocks stabilized with 5% of cement are higher than those stabilized with 3% of cement, this happened because of packing density (the fraction of a volume filled by a given collection of solids), in this study 5% of cement filled better the empties spaces in the blocks compare to those stabilize with 3% of cement, hence 5% of cement has increased the density of the blocks. A similar observation has been made by Raj, Mohammad, Das, and Saha (2017) in which the density of earth stabilize blocks increase with increase in cement content. On the other hand, it was also observed that the density of the blocks decreased with increase in fibre content. The density was higher for blocks reinforced with treated fibres as compared to those reinforced with non-treated fibres. This may be explained by the hydrophilic properties of the fibre because the treated fibre absorbed less water comparing to non-treated ones. According to Sampathkumar, Punyamurth, and Venkateshappa (2012) alkali treatment improves the water absorption of areca fibres, so after curing they created more space within the block hence its weight becomes lighter than those reinforced with treated fibres.

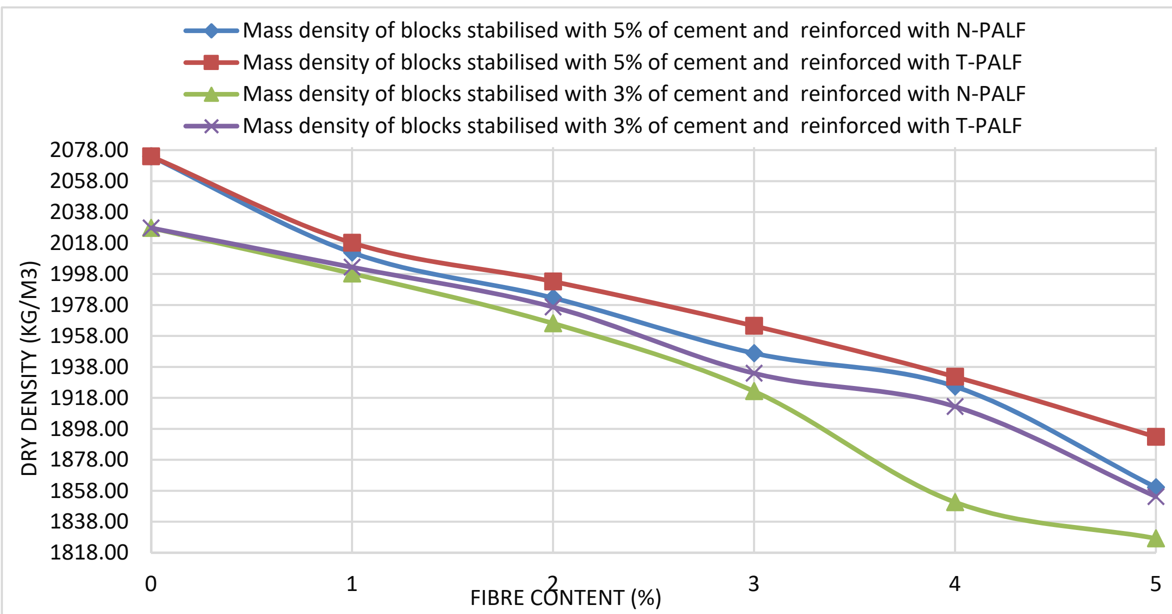
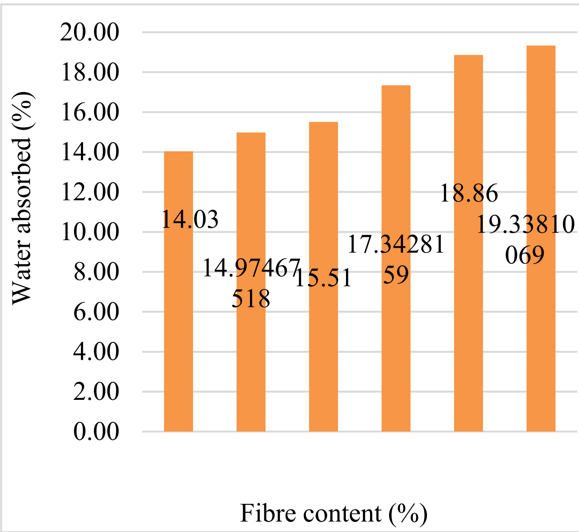


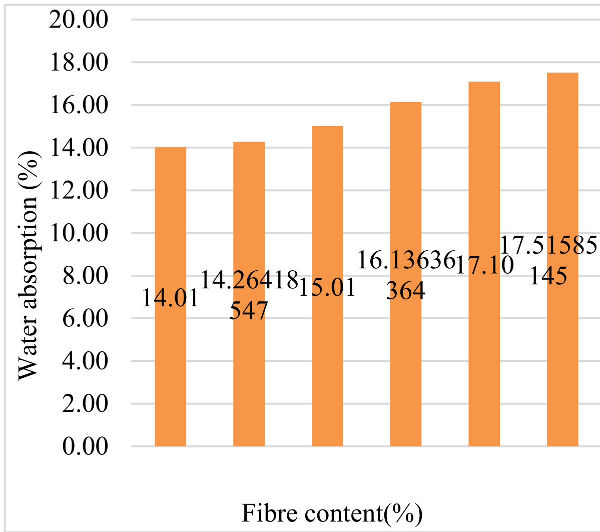
Figure 6. Relation between dry densities of blocks with increase in fibre content

3.4.2 Water Absorption Test

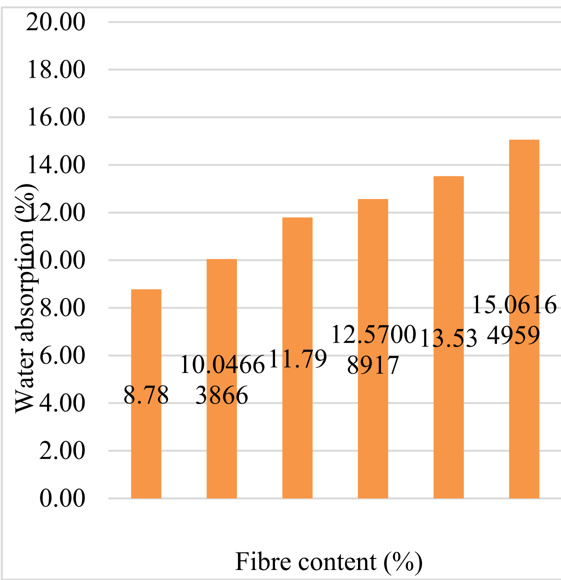
Figure 7 shows the water absorption of the blocks. According to this result it was observed that, first of all the cement stabilize blocks reinforced with T-PALF have less water absorption comparing to others reinforced with N-PALF because the T-PALF absorbed less water than N-PALF as previously described, furthermore it was observed that the stabilized blocks with 5% of cement have less water absorption compare to those stabilize with 3% of cement. It is then important to notice that, 5% of cement is best rate for soil block because with 5% of cement the chemical reaction between the cement and soil particles is higher and this allows a good bondage between the soil particles and hence it absorbed less water. As example C. Egenti et Al. found that the water absorption of laterite bricks decreased with increase of cement content (Egenti, Khatib, & Negim, 2015).



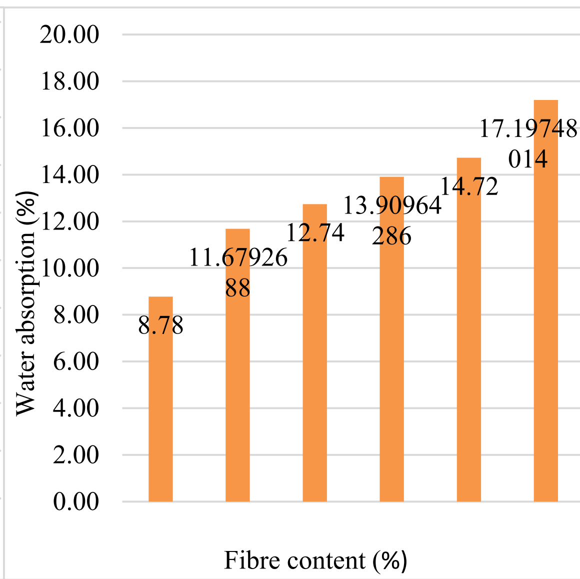
a: N-PALF stabilized with at 3% of cement



b: N-PALF stabilized with at 3% of cement



c: T-PALF stabilized with at 5% of cement



d: N-PALF stabilized with at 5% of cement

Figure 7. Water absorption result

3.5 Durability test result on the blocks: Abrasion test

The results in Figure 4.15 show that abrasion resistance increase with an increase in fibre content up to 3% afterward it decreased. In addition, it was observed that the blocks stabilized with 5% of cement resisted against abrasion more than those reinforced with 3% of cement. Furthermore, the blocks reinforced with treated fibres had higher abrasion resistance as compared to non-treated ones. According to Yan, Chouw, and Yuan (2012), the treated fibres were able to increase abrasion index as the sodium hydroxide treatment makes the surface of the fibre to become rough.

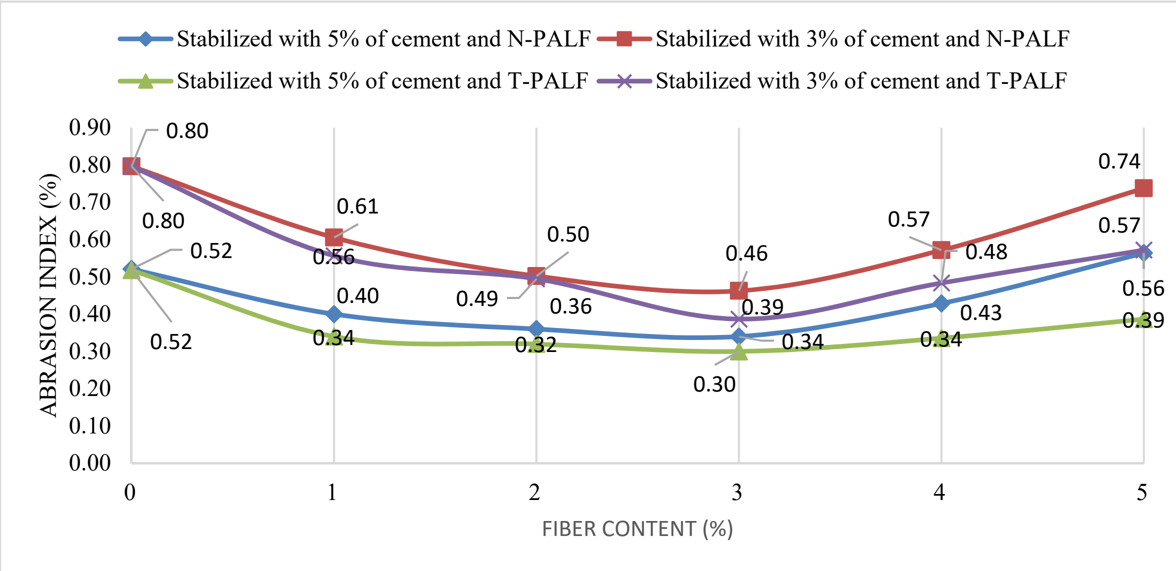


Figure 3. Abrasion test result

4. Conclusion

In the present work, the bellows conclusions can be made:

1) The density of the blocks decrease with increase of fibre content while it water absorption increase due to the water absorption of the fibres, but the treated fibre absorbed less water comparing to untreated fibre,

2) The tensile strength of the blocks increase up to 3% of fibre content afterward it started decreasing, also it was observed that the treated fibre had significantly increase the tensile strength of the blocks while comparing to those reinforce with untreated fibre,

3) The treatment of fibre in sodium hydroxide solution decreased the chemical composition of the fibre, and more the fibre stay in water more chemical composition decreased,

4) The treated fibre had a good adhesion with the soil particles and this led to increase the abrasion index of the block up to 3% of fibre content.

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