Mechanical Properties of Kenaf Fibrous Mortar for Brickworks

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Abstract. Kenaf fibre is a natural fibre from plant that has a potential usage as reinforcement material in cement and concrete. Preliminary study on kenaf fibrous concrete found that kenaf fibre has good properties mainly to improve tensile and flexural strength of concrete. Hence, the fibre may improve the strength properties of mortar as a bonding material for brickwork. This study was conducted to investigate the mechanical properties of kenaf fibrous mortar and brickwork. Kenaf fibre with 0.75% volume fraction and 50 mm length was applied for the study. For testing on kenaf fibrous mortar, the cube samples of 50 mm x 50 mm x 50 mm, cylinder sample of 100 mm diameter x 200 mm height, were casted and tested for compressive and tensile strength. A total of 12 cube samples and 12 cylinder samples have been prepared for the tests. For brickwork samples, the clay brick units with the standard size of 70 mm x 100 mm x 210 mm were employed for the test; the units were bound together as triplet brickwork samples for compression and shear test. While for tensile test, the brickwork samples were prepared as cross couplet brickwork with two brick units. A total of 36 samples of brickworks have been prepared both for compression, shear and tensile tests. The kenaf fibrous mortar was cured in clean water for 7 and 28 days, while the brickwork samples were cured under wet sack in room environment for 7 and 28 days before testing. Results showed that the workability of kenaf fibrous mortar reduced approximately 57% as compared to normal mortar. The compressive and tensile strength of kenaf fibrous mortar was lower than normal mortar. For the brickwork of kenaf fibrous mortar, the strengths were almost lower as compared to the brickwork of normal mortar. It could be stated that the existence of kenaf fibre with 0.75% volume fraction and 50mm length as reinforcement in the mortar was not sufficient to improve the mechanical properties of mortar. The study on the optimum quantity and length of fibre is needed to determine the maximum mechanical properties of kenaf fibrous mortar for brickwork.

Introduction

Fibre reinforced mortar is the solution to control the cracking and the mode of failure by means of post-cracking ductility. Kenaf fibrous mortar is one of the solutions to overcome this problem. Addition of kenaf fibre in mortar also will reduce the problem of cracking which caused by surface tension. Other function of fibre in mortar is to lower the permeability of mortar and to reduce bleeding in water. Important step which take place before mixing kenaf in to the fresh mortar mix is the kenaf fibre need to have treatment to withstand in mortar. Kenaf fibre must achieve ph 13 which have same ph with the mortar [1]. In Malaysia, mortar is commonly used as wall plastering and to bind the brick. Mortars also being used to increase the aesthetic value of the building, improve the sound and water resistance through the building especially through wall structure. There are different types of replacement and addition materials have been made to improve the mechanical properties of the mortar. One of them is natural kenaf fibre addition in masonry mortar. The effective value of addition of kenaf fibre is 0.75% by weigh of wet mortar [1]. The development of construction industry in this country contributes various researches to increase the effectiveness and quality of the construction. Many researches were done to produce high quality of mortar. Previous studies were stated about additives in mortar or concrete from natural fibre and synthetic fibre. Palm oil fibre and glass fibre are example of the natural fibre and synthetic fibre respectively. However, their finding is limited and needed more studies to prove that this fibre can be applied in this construction industry.

The main objective is to investigate the mechanical properties of kenaf fibrous mortar and application of brickwork. In this research, two type of sample will be produced which is kenaf fibrous mortar and normal mortar as control. All tests which are laboratory test will be carried out to determine the mechanical properties of kenaf fibrous mortar such as splitting tensile test and compression test to compare with normal mortar. For application of brick work, which is include triplet clay brick also to be conducted to determine compression and shear value of the normal mortar and kenaf fibrous mortar. While for tensile test, the brickwork samples were prepared as cross couplet brickwork with two brick units to be tested to obtain its tensile srength. In this research, 24 samples for mortar testing will be casting and 36 samples for application of brickwork will produced. The testing will be conducted after 7 and 28 day of curing. The usage of kenaf fibre, which is natural renewable resources as an additive in mortar not much practiced in this construction industry. It is important to involved biocomposites materials such as kenaf fibres which improved the sustainable aspect in construction technology. National Tobacco Board has taken a drastic action to expand the plantation of kenaf fibres since it is very beneficial to any industrial aspects and also act as one of the green materials which help to improve the quality of the environment. Second reason is to reduce the plantation of tobacco by replaced it with the plantation of kenaf plants because both of this plant can be planted on the same type of soil. Research on the natural fibres should be done widely in the country to achieve a sustainable environment. So, the significant of research for this study are to investigate the mechanical properties of mortar when natural kenaf fibre was used as an additive in mortar.

Previous Studies

Mortar is basically a construction material that consists of water, cement and fine aggregates. It can be added with additives to produce mortar with certain properties. Cement mortar becomes hard when it cures, resulting in a rigid fine aggregate structure. However the mortar is intended to be weaker than the building blocks and the sacrificial element in the masonry because it is cheaper and easier to repair than the building blocks. The most common binder since the early 20th century is Portland cement but the ancient binder lime mortar is still used in some new construction.

Mortar is designed to be used in thicker applications and to reach very high strengths. Mortar is also designed to be durable but achieves its goal through finesse. Its strengths are quite low compared with concrete and it is never used in thick applications. It is much creamier and more workable than concrete. Mortar also known as workable paste used to bind building blocks such as stones and bricks together, fill and seal the irregular gaps between them, and sometimes add decorative colours or patterns in masonry walls. It also is used as wall plaster. Mortar must be durable, strong and capable of keeping the wall intact. It must also be a good water and sound resistance. Mortar bonds individual brick together to function as a single element. In its hardened state, mortar must be durable and must help resist moisture penetration. It must accommodate dimensional variations and physical properties of the brick when laid. These requirements are influenced by the composition, properties and proportions of the mortar.

The concept of using fibres as reinforcement has been a fundamental part of human life since the dawn of civilization. Fragments of cotton articles dated from 5000 BC have been excavated in Mexico and Pakistan. According to Chinese tradition, the history of silk begins in the 27th century BC. The oldest wool textile, found in Denmark, dates from 1500 BC, and the oldest wool carpet, from Siberia, from 500 BC. Fibres such as jute and coir have been cultivated since antiquity [2].

Kenaf Fibre

Kenaf (Hibiscus cannabinus, L. family Malvaceae) is an herbaceous annual plant that can be grown under a wide range of weather condition. For example, it grows to more than 3 m within 90 to 120 days in Malaysia environment. Kenaf plants can grow approximately 3m to 4m within 4 to 5 months of growing season with an annual fibre yield of 6 to 10 tons of complete dry fibre per acre [4]. This plant can be found in southern Asia. This kenaf is one of the allied fibres of jute and shows similar characteristics. It is also a close relative to cotton and okra and is originally from Africa. According to [3] kenaf fibre is native to Africa and Asia and one of the most widely cultivated natural fibres. It is a crop that is easily grown and is high in yield. It growing with a woody base and the stems are between 3 to 5 cm of its diameter, often but not always branched. After sowing the kenaf's seeds, it is able to grow under a wide range of weather conditions, to a height of more than 3 m and a base radius of 1.5 cm to 2.5 cm [4]. According to [5], different opinion and view on the fibre length was shared and all of the above information are slightly difference based upon how, where, and when a Kenaf is grown and harvested.

Kenaf is mostly known for its fibres as these are the largest fractions of kenaf. In a kenaf stalk, there are two distinct fibre types, the inner and the outer fibres namely core and bast, respectively. Bast is a coarser fibre in the outer layer while core fibre is a finer fibre in the core. The bast comprises roughly 40% of the stalk's dry weight. The refined bast fibres measure 2.6mm and are similar to the best softwood fibres used to make paper. The core comprises 60% of the stalk's dry weight. These refined fibres measure 6mm and are comparable to hardwood tree fibres, which are used in a widening range of paper products. Kenaf is similar to flax straw, jute and hemp because of the characteristic of having two different type regions of fibres in a stalk [6]. The paper, cardboard, panels, traditional cordages, absorbent agent, packing materials, twine, sackcloth and mats are some of the example product of this fibre [9]. The fibre length increases with the increase of kenaf height. However, it was found that the fibre length reduce as the plant reach its matured phase. It was also discovered from the same study by [6], kenaf bast fibres grow much more active compared kenaf core fibres. This may become important reason why kenaf bast fibres are longer and stronger than kenaf core fibres. According to [7], the distinct of fibre length may also influence by genetic of the tree for the internal factor as well as external factors like sunlight and water. Kenaf is a non wood lignocellulosic material because its main elements are cellulose, hemicelluloses and lignin [8].

Methodology

This chapter will explain in detail about research planning, discussion about methods to determine the mechanical properties of kenaf fibrous mortar study and also about the materials will be used. In the early stage, the data was collected from previous research and form the other resources such as research paper, book, journal, articles, and also some information from the internet. The material that going to be used should be well prepared in term of the types, quality and the quantity of the material. The tests that will be run on this research are divided into two categories which is mortar testing and application of brickwork. The test that to be conducted should follow the standard and the specification that have been establish.

Fibre Content

In this research, the most effective value of addition of kenaf fibre into the mix is 0.75% by weight of young mortar. The length of kenaf fibre to be added in mortar to improve its mechanical properties should be in bulk or short fibre, 50 mm [1]. The bulk density of the fibres used was 1.2 g/cm^3. Water retted Kenaf fibre was obtained from Nasional Tobacco Board at Bachok, Kelantan. The fibre was already extracted, washes with water to remove any impurities, then dried under the sun and was kept in the dried bag to avoid from moisture absorption. The alkali treatment is a commonly used method to clean and modify the fibre surface and enhance interfacial adhesion between a natural fibre and a polymeric matrix [10]. Research by [11] was confirmed that the alkali treatment removed the hemicelluloses from the fibre. Raw kenaf fibre was chopping into length of ±30cm and weight to ±100g by using weighing scale. Kenaf fibre has been tied in a bundle of ± 100g by using cable tie to ease the next step of treatment process. Kenaf fibres were then soaked in sodium hydroxide (NaOH) solutions of pH 13 for 16 hours at the room temperature before extracting the fibres. The optimum concentration of sodium hydroxide (NaOH) in term of cleaning fibre bundle surfaces and with high tensile strength is 6%. [12] found that, when the concentration of sodium hydroxide (NaOH) is higher than 6%, the tensile strength of fibres exhibited significant decrease. Fibres are treated with NaOH to remove lignin, pectin, wax substances, and natural oils that cover the surface of the fibre cell wall [11]. After decortications, the fibres were washed with distilled water until it reached pH 7 and then dried for 3 days in the ambient temperature before chopping into lengths of 50 mm for incorporation into cement matrix.

The mass of treated kenaf, M_1:	The quantity of untreated kenaf, M_2:	(1)
M_1 (Kg)= V x 0.75% x ρ	M_2 (Kg) =M_1 x 97.5% x 1.2(wastage)	

Where:
V is volume of sample (m^3)
ρ is density of kenaf fibre (1202kg/m^3)

Water Absorption

The moisture absorption capability of kenaf fibre increased after chemical treatment. This process is important and need to be conducted at least 15 minutes before casting the sample. This process will avoided treated kenaf fibre from absorb the water for hydration process of cement during mixing of kenaf fibrous mortar

$$\text{Volume of water absorption (kg)} = M_1 \times 4.9 \qquad (2)$$

Cement

Ordinary Portland Cement is going to be used in this study. Portland cement is a product obtained by grinding clinker from the burning of raw-materials namely (argillaceous and calcareous) primarily consisting of lime (CaO), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) to a fine powder. The blended cement should be avoided in this research because the testing result will be varies. Blended cement is a combination between Ordinary Portland Cement (60%) and Pozzolanic materials (40%), which contains reactive SiO_2. Pozzolanic materials in each cement sack will be different. Example of pozzolanic material is slag, fly ash and silica fume.

Water

Water is one of the main materials in the mortar mixture. The presence of water will perform the hydration process of cement. In the presence of water, the cement compound chemically combined with water to form new compounds that are the infrastructure of the hardened cement paste in the mortar. Both Tricalcium Silicate ($3CaO.SiO_2$) and Dicalcium Silicate ($2CaO.SiO_2$) hydrate to form calcium hydroxide ($Ca(OH)_2$) and about 50% calcium silicate ($C_3S_2H_2$) hydrate by mass. The higher volume of water use in the mix will increase its workability but may cause bleeding and reduce its strength. Any impurities in water should be avoided because it may reduce the strength of mortar and create later problem to the mortar. Any water that suitable to be drink is suitable to be used in the mixing of the mortar. Tap water is one of the common water used in the production of cement or concrete.

Fine Aggregate

In this research, fine aggregate which passing 600 µm (no. 30) will be used. Fine aggregate was dried by surrounding around 24 hour to remove any moisture within it. Fine aggregate which contain moisture will interrupt the w/c ratio of the mix.

Clay Brick

In this research, a total 340 of clay brick have been bought from the building material supplier and all of them were used for trial and actual application of brickwork. The price of one brick is RM0.48. For each mortar mix batch, it needs 48 clay bricks for making sample for compression, shear and tensile test.

Mortar Specimen

For the mortar testing, two type of shape will be used which is cube and cylinder. The size of cylinder will be used for splitting tensile test is 100mm diameter x 200mm height. For compression test, 50mm x 50mm x 50mm of cube will be used. Two type of specimen will be used which is kenaf fibrous mortar and normal mortar as control specimen. The total number of mortar specimen is 24. For the application of brickwork, the kenaf fibrous mortar and normal mortar will used to bind the clay brick. The couplet brick which mean two brick and triplet which mean three brick will be used in the application of brickwork test. The total number of specimen for application of brick work is 36.

Mixing Process

The mix proportion for mortar was 0.5:1:2 (water: cement: sand). All of the mixing process are using electric powered mixer. The aim of the mixing the raw ingredients is to ensure that each particle of fine aggregate and the short kenaf fibre in fresh concrete will be coated with the cement paste[13]. The balling effect of fibres is one of the problems encountered. This problem can be solve or minimize by tear the kenaf fibre into the smaller individual piece, dispersed it randomly and mix it gradually. This problem also can be minimized by using the concrete mixer.

Specimen casting and compaction

The cylinder and cube steel mould is being cleared, tight the screw and it is layered with grease so that the mix will not stick at the mould after the mixture is harden. The mix need to put in 3 layers to ease the compaction process. For each layer, it needs to be compacted for ±15seconds by using external vibratory table. The usages of external vibratory table ease the sample preparation process and make work faster with the constant of compaction for each sample. The specimen preparation process should take less than 45 minutes. Later, the sample is being dry for 24 hour and being covered by using dry gunny sack for 24hours. After that, the steel mould is carefully remove from the harden mortar sample to prevent harm any to the samples. Later, the sample is put into the curing tank for further curing process. For the application of brickwork, cut the plywood to make frame or boundary, 10mm height, 90mm width and 200mm length for triplet brick. For the couplet brick, 10mm height, 90mm width and 90mm length is used. The usage of frame is to make constant in thickness of mortar layer and avoid spoil of excess mortar. The mortar is filled between the frame and above the lower brick. Some pressures were applied to make sure bonding between the brick. The frame is removed and lays the upper brick. The process repeated for next layers or samples.

Mortar Flow Table Test

Similar to slump, mortar flow is a relative measure of workability. Water content, fine aggregate gradation, cementitious chemistry, mixing time, air content, and concrete temperature all interact to affect mortar flow. The procedure to conduct flow table test is following the Standard Test Method for Flow of Hydraulic-Cement Mortar, ASTM C 1437. It determines how much a mortar sample flows when it is unconfined and consolidated. Workability of mortar is its ease of use measured by the flow of the mortar. The standard flow tests uses a standard conical frustum shape of mortar with a diameter of four inches. The flow is the resulting increase in average base diameter of the mortar mass, expressed as a percentage of the original base diameter.

$$\text{Mortar flow (\%)} = \frac{A - D_0}{D_0}\, X\, 100 \quad \text{Where } A = \frac{D_1 + D_2 + D_3 + D_4}{4} \qquad (3)$$

D_1, D_2, D_3, D_4 is diameter of spread mortar

D_0 Is original mould base diameter (101.6 mm)

A is average of four reading

Method of Curing

Water is important during the curing process and the suitable pH value of water for mortar construction shall generally be between 6 and 8. Pipe water is used in this study. Curing help to continuing the hydration process of cement and to avoid water loss by dehydration of young mortar. The term "curing" is commonly used to describe the process by which hydraulic-cement concrete or mortar to matures and develops hardened properties over time as a result of the continued hydration of the cement in the presence of sufficient water and heat [14]. In this study, water curing will be applied for mortar testing sample to allow the mortar to develop its potential strength and durability. For application of brickwork, room temperature curing most suitable method to use due to its size and shape. The bricks samples will be covered by wet sack. The sample will be curing for 7 and 28 days.

Mortar Testing

Compression Test. Compressive strength test for mortar cube was carried out according to ASTM C109-1990. The compressive strength was determined after 7 and 28 days. In this study 6 cube samples of normal mortar and 6 cube samples of kenaf fibrous mortar will be tested to get the compressive strength. This test method covers determination of the compressive strength of cement mortars, using 50mm x 50mm x 50 mm cube specimens. To ensure a uniform bearing, thin plywood (60mm x 60mm) were placed between the cubes during testing to take up the irregularities. The pace rate of 6kN/s is applied to the test specimens until it reach its maximum strength. The maximum load carried by the specimens was recorded. The compressive strength, f for the cylinder is calculated using the formula bellow.

$$f = \frac{P}{A} \tag{4}$$

Where:

f = compressive strength, MPa
P = load applied when sample failed (KN)
A = area of mortar cube (2.5×10^{-3} m²)

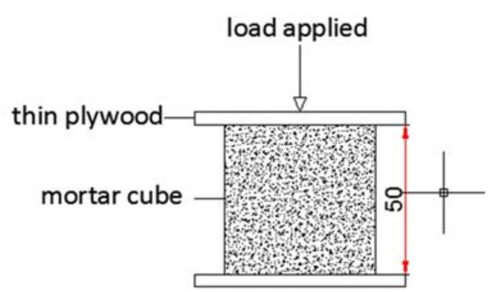

Figure 1: Compressive strength test schematic

Cylinder Splitting Tensile Test. The test is done by testing on mortar cylinder samples according to Standard Test Method for Splitting Tensile Strength of Cylindrical mortar Specimens, C496/C496M – 11. Thin rectangular plywood sheets (30mm x 240mm) were placed between the brick during testing to take up the irregularities. In this test, a 100mm diameter x 200mm height mortar cylinder sample is subjected to a compressive load at a constant rate (4.7kN/s) along the vertical diameter until failure or split into two. This test can give nearest value with actual strength for the tensile strength of mortar. The mould will be filled with mortar in 3 layers. Each every layer should be fully compacted. Mortar cylinder should be placed in the middle of the machine with their axis horizontally between two pieces of steel. The position of the steel must be correct based on the marking provided. The load is subjected to the cylinder until it is split into two. The maximum load recorded. The indirect tensile strength, T for the cylinder is calculated using the formula bellow:

$$T = \frac{2P}{\pi l d} \tag{5}$$

Where:

T = splitting tensile strength, MPa

P = maximum applied load indicated by the testing machine, kN

l = length, mm

d = diameter, mm

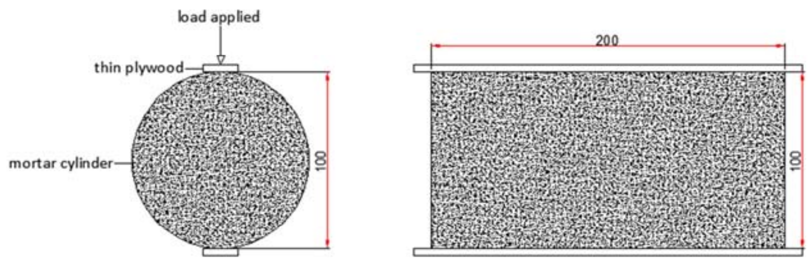

Figure 2: Splitting tensile strength test schematic

Application of Brickwork

Compression Test. The test is the standard practice for modified capping method for compression testing base on ASTM C1522-14a. The test provide plane surface on two bearing surface of samples which purpose to provide consistent and standardized procedure for compression testing. Three clay brick (70 mm x100 mm x 210 mm) is casted together to form 3 layered samples as shown in Figure 16. The normal mortar and kenaf fibrous mortar is used in this test as binder of the clay brick and to determine its compressive strength. The specimens were carefully placed horizontally in the testing machine. To ensure a uniform bearing, thin plywood (120mm x 230mm x 4 mm) were placed between the samples during testing because the brick has rough surface. Increasing compressing load at the rate of 6kN/s will be applied at the combined sample until the sample no longer withstand the load and thus, the maximum compressive load of will be obtained at the bonding interface. The cracking behaviour will be observed. The maximum load carried by the specimens was recorded. The result from this test will be plotted in the graph of compressive strength versus age of mortar.

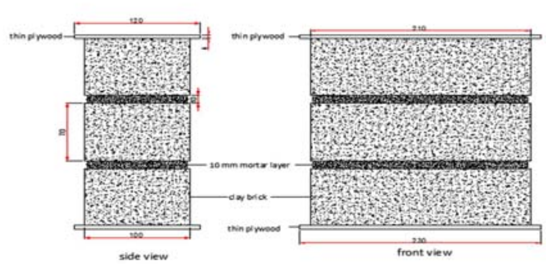

Figure 3: Compressive strength test schematic

Shear Test. This test method covers the determination of the shear strength of mortar specimens by the use of a simple beam with centre-point loading based on ASTM C293. The method of this test involved triplet combined sample as illustrated in Figure 4. This test method may be more appropriate for determining the shear bond strength between mortar and masonry units. Each sample is using 3 clay brick (70 mm x100 mm x 210 mm) with constant 10 mm of mortar layer. The brick is assign as horizontally layer clay brick with the mortar bind them together. The sample is place vertically into the testing machine and the sample is rest on two support which in position of balance side to side of the sample. Another steel support for point load is placed in the upper centre of middle brick for load distribution. Additional plate is added to ensure even loading at the bearing surface.

The triplet brick is tested in shear as a simple beam in centre point loading. The sample rests on two supports and the increasing load of 6kN/s at the centre of loading will be applied at the sample until the sample no longer withstand the load and thus, the maximum shear resistance of will be obtained at the bonding interface. Most of the sample is split into two after several second loads is applied. Test is conducted at the conditions of standard temperature and humidity. The cracking behaviour will be observed. The result from this test will be plotted in the graph of shear strength versus age of mortar.

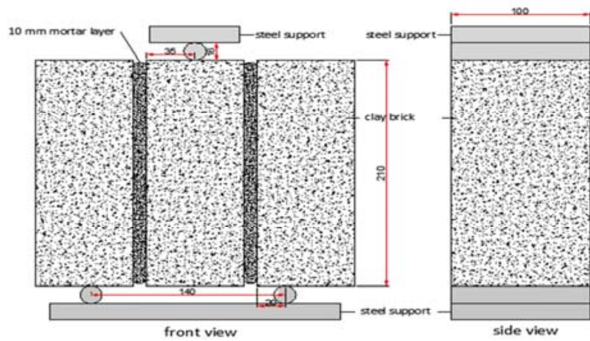

Figure 4: Shear strength test schematic

Tensile test. This direct tensile test follow the modified standard test method for tensile strength of mortar surface and the bond strength based on ASTM C1583/C1583M. The test method is suitable to determine the near surface tensile strength and the bond strength of a repair or overlay material. The crossed-brick couplets method measures a direct tensile strength of the bond between the mortar and masonry unit. It does not determine the flexural strength of the unit mortar assembly. The method of this test involved two combined sample as illustrated in Figure 18. Each sample is using 2 clay brick (70 mm x100 mm x 210 mm) with constant 10 mm of mortar layer. The brick is assign as crossed-brick with the mortar bind them together. Increasing load at both points loading will be applied at the sample until the sample no longer withstand the load and thus, the maximum tensile resistance of sample will be obtained at the bonding interface. The cracking behaviour also will be observed. The result from this test will be plotted in the graph of tensile strength versus age of mortar.

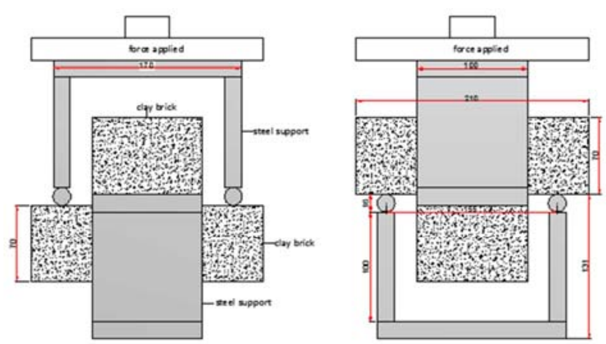

Figure 5: Tensile Strength Test Schematic

Results and Discussion

In this chapter, the results of mortar will be discussed in detail. There are 60 numbers of actual samples for this research, 24 and 36 for mortar testing and application of brickwork respectively.

An average of three samples been used for each test that being conducted in this research. This study was carried out to investigate the mechanical properties of kenaf fibrous mortar and application of brickwork. The natural kenaf fibres are used as an additive in the mortar. Flow table test is done in every time of casting of normal mortar and kenaf fibrous mortar. The performances of kenaf fibrous mortar were analyzed based on the comparisons with the control normal mortar. In order to indicate the results of analysis clearly, graphs, figures and tables were used. Bulk kenaf fibres are added based on weight of wet mortar. Also, the information may become very useful for future study and development of building materials. The entire test methods were done as described in the chapter material properties and experimental program of this thesis.

Flow Table Test Analysis

This test method is intended to be used to measure the workability of the young mortar. It determines how much a mortar sample flows when it is unconfined and consolidated. Workability of mortar is its ease of use measured by the flow of the mortar. The mix proportion for mortar was 0.5:1:2 (water: cement: sand). Table 1 below shows the average value of flow table test for normal mortar and kenaf fibrous mortar which is conducted before casting the specimen.

Table 1: Result of flow table test of normal and kenaf fibrous mortar

Flow Table Test		
Type of mortar Number	**Normal mortar Diameter, cm**	**Kenaf fibrous mortar Diameter, cm**
1	16.5	12.6
2	17.0	13.0
3	17.0	13.0
4	17.0	13.0
average	16.8	12.9

From the table 1, for the normal mortar, the result shows the average diameter of flow table test for normal mortar is 16.8 cm. However, when the mortar is added with bulk kenaf fibres the average diameter of flow table test for kenaf fibrous mortar were reduced to 12.9 cm. Based on the above data, the percentage of mortar flow is 63.35 % for normal mortar, while the percentage of mortar flow for kenaf fibrous mortar is 26.97 %. The result clearly shows that the workability of normal mortar is higher than kenaf fibrous mortar. Several factors that can be considered in this test are type of fibre added in mortar mix, quantity of fibre, orientation of fibre and length of fibre. The physical properties of fibres may also affect fresh mortar’s workability and the longer fibres used will reduce the workability to a greater degree than shorter fibres. Non-uniform distribution of the natural fibres also produced poor workability of fibrous mortar.

Mortar Testing

In this study, the mechanical properties of kenaf fibrous mortars were investigated which consist of splitting tensile and compressive strength. The results are summarized in figure 6 and figure 7. The data will be discussed further in each section.

Compressive Strength. As mentioned in chapter 3, 12 cube specimens with the size of 50 mm x 50 mm x 50 mm were tested for compression strength. The specimen was tested at 7 and 28 days after curing in water. The sample was tested for compressive strength by applying increasing compressive load until failure occurs. Mortar cube compression test were done to obtain the strength of the mortar based on the mortar mix ratio. The coefficient of variation (COV), also known as relative standard deviation, is a standardized measure of dispersion of a probability distribution or frequency distribution and it is often expressed as a percentage.

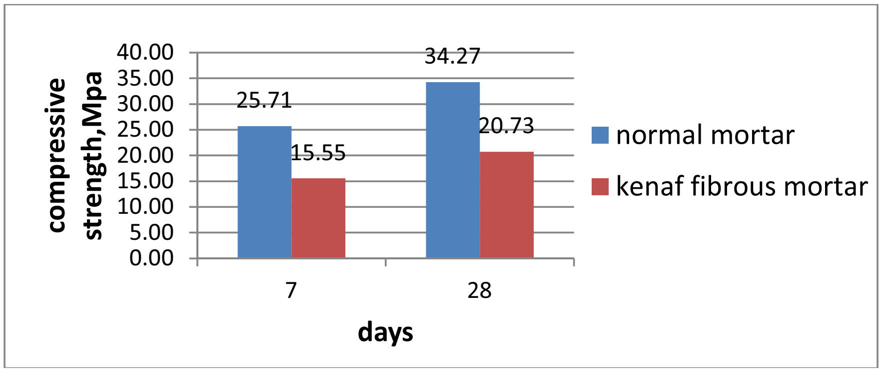

Figure 6: Graph of compressive strength versus age of mortar

From Figure 6, the result shows the average compressive strength for the normal mortar is 34.27 MPa at 28 days. When the plain mortar is added with Kenaf fibres, the average compressive strength was decreased to 20.73 MPa at 28 days. Coefficient of variation is 2.19 % and 2.10% for normal mortar and kenaf fibrous mortar respectively. Since both data is less than 20%, it shows the data is acceptable and within range. The introductions of kenaf fibre in samples not assist the strength of mortar. Other than that, it is may be because of non uniform distribution condition of fibre which is main cause of the void appearance in the mix.

Splitting Tensile Strength. As stated in chapter 3, 12 cylinder specimens with the size of a 100 mm diameter x 200 mm height mortar cylinder were tested for compression strength. The specimen was tested at 7 and 28 days after curing in water. The sample was tested for tensile strength by applying increasing load along the vertical diameter until failure occurs. Splitting tensile is a standard test conducted to determine the tensile strength of mortar in an indirect way. Tensile strength is an important property of mortar because that the mortar structure is very vulnerable to tensile cracking due to various kinds of applied loading itself. However, the tensile strength of mortar is very low compared to its compressive strength with the same mortar mix ratio.

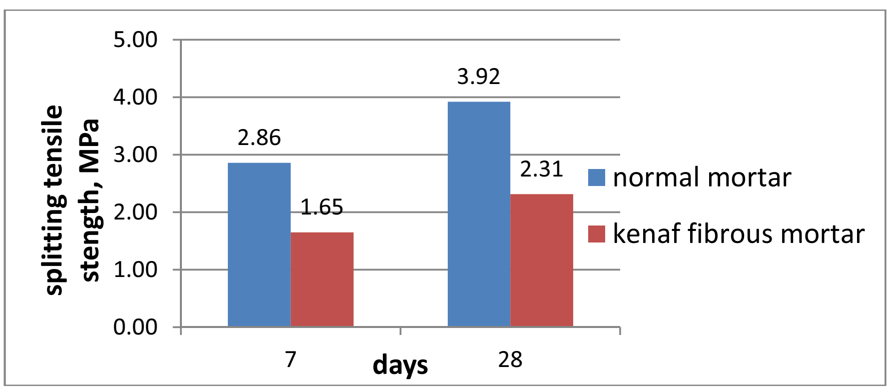

Figure 7: Graph of splitting tensile strength versus age of mortar

For comparison between control samples and samples with natural fibre, average results were considered. From figure 7, the result shows the average splitting tensile strength for the normal mortar is 3.92 MPa at 28 days. When the plain mortar is added with Kenaf fibres, the average splitting tensile strength was decreased to 2.32 MPa at 28 days. Coefficient of variation is 12.81 % and 8.90% for normal mortar and kenaf fibrous mortar respectively. Since both data is less than 20%, it shows the data is acceptable and within range.

Application of Brickwork

Compressive Strength. As mentioned in previous chapter, a number of 12 specimens with the size of 230 mm x 100 mm x 210 mm were tested for compression strength. It consists of three clay brick (70 mm x100 mm x 210 mm) is casted together to form 3 layered horizontal samples. The normal mortar and kenaf fibrous mortar is used in this test as binder of the clay brick and to determine its compressive strength. The specimen was tested at 7 and 28 days after air curing. The sample was tested for compressive strength by applying increasing compressive load until failure occurs.

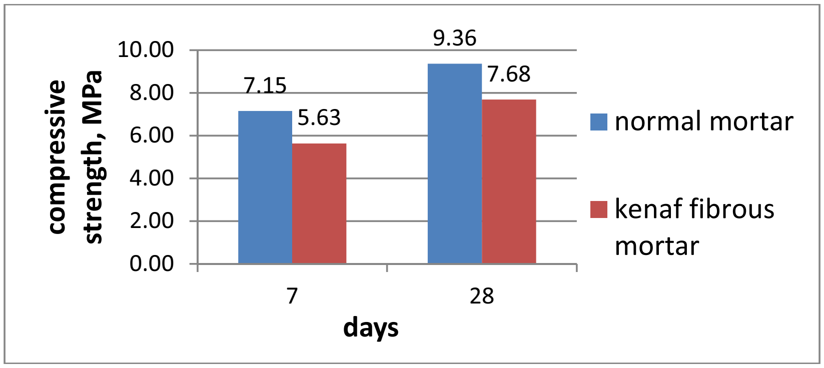

Figure 8: Graph of compressive strength versus age of mortar

From figure 8, the average compressive strength for the normal mortar is 7.15 MPa at 7 days which is exceed 2/3 of the design compressive strength at age of 28 days. At 28 days, the average compressive strength was 9.36 MPa. When the plain mortar is added with Kenaf fibres, the average compressive strength was decreased to 5.63 MPa and 7.68 MPa at 7 and 28 days respectively. Coefficient of variation is 1.72 % and 7.69% for normal mortar and kenaf fibrous mortar respectively. Since both data is less than 20 %, it shows the data is acceptable and within range. One of the purposes of adding fibre in mortar is to control cracking and the mode of failure by means of post cracking ductility. Addition of natural fibres in this test not contribute too much in compressive strength.

Shear Strength. This test method covers determination of the flexural strength of mortar specimens by the use of a simple beam with center-point loading. The load shall be applied at the centre point of the span, normal to the loaded surface of the beam, employing bearing blocks designed to ensure that forces applied to the beam will be vertical only and applied without eccentricity. The direction of the reactions shall be parallel to the direction of the applied load at all times during the test. For this test, same type of specimen with the compression test of application of brickwork will be used. The different is the sample will in vertical position during the testing. The normal mortar and kenaf fibrous mortar is used in this test as binder of the clay brick. The specimen was tested at 7 and 28 days after air curing.

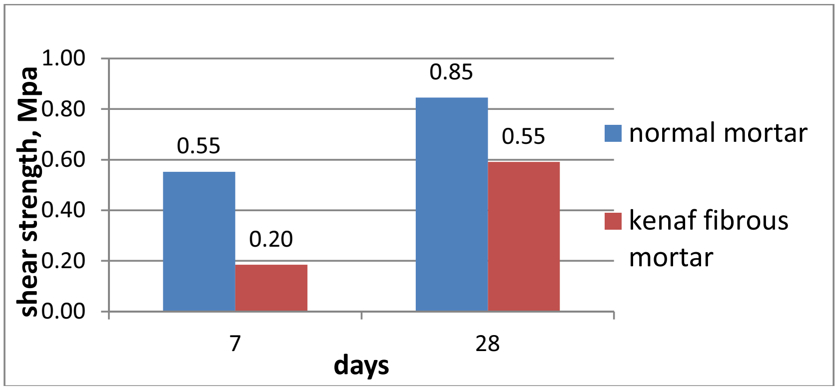

Figure 9: Graph of shear strength versus age of mortar

The results for 7 day-test shear strength for all specimens tested and the average reading is shown in figure 9. According to the test, average shear strength for normal mortar and kenaf fibrous mortar are 0.55 and 0.20 respectively. For the 28 days-test result, average shear strength are 0.85 and 0.55 for normal mortar and kenaf fibrous mortar respectively. Coefficient of variation is 12.74 % and 14.96 % for normal mortar and kenaf fibrous mortar respectively. Since both data is less than 20%, it shows the data is acceptable and within range. For comparison between control samples and samples with fibre, average results were considered. Fibres in this test are not assisting too much in shear strength. The strength is affected to a much lesser degree by the present of fibres.

Tensile Strength. The crossed-brick couplets method measures a direct tensile strength of the bond between the mortar and masonry unit. It does not determine the flexural strength of the unit mortar assembly. This test involved sample of combining two clay brick (70 mm x100 mm x 210 mm) with constant 10 mm of mortar layer. The brick is assign as crossed-brick with the mortar bind them together. The normal mortar and kenaf fibrous mortar is used in this test as binder of the clay brick. Increasing load at both points loading will be applied at the sample until the sample fail. The specimen was tested at 7 and 28 days after air curing.

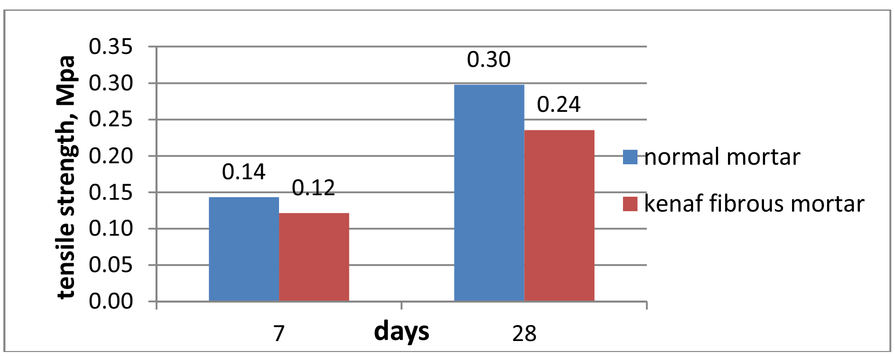

Figure 10: Graph of tensile strength versus age of mortar

The Figure 10 shown that kenaf fibrous mortar has lower shear strength than normal mortar. According to the test, average tensile strength for normal mortar and kenaf fibrous in air curing are 0.14 MPa and 0.12 MPa respectively. For 28 days strength results, it shown that the average tensile strength for normal mortar and kenaf fibrous mortar sample in air curing are 0.30 MPa and 0.24 MPa respectively. Coefficient of variation is 11.55 % and 4.89 % for normal mortar and kenaf fibrous mortar respectively. Since both data is less than 20%, it shows the data is acceptable and within range. The sample fails after several second of applying load to the sample. From this result, we can see that the tensile test for application brickwork recorded lowest strength.

Conclusion

All conclusions drawn upon here are based on the objectives of this study, observation and analysis done through the whole course of this study. In this studying the mechanical properties of kenaf fibrous mortar on material and application properties, the conclusion are:

1. Results showed that the workability of kenaf fibrous mortar reduced approximately 57% as compared to normal mortar.
2. In my research, the compressive and tensile strength of Kenaf fibrous mortar was lower than normal mortar.
3. For the brickwork of kenaf fibrous mortar, the strengths were almost lower as compared to the brickwork of normal mortar. It could be stated that the existence of kenaf fibre with 0.75% volume fraction and 50mm length as reinforcement in the mortar was not sufficient to improve the mechanical properties of mortar.
4. During testing, it was observed that the failure of kenaf fibrous mortar samples was slow and gradual, compared to the sudden failure of control or normal mortar samples. Thus the fibrous mortar composites exhibited greater ductility, hence its ability to sustain load for a considerable length of time before failure.
5. The higher weigh of samples give a higher strength of mortar

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