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Collapse Pattern and Strength Improvement at Wall Structure with Coconut Fiber Mortar

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Abstract *— Coconut fiber is lignocellulose contained materials can be obtained easily and used as one of raw materials alternatif of coconut fiber, coconut shell which consist of fiber located between inner hard shell, consist of about 35% from total weight of mature coconut. Beside easy to find, cheap, fiber coconut often be used because the making process is easy and much found at all area in Timor Leste. Also, bricks are material which easy to find and easy to make. Beside bricks, in the wall laying cannot be separated from the adhesive composer between bricks that is mortar. Mortar mix that is used in general consist of various comparison between cement: sand. The research want to know the influence of coconut fiber percentage 0%, 1%, 2.5% and 5% that is used in the mortar mix composition 1:15 with cement water factor of 0.7 toward cube compressive strength, flexural tensile strength, and brick laying. With horizontal, vertical and diagonal compressive direction of mortar. It was obtained that the wall laying. From the obtained results, the cube compressive strength of coconut fiber of 5.76 MPa, 3.30 MPa and 1.36 MPa while the without coconut fiber of 3.84 MPa. And also for the flexural tensile strength of 1.704 MPa, 1.659 MPa, 1.217 MPa, compared without coconut fiber of 1.212 MPa. The compressive strength test results of wall for horizontal direction of 0.9303 MPa, 0.9008 MPa and 0.044 MPa with strain of 0.0299, 0.0372 and 0.0344 compared without fiber of 0.8415 MPa with strain of 0.014, 0.0220 and 0.030 while without coconut fiber of 0.944 MPa with strain of 0.0224.*

Keywords— *Coconut fiber, mortar, compressive strength, tensile strength, Masonry wall.*

I. INTRODUCTION

So far mortar known as the adhesive between structure of mortar laying, concrete brick and other which consist of cement, sand and water. Mortar is one of concrete materials which consist of aggregate and cement pasta, with advantage able to sustain the compressive strength and weak at the tensile strength. Because of that, the research want to add several percent of weight or volume of coconut fiber in the mortar at the brick wall laying so become composite materials whose bound called with fiber to improve the tensile strength of the wall laying.

Wall is one of structural elements known since long time and used in each building served as the room separation. But in the use of brick wall laying no study which discusses scientifically, even many factors which influence the damage of wall such as the loose bonding between brick and mortar or tensile crack at the brick (Meli, 2011). Damage at the wall in general begun with crack at mortar, where mortar has no sufficient strength to sustain the tensile.

II. THEORETICAL BASIS

Mortar is one of concrete materials, with function to bind the construction composer materials. Concrete also the homogenous composite materials consist of combination between aggregate, water and cement as the binder, also use additive with chemical or physical characteristic with certain ratio that will harden as rock. In general is used at the bridge construction, building, road, and other construction.

Stress and Strain

Strength unit of material usually defined as the stress at material. Where stress is force per area unit. The stress can be calculated with formula:

$$\sigma = \frac{P}{A} \quad (1)$$

Where :
σ = Compressive strength (MPa)
P = Maximum load (kN)
A = Diameter area (mm^2)

$$\varepsilon = \frac{\Delta L}{L} \quad (2)$$

Where :
ε = Strain without unit
ΔL = Length addition (mm)
L = Initial length (mm)

Relationship between Stress-Strain of Brick Wall

(Kaushik, Jain, Rai, & Asce, 2007) proposed the relationship of parametric stress-strain of brick laying consist of two section, parabolic variation and linear variation. At the parabolic variation is used the curve formula up to f'_m decrease up to 90% then prevail the linear formula up to f'_m decrease to 20%. For mortar without calcium, the used linear equation so the strain reach $2\varepsilon'_m$, or from initial point $\{\varepsilon_{m@}$ $0.9f'_m$, $0.9f'_m$, $0.9f'_m\}$ up to final point $\{2\varepsilon'_m$, $0.2f'_m)$. While for mortar with calcium, the used linear equation so the strain reach $2.75\varepsilon'_m$, or from initial point $\{\varepsilon' f'@0{,}9f'_m, 0{,}9f'_m\}$ up to final point $\{2{,}75\varepsilon'_m, 0{,}2\varepsilon'_m\}$.

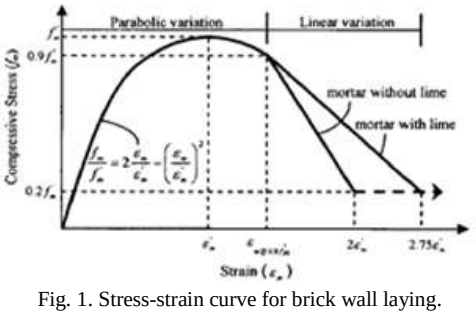

Fig. 1. Stress-strain curve for brick wall laying.

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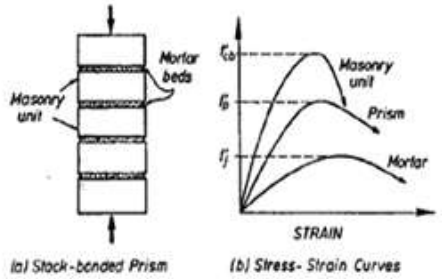

Fig. 2. Relationship of stress-strain of brick, mortar, and wall laying. Source: Paulay & Priestley 1992.

Up to now only little accurate data information about the behavior of the relationship between stress-strain of brick laying with mortar, so still uses the stress-strain relationship of concrete structure. It is based on the stress-strain relationship of brick wall laying which has same behavior with concrete with lower strength (Paulay & Priestley, 1992). Concrete compressive strength is influenced by aggregate grains, ratio between cement aggregate and water.

III. Research Method

The research used experimental method. Testing used such as physical and mechanical test. The physical test such as physical properties of brick based on (SII-0021, 1978) about the quality and solid brick test and smooth gradation test based on (ASTM -C144, 2002). At the mechanical test such as

1. Mortar compressive test
2. Coconut fiber tensile test
3. Brick compressive test
4. Flexural tensile test
5. Split tensile test
6. Cohesive strength test
7. Wall laying compressive test

Research Variables

Research variables include:

a. Independent variable include variables which influence or that cause the change occurrence, at the research the independent variable is coconut fiber in mortar such as 0%, 1%, 2.5%, and 5% toward mortar volume
b. Dependent variable in the research such as cube compressive strength, compressive strength and wall deformation is independent variable.

Data Analysis

Data analysis by using Microsoft Excel 2010 to calculate the coconut fiber percentage toward mortar compressive strength at the brick laying wall strength, then it need data processing and data analysis according the analysis procedure presented in the graphic and table.

IV. Results And Discussion

Mortar

The mortar testing in the form of mortar making by using iron cast of 5 cm x 5 cm x 5cm. In the research by using one type composition ratio of cement and sand of 1:5, and cement water factor of 0.7 with coconut fiber percentage addition of 0%, 1%, 2.5% and 5%. Mortar test by giving axial pressure obtain the average compressive strength at 1% coconut fiber of 5.76 MPa, 2.5% of 3.30 MPa and 5% of 1.36 MPa while mortar without coconut fiber of 3.84 MPa in table I.

Coconut Fiber

Coconut fiber is the biggest component of coconut, mostly used as furl at copra drying and household, only little is used in the industrial process. The coconut fiber use as the filler has several advantages compared to the foam rubber such as has ability to absorb body heat, strong, difficult to decay, light in weight, elastic so comfort in use (Suhardiyono, 1999).

Because of that in the research use of eleven coconut fibers with average length of 83.5 mm and average diameter of 0.25 mm. From the test obtained the break stress of the fiber of 119.28 MPa with standard deviation of 56.90 and variation coefficient 34.90%. Same thing with the results of (Delarue, 2017), also obtained the average value of tensile strength of 117.46 MPa

Brick

Physical characteristic of brick should be considered by looking at the condition visually. Size (dimension) influence heavily to the compressive strength of brick because the compressive strength obtained from the compressed area. So, it is cut the brick in size suitable with cube the dimension follow the brick thickness. From the compressive strength test at brick on table II obtained compressive strength average of 1.704 MPa, standard deviation of 0.239 and variation coefficient

Flexural Tensile Strength of Mortar

The test was conducted when the mortar beam has passed the curing period and in 28 days old, with the beam dimension of 8cm x 8 cm x 30 cm by using two loading points with load distance 1/3L from the pedestal. From the test obtained the flexural tensile strength average of the mortar with coconut fiber in average increase compared without coconut fiber as given in table III, where 1% of 1.704 MPa, 2.5% of 1.659 MPa and 5% of 1.217 while without coconut fiber (0%) of 1.212 MPa.

Split Tensile Strength of Mortar

The test was conducted when the mortar cylinder has passed the curing period and tested in 33 days old, with dimension of 8 cm x 16 cm by using compression machine test, where the beam cylinder laid and given maximum loading to obtain mortar split tensile. At the test the split tensile strength average as given in table IV, with addition of coconut fiber get no improvement with value lower at fiber 1% that is 0.58 MPa, 2.5% of 0.48 MPa and 5% of 0.25 MPa while without fiber (0%) of 0.70 MPa.

TABLE I. Compressive strength average of mortar cube.

No	Specimen Code	Ages (days)	Coconut Fiber (%)	Compressive Strength Average of Mortar (MPa)
1	KTS	33	0	3,84
2	KS1	33	1	5,75
3	KS2	33	2,5	3,30
4	KS3	33	5	1,36

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TABLE II. Compressive strength average test of brick.

Code	Weight (kg)	Length cm	width cm	thick cm	Area cm²	Maximum Load (kg)	Compressive Strength (Mpa)
1	0,074	3,926	3,824	3,815	15,013	305,910	2,038
2	0,070	3,734	3,706	3,753	13,838	234,531	1,695
3	0,092	4,137	4,080	4,115	16,879	326,304	1,933
4	0,080	3,999	3,886	3,912	15,540	254,925	1,640
5	0,064	3,764	3,734	3,610	14,055	244,728	1,741
6	0,084	4,034	4,033	3,978	16,269	254,925	1,567
7	0,075	3,853	3,833	3,805	14,769	193,743	1,312
				Compressive Strenght Average			1,704
				Standart deviation (S. Dev)			0,239
				Coefficient of Variant (CV)			14,011

TABLE III. Flexural tensile strength average test of mortar.

No	Specimen Code	Coconut Fiber (%)	Flexural Tensile Strength of Mortar (MPa)
1	BTS	0,00	1,212
2	BS1	1,00	1,704
3	BS2	2,50	1,659
4	BS3	5,00	1,217

TABLE IV. Split tensile strength average test of mortar.

No	Specimen Code	Coconut Fiber (%)	Split Tensile Strength of Mortar (MPa)
1	STS	0,00	0,70
2	SS1	1,00	0,58
3	SS2	2,50	0,48
4	SS3	5,00	0,25

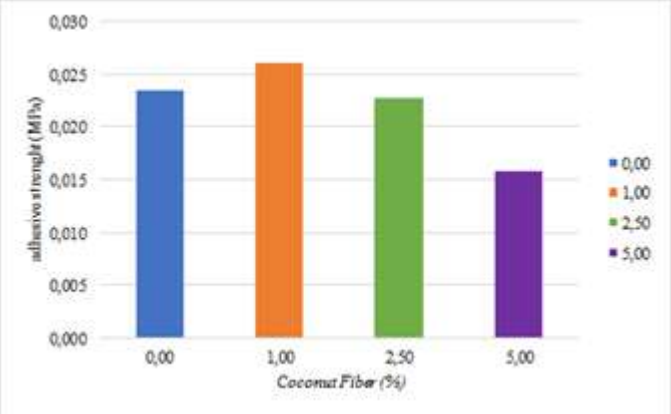

Fig. 3. Adhesive strength relationship average of mortar toward coconut fiber Percentage.

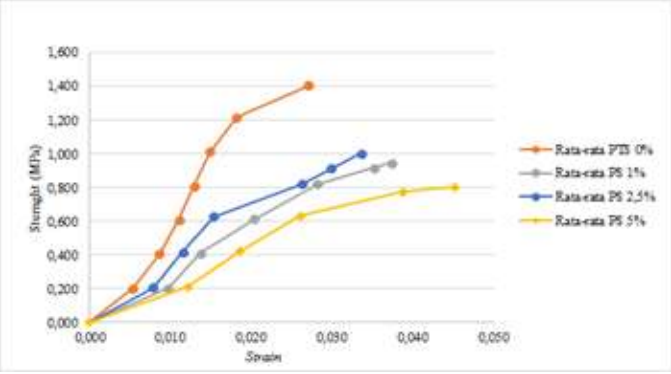

Fig. 4. Prism stress-strain relationship average.

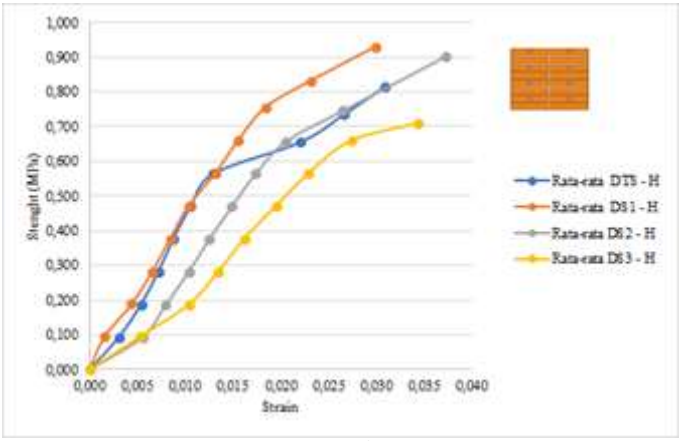

Fig. 5. Stress-strain relationship average of wall laying in horizontal direction.

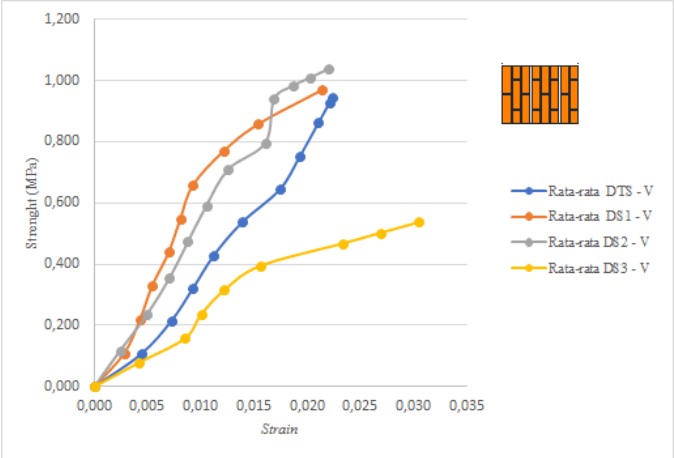

Fig. 6. Stress –strain relationship average of wall laying in vertical direction.

Adhesive Strength of Mortar

At the test the specimen is arranged in cross and lined with mortar in the mix composition 1:5. The adhesive strength test done by giving compressive load at the brick surface by using the universal testing materials (UTM) and aided by load cell. Figure 3, showed that the adhesive test results by adding coconut fiber 1% obtained the highest adhesive strength value of 0.026 MPa compared without coconut fiber (0%) only 0.023 MPa.

Prism Compressive Strength Test

Prism compressive strength test to get the real strength from the prism laying of mortar mix with coconut fiber in four variables 0%, 1%, 2.5% and 5% used in the research. From the obtained results in figure 4, the compressive strength value successively not increase but the strain values with coconut fiber addition increase, without coconut fiber (0%), the compressive strength 1.407 MPa and the strain of 0.0271, while with fiber 1% the prism compressive strength of 0.9452 MPa, strain of 0.0373, coconut fiber of 2.5%, the compressive strength value of 1.u0027 MPA, strain of 0.0336, and also the prism compressive strength with coconut fiber of 5% of 0.8051 MPa with strain of 0.0453.

Wall Compressive Strength Test of Horizontal

The average compressive strength test of horizontal direction on wall is formed by laying intact brick with length

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of two brick and arranged at 8 layers adhered by mortar with mortar mix composition of 1:5. From the obtained results, the compressive strength at horizontal direction with mortar mix composition with coconut fiber of 1% has highest compressive strength of 0.9303 MPa with strain of 0.8145 MPa and the strain 0.0309. For fiber percentage 2.5% obtained also the high compressive strength of 0.9008 MPa and the high strain of 0.0372, but the compressive strength for fiber 5% experience decrease that is 0.7107 MPa but the strain higher of 0.0344 compared without fiber as given in figure 5.

Wall compressive strength test of vertical

The wall average compressive strength in vertical direction is formed by laying intact brick of 2 brick in length and arranged in 8 layers gummed by mortar in the mortar mix ratio 1:5. From the test as given in figure 6, obtained the coconut fiber 1% and 2.5% that has the highest compressive strength of 0.9692 MPa and 1.0382 MPa, lower strain of 0.0214 and 0.0220 MPa compared without coconut fiber of 0.9446 MPa and strain of 0.0224. For percentage of coconut fiber of 5% obtained the low compressive strength of 0.7596 MPa with higher strain value than the three test variable of 0.0304

Wall Sliding Strength Test of Diagonal

At the test the specimen is formed by arranging the brick of 8 layers and adhered by using mortar. At the test the specimen is compressed at the wall diagonal where the vertical load is normal force has sliding strength average without using coconut fiber of 0.1856 MPa with low strain of 0.0097. For wall by using coconut fiber 1%, 2.5% and 5% the sliding strength successively 0.0925 MPa, 0.1536 MPa, 0.0215 MPa lower than without coconut fiber, while the strain value at the wall with coconut fiber 1% of 0.0100 and 2.5% of 0.0108 and 5% of 0.0037 viewed from figure 7.

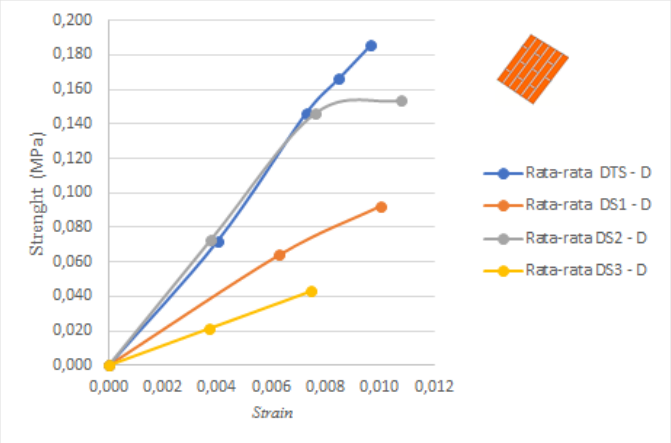

Fig. 7. Relationship average of stress-strain of diagonal wall.

Wall Collapse Pattern

From the test obtained the collapse pattern of wall begun with the brick crack compared with the mortar destruction. The higher coconut fiber percentage use in the mortar mix at the wall laying then the collapse pattern increase. The collapse pattern average (crack) at the wall laying without coconut fiber in horizontal direction has 4 cracks, as given in figure (8a), at wall laying with coconut fiber 1% of 6.5 can be seen in figure (8b), 2.5% that is 7cracks in figure (8c) and 5% of 9 cracks in figure (8d).

And also for wall laying in vertical direction, without coconut fiber (0%) of 2.5 cracks seen in figure (9a), 1 % of 4 cracks figure (9b), 2.5% of 4.5 cracks figure (9c), and 5% of 5.5 cracks can be seen in figure (9d)

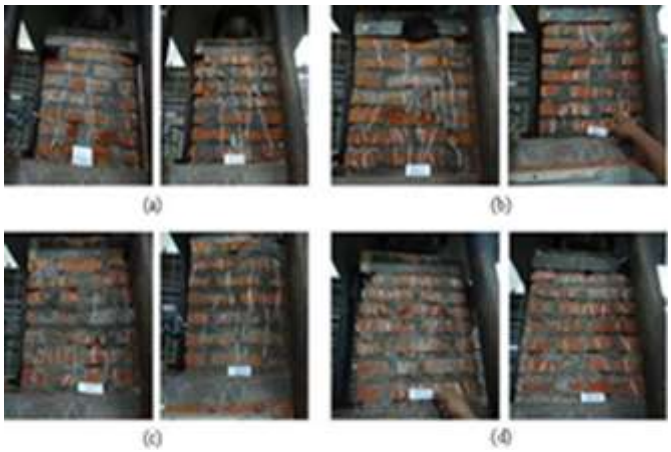

Fig. 8. Collapse pattern of horizontal direction wall each coconut fiber percentage.

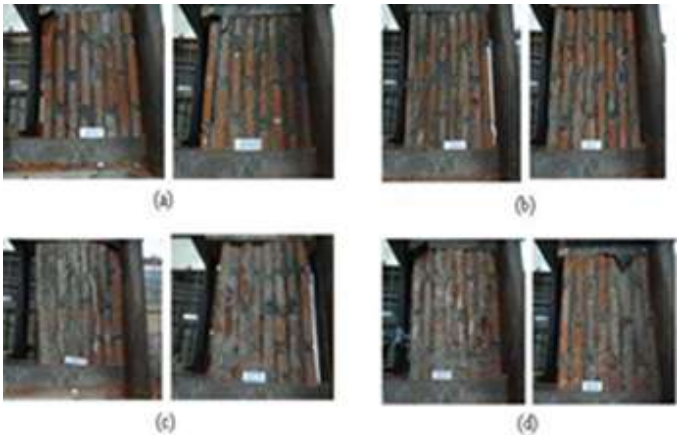

Fig. 9. Collapse pattern of vertical direction wall each coconut fiber percentage.

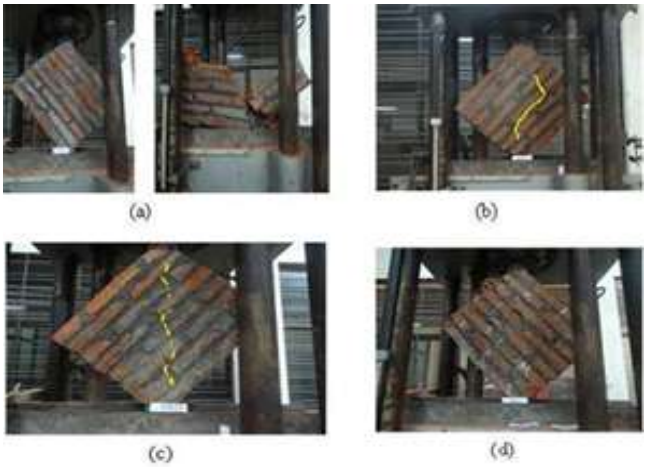

Fig. 10. Collapse pattern of diagonal direction wall each coconut fiber percentage.

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While the diagonal wall without coconut fiber the collapse is suddenly can be seen in figure (10a), while fiber 1% cut at the mid-diagonal in figure (10b), fiber 2.5% cut at the diagonal path from up to down like in figure (10c), for 5% obtained the collapse pattern consist of two section in figure (10d).

V. Conclusion and Suggestions

Conclusion

Mortar mix composition 1:5, with coconut fiber 1% influence heavily to the mortar cube compressive strength, flexural tensile strength, adhesive strength of brick and wall compressive strength at 2 loading directions, horizontal and vertical. It can be seen that the mortar compressive value produced with 1% coconut fiber of 5.76 MPa, the flexural tensile strength value of 1.704 MPa and the adhesive strength value of 0.026 MPa, and the compressive strength value in horizontal direction of 0.9303 MPa with strain of 0.0299, compressive strength in vertical direction of 0.969 MPa with strain of 0.0214, coconut fiber 2.5% is 0,9825 MPa, with strain of 0,0186 while for the sliding strength value produced not increase because by addition of fiber the compressive strength lower than without coconut fiber of 0.1877 MPa and lower strain of 0.0097, but the value of strain on the wall by using coconut fiber has increased, are 1% of 0.0925 MPa, stain of 0.0100, 2.5% of 0.1536 MPa, strain of 0.0108 and 5% is 0.0928 MPa, strain of 0,0108

Suggestions

1. To get more accurate data results especially to obtain compressive strength for wall and prism more optimum than the brick laying then it need research about the varied mortar mix, the more varied cement water factor.
2. Effect of the coconut fiber use in the mortar mix to obtain the optimum split tensile strength and flexural tensile strength then it need further research by using various fiber composition or interval between fiber percentage which is not to much, and various fiber size in the mortar composition.
3. To get uniform length size and time efficiency it is better by using coconut fiber cutter machine.

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