Effect Of Fiber Length Of The Oil Palm Empty Fruit Bunch On Manufacture Particle Board With Urea Formaldehyde Adhesive Toward The Characteristics

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Abstract: Oil palm empty fruit bunches (OPEFB), which is abundant in every crude palm oil industry and has not been optimally used, oil palm empty fruit bunches has the high potential for particle board materials. The characteristic of the particle board is determined by the composition, fiber length, fiber orientation, and fiber diameters. This research is aimed to determine the effect of fiber length toward characteristics particle board. The fiber length OPEFB from 0.1 to 8 cm, used Urea Formaldehyde adhesive with the composition of 12%wt. The fiber and adhesive evenly mixed and press cold for 15 minutes, followed by hot press at the temperature of 130ºC for 15 and 20 minutes, then cooled. Determined the characteristic of the particle board is a measurement of density, moisture content, and Modulus of Rupture, Modulus of Elasticity with bending test and Internal Bonding. The result particle board with eight treatments of fiber length showed that fiber length does not affect density but affect the moisture content, Modulus of Rupture and Modulus of Elasticity. Modulus of Rupture, density and moisture contens meet the standards SNI 03-2105-2006 and JIS A 5908-2003 for medium density. Modulus of Elasticity and Modulus Rupture tend to decrease against increasing length fiber.

Keywords: particle board, fiber length, MOR and MOE, density, moisture content, OPEFB.

1 INTRODUCTION

THE increase in oil palm production in 2015 also increased palm waste. The oil palm mill waste can be classified into four types: solid, liquid, gas, and B3. Figure 1 shows the oil palm fruits. The process of one ton of oil palm will generate 23% or 230 kg of oil palm empty fruit bunches (OPEFB), 6.5% or 65 kg of shells, 4% or 40 kg of oil sludge, 13% or 130 kg of fiber and liquid waste for 50% or 500 kg. If the amount of solid waste of OPEFB 23% or 230 kg/ton, therefore the total waste in 2015 is predicted to 7,118,254.2 tons. It is a very large number[1]. In order to avoid the OPEFB waste causing problems, it needs good management. OPEFB numbering over 7.1 million tons /year partly processed for organic fertilizers, compost, fuel boilers and gas bioethanol but it is still limited. Composite fiber oil palm empty fruit bunches (fiber reinforced composite, fiber matrix composite, bio-composites, nano-composites) is an effort to improve its function to be more useful and reduce the waste of oil palm empty fruit bunches. The potential of oil palm empty fruit bunches are large but it has not been used optimally. Therefore optimization efforts become important for the economic product. Fibre matrix composites of oil palm empty fruit bunch (particle board) with adhesives Urea Formaldehyde (UF) is an attempt to make it more useful and have economic value as well as reducing waste. Composites are made from empty oil palm bunches fiber that can be innovated for home interiors.

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Results of testing three types of adhesives for particle board made from palm trunks showed adhesives Urea Formaldehyde, Phenol Formaldehyde and isocyanides grading 7% and 10% resulted in physical and mechanical properties of particle boards which do not meet the standard SNI 03-2105-1998[2].

Fig. 1. *Oil palm, oil palm fruits, oil palm empty fruit bunches in the caption.*

The results of the study of particle board made from Merbau wood waste, better properties obtained in adhesives Urea Formaldehyde concentration of 12% and a particle size of 2 mm sieve escaped and endured 5 mm[3]. This initial research aimed at obtaining matrix fiber composites (particle board) that met the standard value of physical properties and mechanical properties that refer to SNI 03-2105-2006. EFB fibre length varied: 0.1-1; 1.1-2; 2.1-3; 3.1-4; 4.1-5; 5.1-6; 6.1-7; 7.1-8 cm; UF adhesive concentration 12% weight and temperature compression of 130ºC. Composite density target: 0.8 g.cm^{-3} and this density refers to the SNI 03-2105-2006, for medium density is 0.4 - 0.9 g.cm^{-3}[2]

2 MATERIALS AND METHOD

This research was conducted by methods;

Preparation of fiber and adhesive

The fiber was taken from production waste Oil Palm Empty Fruit Bunch (OPEFB) in West Pasaman, Indonesia. The fiber was dried in the open air with a 400-720 watt solar radiation for 24 hours, then cut following fiber length 0.1-1; 1-2; 2-3; 3-4; 4-5; 5-6; 6-7; 7-8 cm. Cutting is done with fiber cutting machine. The fibers that have been cut then filtered so that impurities that come with the fiber can be separated. Fiber filtration process is done manually (hand), the filter is moved left or right repeatedly that will help speed up the screening process. Manufacturer of filter does in the lab. The machine, hole adapted to the length of the fiber. The function of the hole is to pass the impurities to be separated. So that the fibers used are free of impurities. Fiber weight for each treatment length was 2.4 kg for three panels. Dry fiber-based density at air was 0.2134 $g.cm^{-3}$. The sum particle board of that made ie 48 panels, 24 panels with hot press time 15 minutes and 24 panels with hot press time 20 minutes. Urea formaldehyde (UF) with a solid content of 63%, density of 1.28 g cm^{-3}, viscosity of 45 cp, gelation time of 67 s, and pH of 7.5 was applied. As a hardener, ammonium chloride (NH_4Cl) solution (solid content: max. 20%) was added to the adhesive. UF and the hardener recommended is UFP 1001 (Resin Powder) 100%wt, water 80%wt and hardener 6%wt. UF formulations used allowed flexible, therefore the authors do not follow the recommended formulation. Our consideration is the formulation that was in common use and fabric recommends other variations. Adhesive the amount of 12% weight adhesive powder from raw material [4][5][6][7] is mixed with 200 ml of distilled water and 2 ml hardener for one panels.

Preparation of particle board

The fiber is cut then filtered in order to obtain good fiber and clean. Each of the samples was weight to require 0.8 kg of fiber, a sample size of 30 x 30 x 1.2 cm. Fiber with a weight of 0.8 kg is mixed with the adhesive in a container, a compressor is used to inject the solution into the fiber adhesive is then stirred manually. After mixing the adhesive evenly fibers and subsequently included in molds measuring 30 x 30 x 8 cm, the mold is closed and then cold compression for 15 minutes. Prints made from 5 mm thick steel plate. Cold press at a temperature of 28ºC followed by a hot press at a temperature of 130ºC [4] for 20 minutes and 15 minutes, then panels cooled in a plywood box for 7 days, ambient air temperature of 28ºC.

Density

The test specimen density of size 10x10x1.2 cm. Specimen volume was calculated and weighed. Density particle board (particle board) was determined by dividing the weight (m) and volume (V) of a specimen as shown below:

$$\rho = m/V \ g.cm^{-3} \qquad (1)$$

Moisture contents

All of the specimens with a dimension of 10 cm × 10 cm × 1.2 cm were measured by using a weighing balance and recorded as M_1. The samples were dried in the oven at 105 ºC for 24 hour and reweighed (M_2). The moisture content(φ) was calculated using formula shown below:

$$\varphi = ((M1-M2)/M2)x100\% \qquad (2)$$

Modulus of Elasticity (MOE)

Tensile and three-point bending flexural tests were conducted using computers system according to ASTM D1037 [8] and SNI 03-2105-2006 showed figure 2. Universal Testing Machine (UTM) capacity 300 kN was used to determine the modulus of elasticity (MOE). Modulus of elasticity is the ability to withstand concentrated loads of particle boards in the oven dry state. The size of the test specimen, 20 cm x 4 cm x 1.2 cm

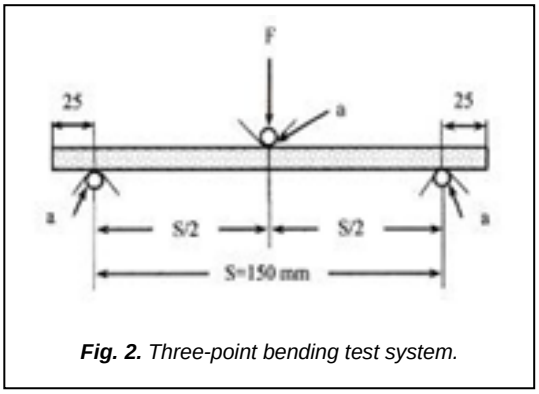

Fig. 2. *Three-point bending test system.*

$$MOE = F_{pl}S^3/4wt^3y_1 \qquad (3)$$

Modulus of Rupture (MOR)

$$MOR = 3F_{pl}S/2wt^2 \qquad (4)$$

Internal Bonding (IB)

Calculated using the following equation [9]:

$$IB = \Delta F/A \qquad (5)$$

3 RESULT AND DISCUSSION

Particle board

Fiber cutting for panels is used to cut straight motion machines, the length of the fiber to be cut can be set and the maximum length of 10 cm. OPEFB fibers that have been cut needs to be filtered in order to separate the fiber length and less excess fiber length, in this way greatly help obtain fibers with uniform length. Figure 3 shows fibers that have cut with cutting machine. Each sample requires 710 grams fiber, each treatment takes 3 samples, and therefore the amount of fiber needed 710 gr x 3 x 8 = 17040 gr or 17.04 kg. Mixing the fibers with the adhesive composition 12% at UF as an adhesive, add water 200 ml and hardener 2 ml.

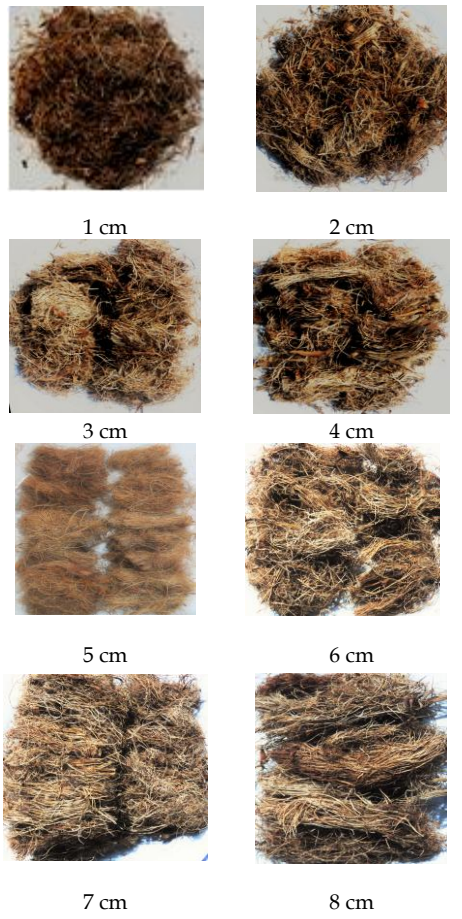

Fig. 3. *The fiber after a cut with cutting machine*

These three ingredients were mixed evenly in 2-liter bottle contents, each time the mixing is done for 3 samples, then the adhesive solution included in the spray tube of adhesive and compressed air obtained from the compressor and then adhesive that comes out of the spray tube of adhesive in the form of fine grains. The sprayer of fine adhesive grains that is directed into the fiber, the adhesive beam is able to penetrate the gap between fibers, so that the fibers that are behind get a uniform adhesive and facilitate mixing. Mixing is done manually, fibers and adhesives are mixed with either inserted in the mold and random fiber arrangement, the mold can be used sustainably. Particle board made of 24 panels, each treatment requires 3 panels. The time mixing fiber and adhesive is 15-30 minutes, the fiber length of 1-3 cm ± 15 minutes of mixing time and a fiber length of 4-8 cm mixing time 20 minutes and 30 minutes. Perfection mixing can be observed visually marked discoloration fiber and moisture, if the fiber is held will feel attached and moist. On the other side of the development is also affected by the stiffness of the fiber, fiber diameter > 0.5 mm tends to be more rigid than the fiber diameter < 0.5 mm and a length of > 2 cm tends to produce a cavity[10], the effect of the two will lead to the development of thick after press cold. The press cold of fiber was done by the hydraulic press machine of capacity up to 20 tons, figure 4 shows of the cold pressed fiber in steel molds made specifically for particle board, time press average of 10 minutes with a thick target of particle board 2 cm, the pressure is stopped when the thick target has reached 2 cm. After of a cold press followed by a hot press, the press time is 20 minutes with a target of 1.2 cm thick. The cold press has helped increase adhesivity up to not necessarily the heating long from the average thickness of 2 cm to 1.2 cm. The hot press on panels the conducted in hot press machines with a capacity of 50 tons and a maximum temperature of 300ºC. The test specimen density and moisture content refer to the SNI 03-2105-2006, its dimensions are 10 x 10 x1,2 cm. Cutting the field at panels for a test specimen as shown in figure 5. The test specimens of MOE and MOR refers to the SNI 03-2105-2006, its dimensions are 25 x 4 x1,2 cm. the cutting of test specimen for density, MOE, and MOR is shown in figure 6

Fig. 4. Panels current cold press and after cold press

Density and moisture contents

The characteristics of particle board (composite) that determined i.e., density, moisture contents, modulus of elasticity and modulus of rupture. Density testing is done to the length of the fiber 1, 2, 3, 4, 5, 6, 7 and 8 cm in the number of specimens of 24 pieces. Each treatment is three specimens. Figure 7a shows that the particle board density is relatively stable that is 0.8 to 0.92 g.cm^{-3} and the fluctuation is relatively small, the average density of each treatment fiber meet the standards SNI 03-2105-2006 and JIS A 5908-2003 for medium density is 0.4-0.9 g.cm^{-3}. The density data which was obtained indicates that the incoming composite group of medium density particle board Type 13. The specimens have tested the density followed by measurement moisture content the in an oven at a temperature of 105ºC for 24 hours, then weighed using digital scales with the accuracy of 0.01 kg. The graph in figure 8b shows the moisture contents was ranged from 10.38 to 6.75%, the water contained in the specimen was the effect of liquid glue with a concentration of 12% weight. The water contained in the particle board had not completely evaporated during hot press and influence the surrounding air humidity during the cooling process. The moisture contents of the composite board tend to be reduced to the increasing length of the fiber. Particle boards with fiber length 0.1-3 cm show low evaporation of water during the hot pressed (moisture contens: 9.2-9.8 %) and particle board with fiber length 5-8 cm show high evaporation (moisture contens: 6.75-7.5%).

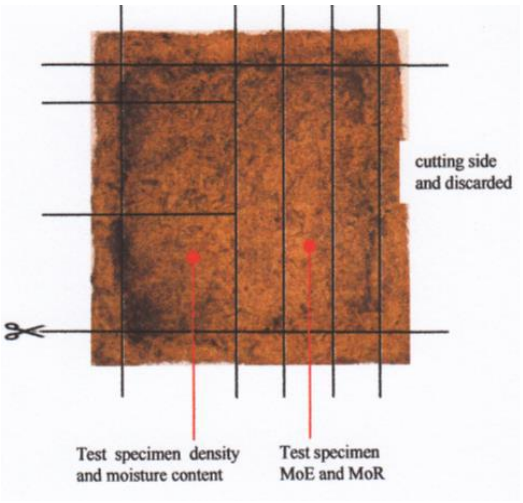

Fig 5. *Test specimens of density and moisture content*

Particle boards with fiber length 0.1-3 cm show low evaporation of water during the hot pressed and particle board with fiber length 5-8 cm show high evaporation. This happens at hot press time 15 minute and 20 minutes and also, the influence of the size of the particle board cavity on the fibers is 5-8 cm long so that the fiber is unable to withstand the rate of evaporation of water during drying. Decreased moisture contents on fiber lengths of 5, 6,7 and 8 cm are advantageous because the particle board from EFB fiber material will not moldy and be durable. Refers to the standard SNI 03-2105-2006 and JIS A 5908-2003 that the moisture content of particle board is not introduced more than 14% [2], the experiment showed that the moisture content is 10.38 to 6.75%. So moisture contens the particle board meets standard SNI 03-2105-2006 and JIS A 5908-2003

MOE and MOR

Bending test results showed that the MOE in this condition is obtained: 245.25 – 1,824.66 MPa. The average value highest of MOE obtained at the fiber length 1 cm and 2 cm ie 1,710.86 MPa and 1,412.64 MPa for hot press time 15 meniutes, 1824.66 MPa and 1402.4 MPa for hot press time 20 minutes.

Fig 6. *Test specimens of MOE and MOR*

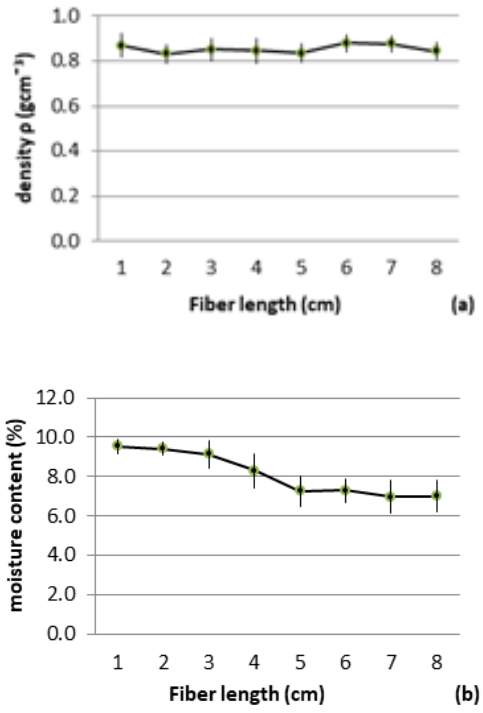

Fig 7. *The average value of the density (a) and moisture content (b)*

The MOE values this not met price standard particle board type 13, SNI 03-2105-2006 i.e 2,501.55 MPa [2] and has not met the equivalence with JIS A 5908-2003 for particle board 1.2 cm thick is minimum 1962 MPa and JAS 1951-2008 is 4000 MPa [11], bending test chart Figure 8a showed that the tendency MOE value decreases with increasing length of fiber. Figure 8b. shows the average price of MOR which tends to decrease with increasing fiber length. It indicates that the composition of the composite fibers randomly and concentration of 12%wt has not resulted in better strength for a longer fiber length. On the fiber length 1 and 2 cm showed high MOR value ie 21.82 MPa, 17.54 MPa for hot press time 20 minutes and 20.12 MPa, 17.6 MPa for hot press time 15 minutes[12][13]. Refers to the standard SNI 03-2105-2006 that MOR value type 13 ie 6.5-13.05 MPa, JIS A 5908-2003 ie minimum 7.85 MPa. MOR value of the particle board this meet the standard SNI 03-2105-2006 and JIS A 5908-2003. The MOR value equivalent with research corrugated bamboo particle boards fabrication, particle size ranging from 5 to 10 mm. The resin UF content was 9% solid resin, 2 wt% as a common hardener. MOR increased from 16.7 to 21.3 MPa with hot press temperature is 150^{o}C and 180^{o}C[14] and the equivalent with particle board using a mixture of bagasse 40% and industrial wood particles 60% with 11% UF adhesive, MOR results was 16.59 MPa[15]. The objective is to evaluate the primary mechanical and physical properties of particleboard made from hammer-milled rice straw particles of six different categories and 12% UF adhesive. MOR: 10 MPa and MOE: 1830 MPa[4]

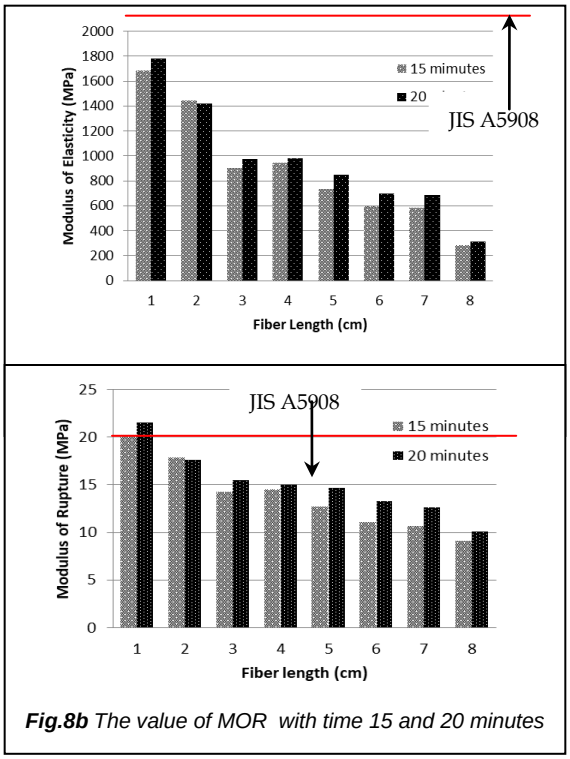

Fig.8b *The value of MOR with time 15 and 20 minutes*

Study examines the possible feasibility of canola straws in the production of particleboard with 10 % UF adhesive. The highest MOR (18,65 MPa) and MOE (2770 MPa)[16]. other research about mechanical properties particle board with raw material oil palm fronds with addition 12-15% UF adhesive, obtained MOR 12.62 MPa; MOE 953.93 MPa. [5][17].

Internal Bonding

Internal Bonding values of the experimental panels ranged from 0,15 to 0,3 MPa. The highest IB value was observed for fiber length 0.1-1 cm with press time 20 minutes while the lowest was recorded for fiber length 8 cm with press time 15 minutes. All panels produced meet the requirements for particle board and end users meet the minimum requirements. IB values tend to decrease with increasing fiber length in uniform particle density and thickness, this occurs at hot press times of 20 and 15 minutes (Figure 9). Particle boards made of rice straw also show the value of IB which tends to decrease with increasing particle length. The highest IB is at a particle length of 3.18 mm and the lowest is at a length of 25.4 mm[4][18][18][19]. IB value decreases in long fibers which are affected by the stiffness of the oil palm's empty fruit bunches. This reduces the strength of the fiber bond and if there is an external force the fiber bond is easily released. Many cavities on long fibrous particle boards can show the effect of the remaining fiber stiffness. The fracture surface of composite shown in figure 10. Composite or particle board obtained has a value of MOE and MOR diverse on the average density and the concentration of UF adhesive (12% weight) uniform, the average price of MOR and highest MOE obtained at 0.1-1 cm fiber length is 1710.86 MPa and lowest average value of MOR and MOE obtained at the fiber length of 7-8 cm which is 8.04 MPa and 252.02 MPa. a low value of MOR and MOE on the long fibers, looking at the cross section, the fiber detached from the adhesive and no fibers were damaged, the specimen did not break immediately, but one fiber and the other was still bound. A separate fiber bond is believed that the bond is not strong or the bond is uneven because it is easily released when pressed.

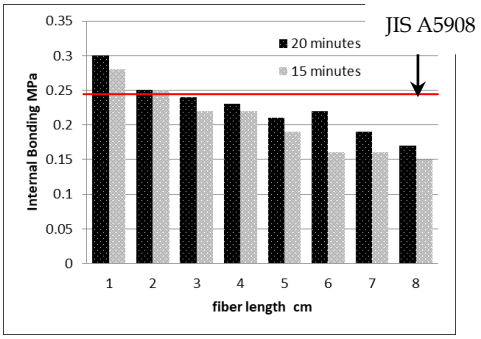

Fig. 9. *Internal bonding of particle board panels*

On the other hand, long fibers have a great chance to form fine holes on the particle board, figure 11. The particle board fiber profile is not uniform observed from the cross-section, the view straight fiber position, tilted left or right, horizontal, vertical, curved and all fiber positions are random. The diverse fiber geometry is potential to form a composite particle board but on length fiber 6-8 cm require higher press force. The cold pressure to particle board at fiber length 8 cm is 10,833 kgf and the fiber length of 1 cm is 1,948 kgf. It shows that the need of press force is greater on the long fiber and otherwise. Despite the pressing force applied is high enough on the particle board length 8 cm, but not significantly influence the value of MOR and MOE. Figure 12 showing the failure mechanisms of composite particle boards if pressing. the examine important for studying the mechanism so that we will know the limits of failure and deflection occur and can restrict a pressure force or load is applied to the particle board in order to avoid failure.

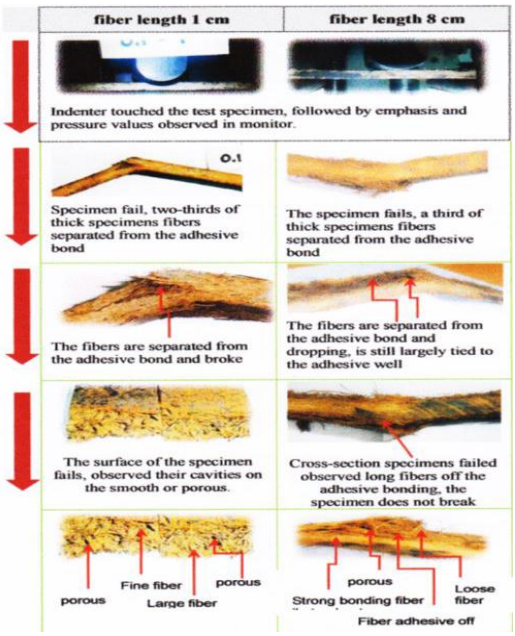

Fig. 10. *The fracture surface of composite particle board, the fiber length is 1 cm and 8 cm*

On the other hand with study the mechanism of failure we can build a more solid construction system if the particle board applied to the interior or exterior. Here are the stages of the failure mechanisms of particle board on the bending test. Thickness of specimen: 1.2 cm, width: 4 cm, length: 20 cm. Angle deflection maximum to avoid failure on particleboard is 6^o, if the angle of deflection exceeds 6^o, will be a failure of particle board. It is certainly not desired, although the crack have shown a failure but not broken specimens, the specimen need a greater load to break and deflection

4 CONCLUSION

From the discussion results of density, moisture content, MOE and MOR of particle board with eight treatments, fiber length 1, 2, 3, 4, 5, 6, 7 and 8 cm, it can be concluded that: fiber length does not affect the density but affects the moisture content, MOR, MOE and IB of particle board. the average density of 0.84 $g.cm^{-3}$, the lowest density of 0.76 $g.cm^{-3}$ and the highest density of 0.9 $g.cm^{-3}$. The average moisture content is 9.311%, the highest moisture content is 10.78% on the length of the fiber 1-3 cm and the Lowest moisture content is 7.84% on fiber length of 4-6 cm. Modulus of Rupture, Modulus of elasticity and Internal Bonding tends to decrease to the increasing length of the fiber. the highest value MOR: 21.12 MPa, MOE: 1710.86 MPa and IB: 0.3 MPa on fiber length of 0.1-1 cm.

NOMENCLATURE

Symbol	Quantity	Units
P	Density of the particle board	$g.cm^{-3}$
m	The weight of particle board	g
V	The volume of particle board	cm^3
M_1	Weight of air dried specimen	g
M_2	Weight of oven dried specimen	g
φ	Moisture content of particle board	%
F_{pl}	Load at proportional limit	kgf
F_{max}	Maximum load	kgf
Δ F	Difference start and end load	kgf
S	The distance buffer	cm
W	Width of the test specimen	cm
T	Thickness of the test specimen	cm
y_1	Deflection that occurs in the load F_{pl}	cm
	Modulus of Rupture	
MOR	Modulus of Elastisity	MPa
MOE		MPa

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