Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

Developing and Prototyping of Empty Fruit Bunch High Density Board

J. Sahari[*,1], *M. K. M Shah*[2], *M. N. Nuratiqah*[2] *and M. M. Rao*[2]

[1]Faculty of Science and Natural Resources,
[2]Faculty of Engineering,
Universiti Malaysia Sabah,
Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
[*]*sahari@ums.edu.my*

Abstract – *Empty fruit bunches and wastepaper together with urea formaldehyde (UF) were evaluated to figure out potential applications in engineering field. The purpose of this project is to determine the mechanical properties of a new high density board. This composite was manufactured by hot-press technique with 3 different ratios i.e. 10:0, 6.67:3.33 and 9.33:0.67. The mechanical properties were evaluated using the GOTECH/AI-7000M Electronic Mechanical Testing. Tensile tests were carried out according to ASTM D638. The results were analysed to calculate the tensile strength. Tensile strength at break ranged from 4.712 N/mm2 to 12.941 N/mm2 while hardness number obtained ranged from 6.76 RHN to 75.84 RHN. This fibreboard has better properties when reinforced with wastepaper compared to that of 100% empty fruit bunches. It is also found that the hardness number is higher, which means that this fibreboard can withstand any load not more than 75.84 RHN. Finally, through Scanning Electron Microscope (SEM), the surface structure of the new high density board has been studied in terms of their surface morphology.*

Keywords: Empty fruit bunches, wastepaper, urea formaldehyde, tensile strength, hardness test, scanning electron microscope

1.0 INTRODUCTION

In the last few decades, the wood composite industry has been faced with a serious shortage of forest resources. Uncontrolled harvesting, unsystematic replanting of timber and also the time taken to make plants grow are among the reasons for these problems. Therefore, to overcome this problem, lignocellulose or natural fibre based on composites from other materials is the most feasible alternative [1] to replace the depleted resources. The use of lignocellulose or natural fibres in various applications have received considerable attention by many researchers, whereby this shows increased interests in the production of lignocellulose based composites from other materials.

Natural fibres are fibres produced from plants (vegetable, leaves and wood), animals and geological processes. Researchers have used plant fibres as an alternative source for steel and artificial fibres to be used in composites to increase its mechanical properties. These plant fibres, henceforth referred to as natural fibres, include palm oil, coir, jute, Hibiscus cannabinus, pineapple leaf, kenaf bast, rice husks and bamboo [2].

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

Empty fruit bunches (EFB) is one of the major biomass types produced in the Malaysian oil palm industry; this industry contributes 85.5% of the total biomass production in Malaysia. From 85.71 million tonnes of Fresh Fruit Bunches (FFB) produced in 2009, an estimated amount of 6.76 million tonnes of dried EFB was generated from oil palm mills. Among various oil palm fibre sources available, EFB has the potential to yield up to 73% of fibres and becomes the preferred material for the bio-composite industry based on its high availability and low cost [3].

Since the late 1960's, there have been increasing concerns about the manner in which municipal solid wastes were collected and disposed of and because of increased environmental concerns, recycling has now received global attention. Some attempts to reduce the wastes by recycling have recently been initiated. Since it has the largest share of municipal solid wastes, attempts must be taken to reduce it. Therefore, this initiated the idea to combine Empty Fruit Bunches (EFB) with waste papers to build new high density boards.

High density board (HDB) is a high-density insulation board comprising of an engineered wood product manufactured from exploded wood fibres, combined with max and resin such as urea formaldehyde resin (UF), phenol formaldehyde resin (PF) or isocyanate binder, and then formed into panels by applying high temperature and pressure using a hot press with 800 – 1,100 kg/m^3 [4].

Among various oil palm fibre sources available, EFB has the potential to yield up to 73% of fibres and has become the preferred material for bio-composite industries due to its high availability and low cost. Particularly, the cellulose content and high toughness of EFBs make it suitable for composite applications [5].

Many studies have reported on the results of incorporating EFB into composite products. However, some researchers have claimed that Medium Density Board or MDB made from oil palm EFB were inferior in properties compared to those made from rubber-wood and other oil palm fibres. Chipboards made from this material, however, has comparable properties to those manufactured from rubber-wood, except for machining properties [6].

2.0 METHODOLOGY

Empty fruit bunches used in this project were supplied by Makmal Konkrit, Sekolah Kejuruteraan & Teknologi Maklumat, Universiti Malaysia Sabah. The empty fruit bunches are discharged as solid wastes after being separated from fresh fruits at palm oil mills and is a bouquet combining individual strands in its natural condition with a natural blunt brown colour. The fibers are partly loose and partly parallel-lapping each other in thick formation through soft composition. It is not truly rounded. However, the range of the fiber diameter is between 0.4 mm and 0.8 mm with length of more than 50 mm.

Penerbit Akademia Baru
Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

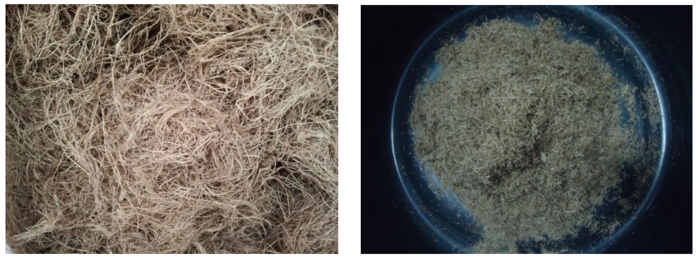

Figure 1: Different conditions of EFB before and after chopped.

Waste-papers should firstly be shredded before being used as reinforcement material with empty fruit bunches. These waste-papers were collected from offices around Penampang, Sabah. The type of resin used in this project is Urea Formaldehyde (UF). This resin was obtained from Sepangar Chemical Industry Sdn. Bhd. and was used as a matrix. Besides that, this resin's attributes include high tensile strength, flexural modulus and heat distortion temperature, low water absorption, mould shrinkage, high surface hardness, elongation at break and volume resistance. Urea Formaldehyde is used in many manufacturing processes due to its useful properties that include textiles, paper, cotton blends, etc. This product is widely chosen as an adhesive resin due to its high reactivity, good performance and low price.

The high density board specimen was formed using a concrete mould. The mould size is 150 mm ×150 mm ×150 mm. This mould was heated in an oven at temperature of 120°C - 200°C for a day before used.

The specimens were manufactured in the Makmal Konkrit, SKTM, UMS via hot-pressed method. The matrix material, urea formaldehyde (UF), is reinforced with empty fruit bunches and wastepaper. The combinations are mixed thoroughly in ratios of 10:0, 9.33:0.67 and 6.67:3.33, equivalent to the weight of empty fruit bunches with wastepaper and 50 g of urea formaldehyde for each specimen. Three boards with dimensions of 150 mm X 150 mm for the different ratios were manufactured.

Tensile test is aimed to obtain tensile properties. Tensile test is commonly used to determine mechanical properties such as strength, toughness and modulus of elasticity. There are 3 specimens for the three different compositions. The tensile test was run by using GOTECH/AI-7000M Electronic Mechanical Testing. All these samples have been cut according to ASTM D638 and will be used in the tensile test.

All the specimens are tested using the Electronic Mechanical Testing with a speed rate of 1mm/min. Samples are placed in the grips of the machine at specified grip separation and pulled until failure. The machines will automatically produce a stress versus strain diagram, thus the mechanical behaviour of the composites can be interpreted from the diagram. The specimen will elongate as the tensile test starts. The load value (F) is recorded up to the point where the specimen breaks. The instrument software, which is provided with the machine equipment, will calculate the tensile properties such as the tensile, yield strength and elongation.

The Rockwell hardness tester has been widely used to measure hardness of various materials, from metals to plastics; the SHIMADZU Digital Rockwell Hardness Tester was used to test the high density board specimens as shown in Figure. The Rockwell hardness tester can

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

easily be operated even by inexperienced people and provides reliable measurement results regardless of the operator's skill. The measuring principle and structure of a Rockwell superficial hardness tester are almost the same as those of the Rockwell hardness tester.

Tensile tests have been performed and the mechanical properties such as tensile strength and tensile modulus were determined. In this project, there were 3 specimens prepared. The test specimens were cut into the dimension of 150 mm X 25 mm.

3.0 RESULTS AND DISCUSSIONS

The aim of this paper is to establish mechanical properties such as tensile strength and hardness number from the new high density board with different ratios. Basically, three main tasks were carried out in order to achieve the objectives of this project. The first task is to prepare the high density board by combining empty fruit bunches, wastepaper and Urea Formaldehyde. This is followed by performing the hardness test and tensile test, and lastly, a microstructure analysis is carried out to study the de-bonding mechanism of the fiber composites with regards to the wastepaper content in the high density board.

As previously known, fibreboards are brittle and the fracture strengths of fiber materials are low compared to metals and ceramics. Cracks form at a region where there is stress concentration (air bubble) during the fracture process. Air bubbles have been trapped in this composite during the mixing process of fiber, wastepaper and resin. These air bubbles are also defined as voids. When applied stress is concentrated to the void, it causes cracks that subsequently lead to crack propagation and fracture. Figure 2 shows the final product of the high density fibreboards.

Figure 2: Different ratios of new high density board

Table 1 shows the tensile strength of EFB fibres, whereby the range of its strength is 49-62 N/mm^2 while the diameter is 0.4-0.8 mm. After the fabrication of the high density fibreboard, it was found that the tensile strength of high density fibreboard decreased as shown in Table 2. Meanwhile the tensile strength of the specimen increased with the increase in EFB fibres as shown in Table 2 and Figure 3.

Journal of Advanced Research Design
ISSN (online): 2289-7984 I Vol. 3, No.1. Pages 1-8, 2014

Table 1: Properties of Empty Fruit Bunches Fibres

Properties of Empty Fruit Bunch (EFB) Fibres	
Description	**Result**
Diameter, mm	0.4 – 0.8
Tensile strength, N/mm^2	49 - 62

Table 2: Tensile Properties of High Density Board Specimens

Specimen (Ratio)	Width mm	Thickness mm	Area mm^2	Gauge mm	Max. Load N	Tensile Strength N/mm^2	Elongation mm
1 (10:0)	21.55	8.55	184.25	50.00	868.274	4.712	2.01
2 (6.67:3.33)	27.35	7.35	201.02	50.00	2601.351	12.941	1.54
3 (9.33:0.67)	24.67	8.55	210.93	50.00	2706.202	12.830	2.43
Average	24.52	8.15	198.73	50.00	2058.61	10.161	1.99

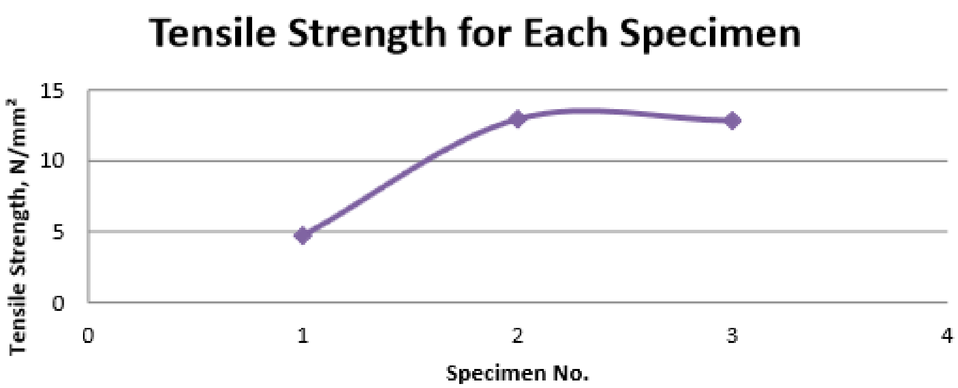

Figure 3: Tensile strength for the 3 specimens

Hardness test were conducted using SHIMADZU Digital Rockwell Hardness Tester to obtain the hardness properties of the high density board specimen. Three specimens of different ratios were prepared for this test; 10:0, 9.33:0.67 and 6.67:3.33. Measurement is made by determining the depth of penetration of the indenter in the material being tested. This measurement is then transmitted to a linear scale in increments from 0 to 100, by which one increment equals to one hardness point. The hardness tests were performed according to the Japanese Industrial Standards and International Standards. Five reference points are used for each specimen board during the test run. Figure 4 below shows the reference points. The hardness properties of the sample also shows increment with increasing EFB in the fibreboard as shown in Table 3 and Figure 5.

Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

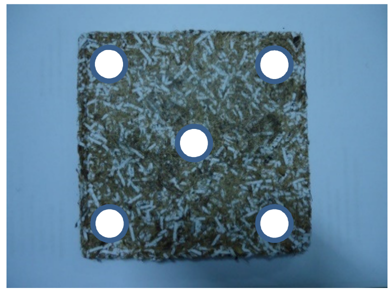

Figure 4: Reference points used during Hardness test

Table 3: Results of Rockwell hardness tests for load of 60 N (HRF)

Load of 60 N (HRF)			
Reference Point	**Specimen 1 (100 g EFB) RHN**	**Specimen 2 (140 g EFB) RHN**	**Specimen 3 (150 g EFB) RHN**
1	73.6	90.3	82.3
2	35.8	65.9	51.4
3	47.4	54.4	86.6
4	49.2	83.2	83
5	70	85.4	75.8
Average	**55.2**	**75.84**	**75.82**

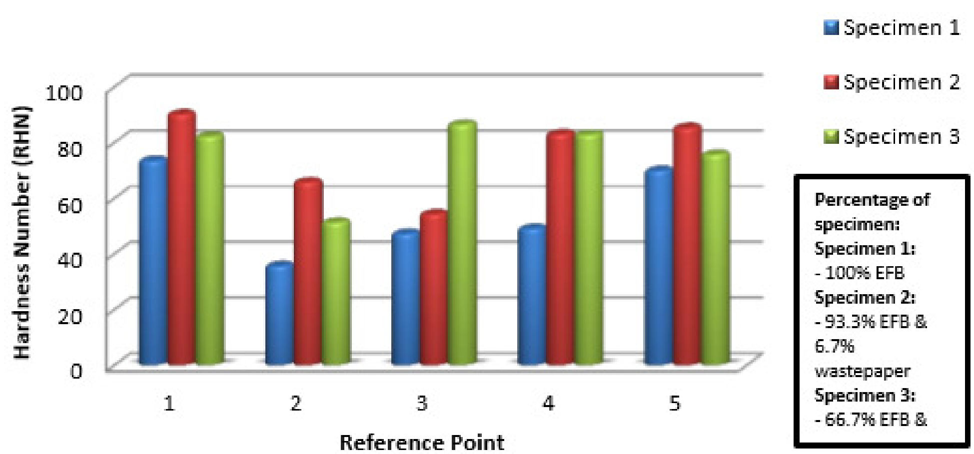

Figure 5: Graph of Rockwell hardness test for 60 N (HRF)

Figure 6 shows SEM micrographs of high density board surface with magnification of 50x. There is a gap of fibres and matrix where the fibres hold up the uniform matrix by carrying loads. The fibres are detached from the resin surface due to poor interfacial bonding. Fibres contain impurities, wax, fatty substances and globular protrusions called ‘tyloses’. The fibre surfaces are extremely heterogeneous with smooth and rough portions in the same fibre.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

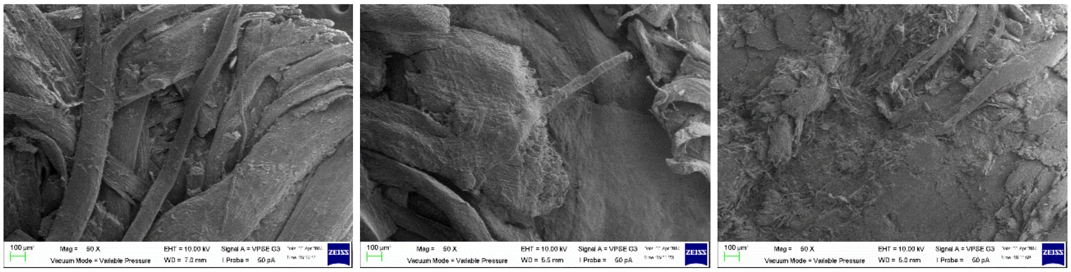

Figure 6: SEM images for HDB of 3 specimens with magnification of 50x

Mechanical keying is a form of adhesive bonding, during which adhesive material physically locks into the crevices of the surface. There are two or more separate components of interlocked molecules, which are not connected by chemical or covalent bonds. The valleys and crevices of each fibre must be filled with matrix that displaces trapped air in order to work well. Matrix and fibre is mechanically interlocked by adhesion and the overall strength of the bond is dependent upon the quality of this interlocking interface [7, 8].

The surface of the fibre is not rough thus indicating that the compatibility between the fibres and matrix is poor. However, this compatibility can be improved by chemically treating the fibres. Some research proved that treated fibres increase the value of tensile strength by 53% as compared to the composites of untreated fibres. They also stated that the treatment improves the fibre-matrix adhesion, allowing an efficient stress transfer from the matrix to the fibre [9].

4.0 CONCLUSIONS

High density fibreboards have been successfully developed using EFB as reinforcements. Overall, the tensile and hardness properties of the high density fibreboards show increase with increasing EFB loading. The possible application that is suitable for this composite material is high density fibreboards. It is suitable because the value of tensile strength and hardness number of this composite material is higher than other existing composites material. This high density fibreboard also has all the advantages of a Medium-Density Fibreboard and is widely used for both indoor and outdoor decorations as well as office and high-grade furniture.

REFERENCES

[1] H.P.S. Abdul Khalil, M.Y.N. Firdaus, M. Jawaid, M. Anis, R. Ridzuan, A.R. Mohamed, Development and material properties of new hybrid medium density fibreboard from empty fruit bunch and rubberwood, Materials & Design 31 (2010) 4229-4236.

[2] S. Hiziroglu, S. Jarusombuti, P. Bauchongkol, V. Fueangvivat, Overlaying properties of fiberboard manufactured from bamboo and rice straw, Industrial Crops and Products 28 (2008) 107-111.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 1-8, 2014

[3] M.A.N. Izani, M.T. Paridah, A.A. Astimar, M.Y.M. Nor, U.M.K. Anwar, Mechanical and dimensional stability properties of medium-density fibreboard produced from treated oil palm empty fruit bunch, Journal of Applied Sciences 12 (2012) 561-567.

[4] X. Li, Y. Li, Z. Zhong, D. Wang, J. A. Ratto, K. Sheng, X.S. Sun, Mechanical and water soaking properties of medium density fiberboard with wood fiber and soybean protein adhesive, Bioresource Technology 100 (2009) 3556-3562.

[5] D.K. Ng, R.T. Ng, Applications of process system engineering in palm-based biomass processing industry, Current Opinion in Chemical Engineering 2 (2013) 448-454.

[6] J. Rathke, M. Riegler, M. Weigl, U. Müller, G. Sinn, Analyzing process related, in-plane mechanical variation of high density fiber boards (HDF) across the feed direction, BioResources, 8 (2013) 3982-3993.

[7] J. Sahari, S.M. Sapuan, Natural fibre reinforced biodegradable polymer composites, Review on Advance Materials Science 30 (2011) 14 -34.

[8] J. Sahari, S.M. Sapuan, E.S. Zainudin, M.A. Maleque. Thermo-mechanical behaviours of thermoplastic starch derived from sugar palm tree (Arenga pinnata), Carbohydrate Polymer 92 (2013) 1711- 1716.

[9] J. Sahari, S.M. Sapuan, Z.N. Ismarrubie, M.Z.A. Rahman, Physical and chemical properties of different morphological parts of sugar palm fibres, Fibres & Textiles in Eastern Europe 20 (2012) 21-24.