FABRICATION OF MEDIUM DENSITY FIBRE BOARD FROM OIL PALM FROND USING WASTE LOW DENSITY POLYETHYLENE (LDPE) COMPOSITES AS POSSIBLE PARTIAL REPLACEMENT FOR BINDER

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SUPERVISOR'S DECLARATIONS

"I hereby declare that I have read this thesis and in my opinion this thesis has fulfilled the qualities and requirements for the award of Degree of Bachelor of Chemical Engineering (Gas Technology)"

Signature: …….
Name of Supervisor: Dr. Ghazi Faisal Najmuldeen
Date: 2 January 2013

STUDENTS'S DECLARATION

I declared that this thesis entitled "Fabrication of Fibre Board from Oil Palm Frond Using Waste Low Density Polyethylene (LDPE) Composites As a Possible Partial Replacement for Binder" is the result of my own research except as cited in references. The Thesis has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

Signature: …….
Name: Fakhri Fadullilah Bin Sulaiman
Date: 2 January 2013

Special Dedication of This Grateful Feeling to My..

Beloved parent;

Mr. Sulaiman Bin Hassan & Mrs. Rokiah Binti Amit

Loving brothers and sisters;

Mashitah, Abdul Fattah, Noor Najla Asyura, Yusri Azman and Muhammad Amirullah

Understanding and helpful friends especially to;

Fakhriyah Ayuni Binti Sahraini

For Their Love, Support and Best Wishes.

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ABSTRACT

There are two objectives in this research. The first objective is to produce the high quality of medium density fibre board from waste biomass material, oil palm frond mixed with waste LDPE composites at the same time reducing the percentages of urea formaldehyde resin. The second objective is to characterize the physical and mechanical properties of fibre board. This research is very important to environment, it is one of the solution in order to reduce the emmission of toxic formaldehyde from MDF. Different composition are use in order to produce the high fibre board in terms of strength and swelling effect. In industry, urea formaldehyde is use as a binder in fibre board manufacturing. In this research, the waste LDPE composite is selected as a possible partial replacement for binder in order to reduce the emission of toxic formaldehyde. Based on this research, the high quality fibre board can be produced which achieved the industrial requirement but strictly limited in its application.

ABSTRAK

Terdapat dua objectif dalam kajian ini. Objectif yang pertama adalah menghasilkan papan gentian berkualiti tinggi daripada sisa bahan biojisim iaitu dahan kelapa sawit yang dicampur dengan polietilina dalam masa yang sama mengurangkan peratusan urea formaldehid. Objectif kedua adalah untuk mengelaskan papan gentian dari segi fizikal dan mekanikal. Kajian ini sangat penting kepada alamsekitar, ia adalah salah satu cara untuk mengurangkan pembebasan toksik formaldehid daripada papan gentian. Komposisi yang berbeza digunakan untuk menghasilkan papan gentian terbaik dari segi kekuatan dan kesan terhadap air. Di industri, urea formaldehid digunakan sebagai bahan pelekat dalan pembuatan papan getian. Dalam kajian ini, sisa bahan polietilina berkepadatan rendah dipilih sebagai sebahagian daripada pelekat untuk mengurangkan pelepasan formaldehid yang bertoksik. Berdasarkan kajian ini, papan gentian yang berkualiti tinggi dapat dihasilkan yang mencapai tahap industri tetapi hanya boleh digunakan dalam aplikasi tertentu.

LIST OF ABBREAVIATIONS

IB - Internal Bonding

LDPE - Low Density Polyethylene

MDF - Medium Density Fibreboard

MOR - Modulus of Rupture

OPF - Oil Palm Frond

SW - Swelling

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Frond, one of the largest waste from palm oil estate today. It is important to convert the waste to useful material. In addition to that, recycling the waste helps mitigate global warming and reduce deforestation activities. The amount of frond in Malaysia keep increasing every year due to a rapid expansion of its planted areas. In 2005, Malaysia produced more than 51 million tonnes of oil palm wastes particularly the empty fruit bunch (EFB), frond and trunk. (MPOB, 2006)

Various agricultural and municipal waste materials including municipal solid waste, biosolids, animal manures, yard trimmings, agricultural residues, waste paper, food processing wastes are composted as potting media without any negative effects on a variety of crops raised in these substrates (Inbar et al. 1986; Bugbee and Frink, 1989; Beeson 1996; Eklind et al. 2001; Hashemimajd et al. 2004).

Areas under oil palm increased from 54,000 hectares in 1960 to 4.05 million hectares in 2005, reflecting a compound annual growth of 10.06%. Production increased from 94,000 tonnes in 1960 to 15 million tonnes in 2005, or by almost 160 times within 45 years, this represents a compound annual growth of 11.93% per year. (Yusof Basiron, 2007)

Eight leaves (fronds) are produced in successive leaf spirals. Five spirals of leaves are retained on each mature tree. Leaf production rate is between 1 to 3 leaves per month. It grow up at low altitude which is less than 500 m above sea level, 15º from the equator in the humid tropics. Evenly distributed rainfall of 1,800 to 2,000 mm/year, but will tolerate rainfall up to 5,000 mm/year. Commercial palms have an economic life span of 20 to 30 years. (Better Crops International, 1999).

The oil palms comprise two species of the Arecaceae, or palm family. The African Oil Palm *Elaeis guineensis* is native to West and Southwest Africa, occuring between Angola and Gambia, while the american Oil Palm *Elaeis oleifera* is native to tropical Central America and South America. Mature trees are single-stemmed, and grow to 20 m tall. The leaves are pinnate, and reach between 3-5 m long. A young tree produces about 30 leaves a year.

This research also concern about the huge amount of polymer waste around the world. Most light weight plastic packaging material is used for a one-time application and discarded when its useful life is over. These materials are durable and inert in the presence of microbes thus leading to a long term performance. (Arvanitoyannis, et al., 1998)

1.2 Problem of Statement

Now a days, up to 70 million tonnes per annum biomass collected in Malaysia. The massive amount of waste mainly comes from palm oil industry which contribute more than 80 percent. The increasing amount of waste around the world leads to environment problem such global warming due to burning of biomass. The wood fibre are the main component in fibre board manufacturing industries. The excess amount of wood fibre used in industry leads to deforestation problem.

There has been much awareness regarding the harmful effects of polymer materials on the environment. Recycling is obviously a better choice at a higher cost but most countries cannot afford to recycle all its polymer wastes. Moreover, all polymers are not recyclable since their properties after recycling are poor compared to their original ones and they are of less economic value (Narayan, 1990).

In Industry, normally urea formaldehyde is used as a binder. After a long period of time, the composites wood products will emit the toxic formaldehyde to the air. The emission of toxic formaldehyde to environment is harmful to human health. It is very important to reduce or replace the used of urea formaldehyde with other type of binder which are safe to environment and economic.

In the mid 1980s the forest cover of Borneo was still at 75%. In 2005 only 50% of Borneo remained under forest cover. Between 1985 and 2005 Borneo lost an average of 850,000 ha of forest every year. If this trend continues, forest cover will drop to less than a third by 2020. The rate of deforestation in Kalimantan (the

Indonesian part of Borneo) is increasing. Between 2000 and 2002 deforestation rose to 1.2 million ha a year. Together with the forest loss in Sabah and Sarawak (the Malaysian part of Borneo) this would amount to a total forest loss of 1.3 million ha a year. This is the equivalent of 148 ha every hour, 2.5 ha a minute. (Mario Rautner *et al.,* 2002)

1.3 Objectives of Research

i. To produce the high quality of medium density fibre board from waste biomass material, oil palm frond mixed with waste LDPE composites at the same time reducing the percentages of urea formaldehyde resin.
ii. To characterize the physical and mechanical properties of fibre board.

1.4 Scope of Research

In order to achieve the objectives, several scopes has been identified.

i. Using different composition of fibre board to produce high quality fibre board.
ii. Observe the swelling effect towards the increase in thickness of fibre board.
iii. Test the strength of fibre board with universal testing machine.

CHARTER 2

LITERATURE REVIEW

2.1 Oil Palm Frond (OPF)

Increase of industrial activities causing an ascending accumulation of different types of wastes such as frond which come from palm oil estate. According to MPOB on 2006, the oil palm frond was produced 26.2 million tonnes per annum from palm oil industries in Malaysia. OPF is one type of the fibre that can be use to produce fibre board in industry.

Figure 2.1.1: Oil Palm Frond (OPF)

Malaysia is currently the world's largest producer and exporter of palm oil. The plantation sector dates back to 1896, with the start of the rubber industry. Oil palm cultivation began in 1917, but growth was initially very slow. It was only during the last 50 years that plantation development was accelerated through large-scale investments in the cultivation of the oil palm as one of the approved crops for diversifying the country's agricultural development. (Yusof Basiron, 2007)

The availability of fronds during the pruning activity was calculated using estimate of 10.4 tonnes ha^{-1}, which currently gives an average of 6.97 million tonnes per year. Meanwhile, it was estimated at an average of 54.43 million tonnes per year of OPF will be available during the replanting process in the years of 2007 – 2020. (Oil Palm Biomass, 2009)

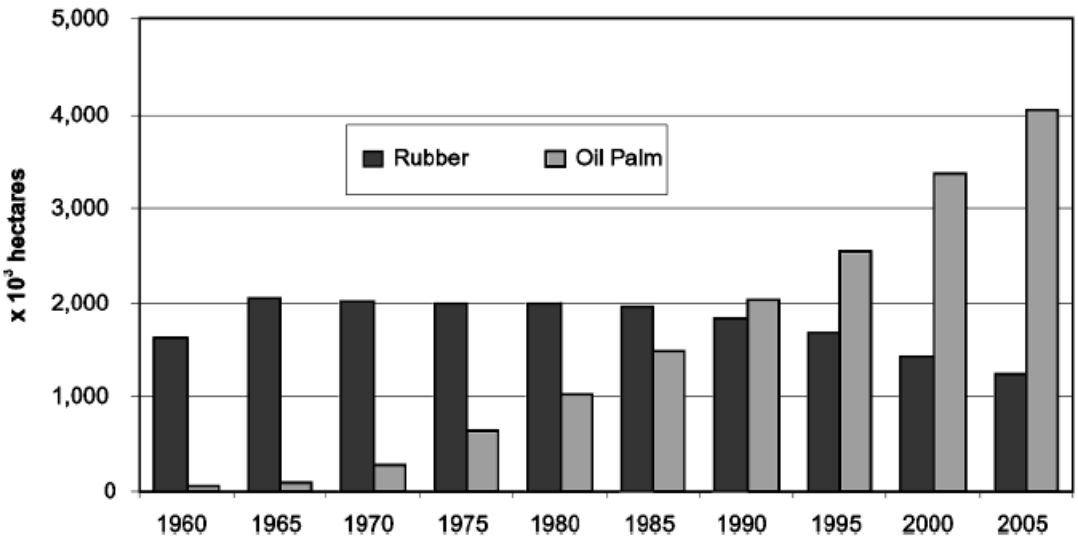


Figure 2.1.2: Planted area for oil palm and rubber in Malaysia.
(Source: MPOB, Malaysian Rubber Board)

Chemically, the frond strands are rich in holocellulose (83.5%) and also high in α-cellulose (49.8%), both of which are important parameters in determining the suitability of a raw material for papermaking (Ona et al., 2000). As a comparison, the data from Canadian aspen (*P. trem.*) is also included. The lignin content (20.5%) is lower than normally found in common hardwood, for example aspen of 18.1% (Law and Jiang, 2001) and eucalyptus of 22% (Alcaide et al., 1990)

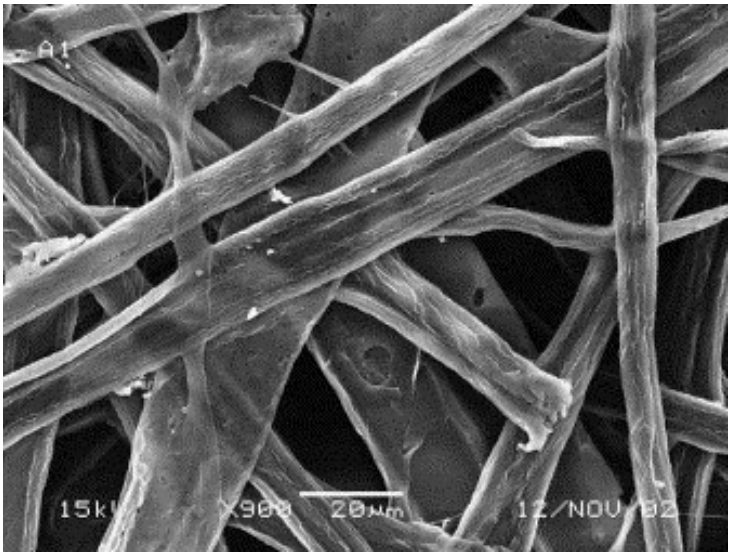


Figure 2.1.3: SEM of oil palm frond
(Source: W.D. Wanrosli *et. al.,*2007)

2.2 Toxic Formaldehyde

Formaldehyde is a suspected human carcinogen that is known to be released from pressed-wood products used in home construction, including products made with urea-formaldehyde resins (Kelly *et al*., 1999; Otson and Fellin 1992). Emissions have resulted in various symptoms, the most common of which is irritation of the eyes and the upper respiratory tract (Pickrell *et al*., 1986).

2.3 Medium Density Fibreboard (MDF)

MDF (Medium Density Fibreboard) was developed in the United States and has since 1973 been produced in Europe, where it achieved an effective breakthrough only in the 1990s. For MDF boards, the weight by volume varies from 450 to 800 kg/m³. (Spanolux, Wood Based Solutions). MDF is denser than plywood. It is made up of separated fibres, but can be used as a building material similar in application to plywood. It is stronger and much more dense than normal particle board.

Figure 2.3.1: Medium Density Fibreboard

In the case of MDF boards, the weight by volume is not constant across the thickness and across the width (and to a lesser extent across the length) of the board. The press can be set for the production of MDF with high or low densified cover layers. MDF is produced in various types and qualities.

In terms of weight by volume, MDF can be classified as follows:

- HDF: $\geq$ 800 kg/m³
- MDF: $\geq$ 650-800 kg/m³
- Light MDF: $\geq$ 550-650 kg/m³
- Ultralight MDF $\geq$ 450-550 kg/m³

2.4 MDF Manufacturing

Medium Density Fibreboard (MDF) is an engineered wood product formed by breaking down hardwood or softwood residuals into woodfibres, often in a defibrator, combining it with wax and a resin binder and forming panels by applying high temperature and pressure (Spence, 2005). MDF is manufactured using the dry process in which the wood fibres are mixed with resin and pressed in dry condition. The weight by volume represents the mass per unit of volume.

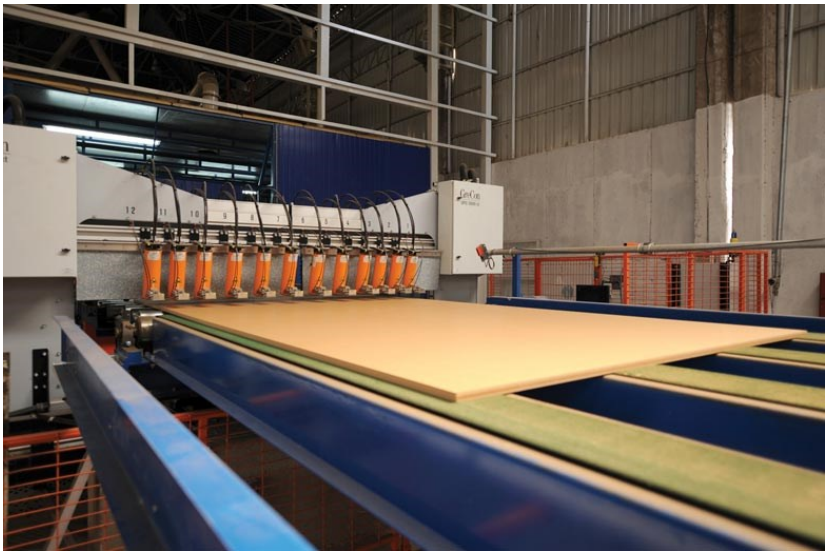


Figure 2.4.1: MDF Manufacturing in Industry

In industry, there are several types of thermosetting resin that is used as a binder such as Urea Formaldehyde (UF) and Phenol Formaldehyde (PF). The wood fibre is dried so that the moisture content is less than 10 percents. Then, the wood fibre is blend and spray properly with resin for a few minutes before it is press in high temperature at certain period of time.

2.5 Moisture Content in MDF

After production, MDF has a moisture content of 8 ± 3%. At the time of delivery to the end-user, however, the moisture content may have altered due to ambient factors during transport and storage. In particular, storing the panels in a humid environment on the construction site will inevitably lead to water absorption. Conversely, the moisture content will decrease in a very dry environment. (Spanolux, Wood Based Solutions). During the blending, chemical spray and pressing, the moisture content of wood fibre should be less than 10 percents.

2.6 Board Testing

2.6.1 Modulus of Rupture

Modulus of Rupture (MOR) is the maximum force necessary to break a specimen of specified width and thickness. According to Andreas in 2007, MOR is an accepted criterion of strength, although it is not a true stress because the formula by which it is computed is valid only to the elastic limit. Figure 2.6.1 show the 3-point bending test for MOR according to European standard EN310.

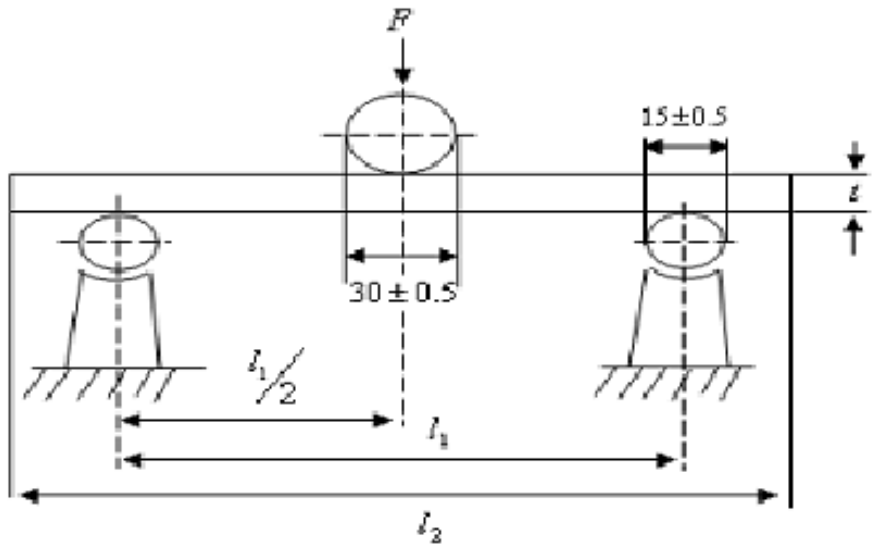


Figure 2.6.1: 3-Point Bending Test

Another European Standard that can be use to test the MOR is EN789. This testing method are called 4-point bending test. EN798 is quite different compared to EN310 which is, two direction of force are applied against the sample at the same time. On the other hand, only one direction of force applied against the sample. Based on study by S.F. Tsen and M. Zamin Jumaat in 2011, tested under EN310 had MOR larger and MOE smaller than EN789.

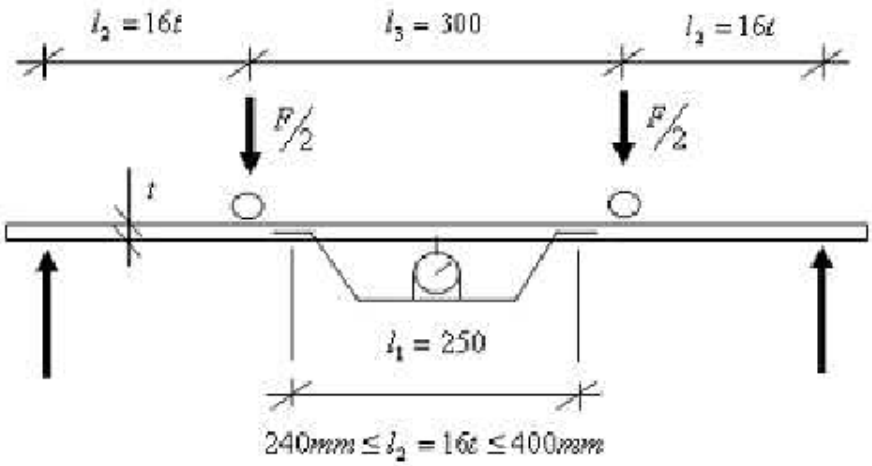
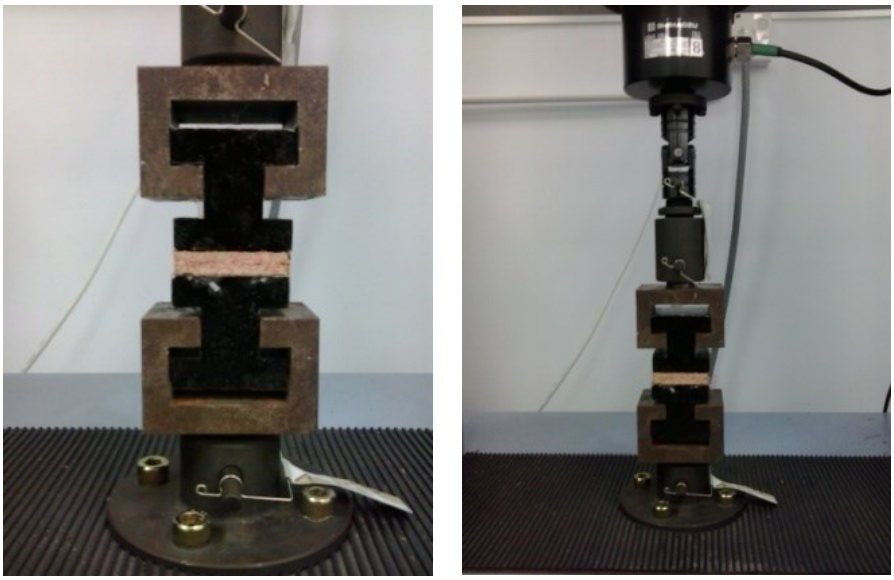


Figure 2.6.2: 4-Point Bending Test

2.6.2 Internal Bonding

The Internal Bonding (IB) is the strength perpendicular to the plane of the board. This testing on board provides direct information on the adhesion of the wood particles. In this testing, special block should be glue with the sample before it can be fit in the testing machine. The European Standard EN319 is used in this test. Figure 2.6.2 (a) and (b) show the internal bonding test with block.



(a) (b)

Figure 2.6.2: The Internal Bonding Test

2.6.3 Thickness Swelling

In swelling test, the effect of water on MDF can be investigate by the different in thickness of MDF after immersed in water for 24 hours. The percentage of swelling can be calculated based on the different in thickness. In this research, The swelling test is conducted according to European Standard EN317.

2.7 Universal Testing Machine

Universal testing machine is one of the important equipment use in this research. The mechanical properties features of wood based panels can be easily and precisely determined. Measurement can be carried out according to European Standards (EN), for the measurement of internal bond strength, according to

alternative testing methods. The alternative measuring methods supply the results within a few minutes.

Figure 2.7.1: Universal Testing Machine

2.8 Hot Molding Place

Hot molding place is the equipment which shape the fibre board according to the target thickness. The sample is pressed with high pressure and temperature. The blending sample is pressed by two heated plate. The temperature of upper and lower pressing plate in this equipment can be set manually according to requirement. In addition, the pressure and time of pressing also can be set.

Figure 2.8.1: Example of Hot Molding Place

2.9 Urea Formaldehyde

Urea formaldehyde (UF) is the common type of resin use in industry. It available in liquid and powder form. Urea formaldehyde is a synthetic resins, it is obtained by chemical combination of urea and formaldehyde. Formaldehyde is a highly reactive gas obtained from methane while the urea is a solid crystal obtained from ammonia. Urea-formaldehyde resins are used mostly as adhesives for the bonding of plywood, particleboard, and other structured wood products. In this research, urea formaldehyde in liquid form is used as a binder. The density of UF is around 1.282 g/cm^3.

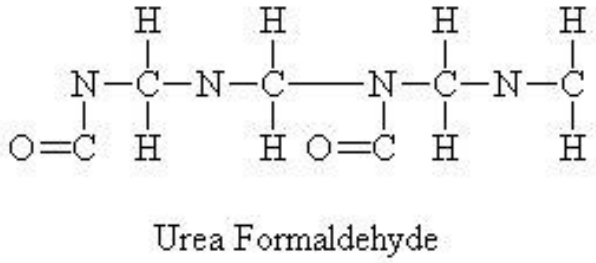


Figure 2.9.1: Molecular Structure of Urea Formaldehyde Resin

2.10 Natural Binder

In MDF manufacturing, synthetic resin is used as a binder. In plant, the wood fiber is bind together with the natural binder. The natural binder in plant are called lignin. It is an organic substance binding the cells, fibres and vessels which constitute wood and the lignified elements of plants, as in straw. After cellulose, lignin is the most abundant renewable carbon source on Earth. (International Lignin Institute)

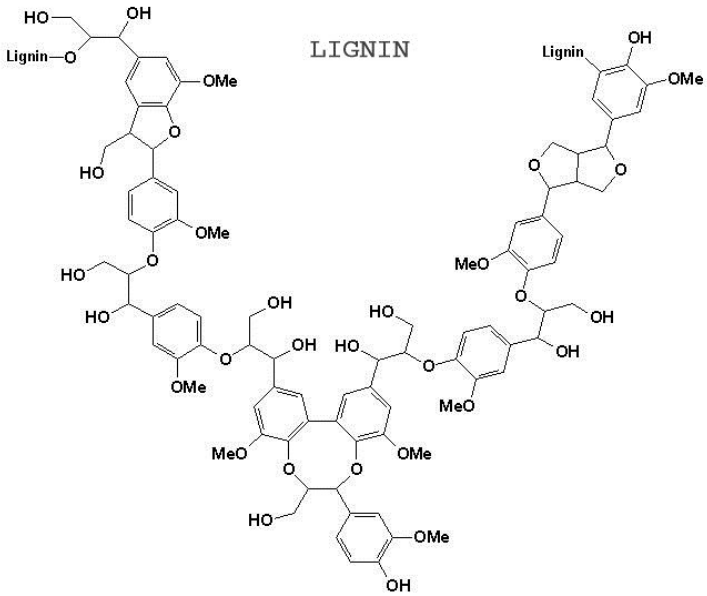


Figure 2.10.1: Molecular Structure of Lignin

2.11 Low Density Polyethylene (LDPE)

LDPE represents the majority of thermoplastics currently used as food packaging materials. Since the production and consumption of these polymers is incessantly increasing (Behjat Tajeddin *et al.,* 2009). There are different types of polymers: natural polymers (for example wool, silk, wood, cotton), half synthetic polymers (natural polymers which are chemically modified, for example casein plastics, cellulose plastics) and synthetic polymers (27, TWGComments, 2004).

Worldwide production of plastics is more than 78 million tons per year and almost half of that is discarded within a short time, remaining in garbage deposits and landfills for decades (more than 30 years) (Volke-Sepulveda et al., 1999). Polymer companies produce a variety of basic products, which range from commodities to high added-value materials and are produced in both batch and continuous processes covering installations with a capacity of some 10000 tonnes per year up to some 300000 tonnes per year.

The underlying building principle is very flexible so that polymers with an extensive range of properties and property combinations can be produced. Polymers in the shape of objects, fibres or films may be:

- Rigid or flexible.
- Transparent, translucent or opaque.
- Hard or soft.
- Weather resistant or degradable.
- Resistant to either high or low temperature.

In addition, they may be compounded with fillers, blended with other products (e.g. glass fibres) forming so-called composites or with other polymers yielding polymer blends. Alternative materials exist and polymers have to be successful in a competitive market. Polymers often bring advantages to numerous applications, for example:

- Weight reductions and consequent transport and fuel savings.
- Electrical insulating properties suitable for wiring, switches, plugs, power tools and electronics.
- Optical transparency suitable for packaging, lighting and lens applications.
- Corrosion resistance which is important for plumbing, irrigation, rainwear and sports articles.
- Resistance to chemicals, fungi and mildew.
- Ease of processing making complicated shapes possible.
- Cost savings over alternative solutions.

(Best Available Techniques in the Production of Polymers, 2007)

LDPE has more branching (on about 2% of the carbon atoms) than HDPE, so its intermolecular forces (instantaneous-dipole induced-dipole attraction) are weaker, its tensile strength is lower, and its resilience is higher. Also, since its molecules are less tightly packed and less crystalline because of the side branches, its density is lower. LDPE contains the chemical elements carbon and hydrogen.

Figure 2.11.1: The Pure LDPE

Figure 2.11.2: Waste LDPE Composites

2.12 Logged and Fragmented Landscapes

Various aspects of timber harvesting and concession development have different impacts on landscapes, habitats, and the life-cycle of endemic species. In forestry concessions, these effects operate in concert, making the specific causes

behind changing species abundances hard to identify without detailed study. Nonetheless, there is some understanding of these various processes.

Beyond removing selected timber trees, concerns include damage to residual trees, streams clogged by debris, ground compaction, increased soil erosion and flooding (DFID 1999), and increased access to forests leading to greater threat of further harvesting, clearance for other land-uses and increased hunting pressure (Robinson & Bennett 2000). Some of these issues are discussed more fully in additional sections below. Poorly planned and implemented logging can result in large, heavily fragmented and unproductive areas, especially in forests with high road density, wide clearings, and many trial-and-error openings. (Putz et al. 2000, 2001)

Figure 2.12.1: Roads and the use of heavy machinery cause fragmentation and lead to severe soil disturbance and erosion. (Photo by Rob Fimbel)

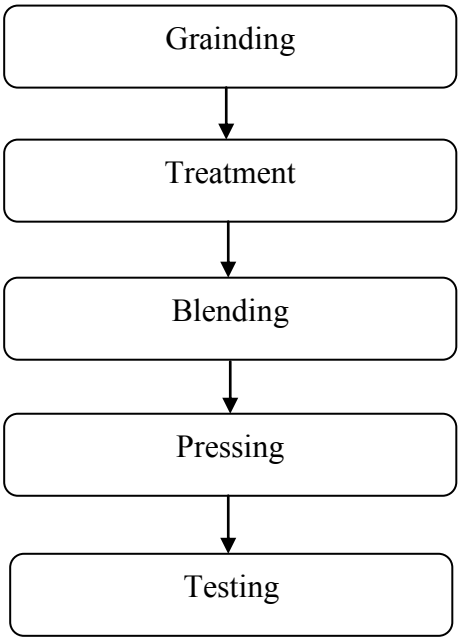
CHAPTER 3

METHODOLOGY

3.1 MATERIAL AND APPARATUS

The main raw materials in this research is palm oil frond. The frond fibre are used as a source of fibre. The frond are taken from Malaysian Palm Oil Estate. Another main material in this study is Urea Formaldehyde resin. It is used to bind all the wood fibre during the pressing. Apart from that, alcohol is used for treatment process. The main equipment that used in this study are the grainding machine, blending machine, hot molding pressing machine and universal testing machine.

3.2 Flow Process



3.2.1 Grainding

The OPF are taken from the estate and wash properly with water to remove the debries on the fronds surface.

↓

The fronds are cut into a small size around 5cm in length. It is very important to dried the fronds before grainding to get the small size of fibre.

↓

The fronds are dried in the oven at 70 ^{o}C for 24 hours to remove the moisture content to at least less than 12 percents.

↓

The fronds are grained with grainding machine. The fronds should be cut as small as possible to avoid the damage during the grainding process.

3.2.2 Treatment

The grained wood fibre is placed in the container.

↓

Around 5L of ethanol is poured in the container until all fronds fibre immersed completely.

↓

The fronds fibre is immersed for 24 hours to remove the unwanted substance such as chlorophyl.

↓

After immersed in alcohol, the fronds fibre is dried again in the oven at 70 ^{o}C for 24 hours to remove the moisture content to less than 10 percents.

3.2.3 Blending

The fronds fibre is placed in the blending machine. The amount of fibre to be blend is depend on volume of MDF sample.

↓

The waste LDPE composites that has been cut into small size is mixed together in the blending machine.

↓

The fronds fibre and waste LDPE composites is blended together for several minutes.

↓

During the blending process, the Urea Formaldehyde is sprayed into the blending machine with compressed air.

↓

The mixture is removed from blending machine after it blended properly with chemical.

3.2.4 Pressing

The blended fibre is placed in the 20 cm^2 molding place.

↓

The blended fibre is pressed by hand in the molding place and then the molding place is removed.

↓

The molded fibre is placed in the pressing chamber. The iron stopper is placed at the left and the right side of molded fibre. The thickness of stopper is depend on thickness of MDF which is 9mm.

↓

The molded fibre is pressed at high temperature and pressure for 10 minutes. After pressing, the stopper is removed from MDF

3.2.5 Testing

The MDF sample is cut into 50 cm^2 for Internal Bonding and Thickness Swelling test. For MOR test, the sample is cut into 50 mm^2 x 185 mm^2.

↓

The IB and MOR of sample are test with Universal Testing Machine. For IB test, the sample is glued at iron block before it can be fit in the testing machine.

↓

The data are taken during the testing and the calculation is performed based on European Standard. For thickness swelling, the sample immerse in water for 24 hours.

CHAPTER 4

RESULT & DISCUSSION

4.1 MDF Samples

In MDF manufacturing, the percentage of resin used is normally 10 percent from the volume of board. In this research, there are four samples produced in order to compare the mechanical and physical properties of MDF in term of Internal bonding, Modulus of Rupture and Thickness Swelling. The first sample is produced with 10 percent of urea formaldehyde resin without waste LDPE composite. For the other samples, The percentage of resin is reduced by 2 percent and at the same time the waste LDPE composite increased by 2 percent. The composition of each sample is shown in Table 4.1.1.

Table 4.1.1: Composition of MDF sample

Sample	Urea Formaldehyde (%)	Waste LDPE Composite (%)
A	10	0
B	8	2
C	6	4
D	4	6

Target density, ρ_{MDF} : 0.75 g/cm^2

4.2 Experiment Data

The universal testing machine is used to obtained the important data which is the maximum load for the Internal Bonding (IB) and Modulus of Ruptur (MOR). For the Thickness Swelling (SW), the sample of MDF is immersed in water for 24 hours. The testing method in this research is based on European Standard. The experiment data and test method for each samples are shown in Table 4.2.1 and Table 4.2.2 respectively.

Table 4.2.1: Experiment data of MDF sample

Sample	Maximun Load (N)		Swelling, Thickness (mm)	
	Internal Bonding Test	Bending Strength Test	Before	After
A	233	25	9	20
B	736	214	9	10
C	73	73	9	11
D	52	55	9	12

Table 4.2.2: Testing method of MDF sample

Property	Test Method (European Standard)
Internal Bonding	EN319
Modulus of Rupture (MOR)	EN310
Swelling (24 hr)	EN317

4.3 Technical Data of MDF

4.3.1 Calculation Based on Standard

<u>Internal Bonding (IB)</u>

$$IB = \frac{F}{A}$$

Where; F = Maximum force applied (N)

A = Surface area of sample (mm^2)

Sample A

$$IB = \frac{233\ N}{50cm\ x\ 50cm}$$

$$= 0.09\ N/mm^2$$

Sample B

$$IB = \frac{736\ N}{50cm\ x\ 50cm}$$

$$= 0.29\ N/mm^2$$

Sample C

$$IB = \frac{73\ N}{50cm\ x\ 50cm}$$

$$= 0.03\ N/mm^2$$

Sample D

$$IB = \frac{52\ N}{50cm\ x\ 50cm}$$

$$= 0.02\ N/mm^2$$

Modulus of Rupture (MOR)

$$MOR = \frac{3Fl}{2bt^2}$$

Where; F = Maximum force applied (N)

l = Distance between the centres of two supports (mm)

b = Width of the test sample (mm)

t = Thickness of sample (mm)

Sample A

$$MOR = \frac{3Fl}{2bt^2}$$

$$= \frac{3\ x\ 25N\ x\ 180mm}{2\ x\ 50mm\ x\ (9mm)^2}$$

$$= 1.67\ N/mm^2$$

Sample B

$$MOR = \frac{3Fl}{2bt^2}$$

$$= \frac{3\ x\ 214N\ x\ 180mm}{2\ x\ 50mm\ x\ (9mm)^2}$$

$$= 14.27\ N/mm^2$$

Sample C

$$MOR = \frac{3Fl}{2bt^2}$$

$$= \frac{3\ x\ 73N\ x\ 180mm}{2\ x\ 50mm\ x\ (9mm)^2}$$

$$= 4.87\ N/mm^2$$

Sample D

$$MOR = \frac{3Fl}{2bt^2}$$

$$= \frac{3\ x\ 55N\ x\ 180mm}{2\ x\ 50mm\ x\ (9mm)^2}$$

$$= 3.67\ N/mm^2$$

<u>Thickness Swelling (SW)</u>

$$SW = \frac{Thickness_{(After\ Immersion)} - Thickness_{(Before\ Immersion)}}{Thickness_{(Before\ Immersion)}}\ x\ 100\ \%$$

Sample A

$$SW = \frac{20mm - 9mm}{9mm}\ x\ 100\%$$

$$= 122.22\ \%$$

Sample B

$$SW = \frac{10mm - 9mm}{6mm}\ x\ 100\%$$

$$= 11.11\ \%$$

Sample C

$$SW = \frac{11mm - 9mm}{6mm}\ x\ 100\%$$

$$= 22.22\ \%$$

Sample D

$$SW = \frac{12mm - 9mm}{6mm} x\ 100\%$$

$$= 33.33\ \%$$

The technical data for Internal Bonding, Modulus of Rupture and Thickness Swelling are summerized in Table 4.3.2.

4.3.2 Technical Data of MDF

Table 4.3.2.1: Technical Data for each MDF sample

Sample	Internal Bonding, (N/mm^2)	Modulus of Rupture, (N/mm^2)	Swelling (%)
A	0.09	1.67	122.22
B	0.29	14.27	11.11
C	0.03	4.87	22.22
D	0.02	3.67	33.33

Based on the technical data, sample B is the best MDF in terms of mechanical and physical properties. The Internal Bonding and MOR of sample B are 0.29 N/mm^2 and 14.27 N/mm^2 respectively. In addition, the thickness swelling is only 11.11 %. Sample A should be the highest quality of MDF in terms of Internal Bonding, MOR and Swelling compared to other samples because it is the standard and contained the highest percentage of urea formaldehyde resin.

Based on study by Keith A. Scott in 2001, internal bond strength increased by nearly 33% when the resin loading was increased from 10 to 12%. The bending properties also increased, but were less sensitive to resin loading. Thickness swell and water absorption after a 24-hour soak both showed improvement with increased resin loading. In this research, sample A show the low quality compared to sample B

because it has been manufactured years ago. The quality of any MDF will be decrease with time as it emit the toxic formaldehyde. The huge different in mechanical properties of samples A, C and D compared to sample B is because of the moisture content is high during the pressing. In addition, that samples do not blend properly.

In this research, clearly shows that, by reducing the percentage of urea formaldehyde and at the same time increasing the percentage of waste LDPE composite as a possible partial replacement for binder, it does't much improve the mechanical and physical properties of MDF. Based on composition of samples, the percentage of waste LDPE composite increase by two percent. Even though the waste LDPE composite is waterproof, it still cannot stop the absorbtion of water that cause the thickness swelling of MDF. This is because the waste LDPE composite does not perform a good interaction with wood fibre and consequently do not change the properties of wood fibre. In other word, the MDF is less sensitive to waste LDPE composites.

As we know, the wood fibre absorbed water from surrounding. When the resin is used as a binder, it perform the interaction with wood fibre. As a result, it changed the properties of wood fibre. In addition, the properties of wood fibre become water resistant because of the chemical effect. In this research, even though the percentage of resin is reduced and the mechanical and physical properties decrease, the MDF still achived the industrial requirement but strictly limited in its application.

Based on European Standard, sample B achived the requirement in dry condition for non load-bearing applications (eg: Part of building or construction), including general purpose boards. Non load-bearing means that it only support itself. For example, in construction, the non-load-bearing wall are interior partition walls. It not carry the structural weight of home. Typically, this MDF can be used as insulation panels providing limited mechanical stiffening. In term of density, the density of this sample is around 0.65 g/cm^3 which is 30% heavier that ultra-light MDF. Table 4.3.2.2 below show the requirements for ultra-light MDF boards for use in dry conditions which can be exceed in this research.

Table 4.3.2.2: Requirements for non load-bearing board, ultra-light MDF boards for use in dry conditions
(Source: European Standard EN 622-5:2006)

Property	Test method	Unit	Ranges of nominal thickness mm				
			> 9 to 12	> 12 to 19	> 19 to 30	> 30 to 45	> 45
Swelling in thickness 24 h	EN 317	%	18	14	13	12	12
Internal bond	EN 319	N/mm^2	0,15	0,15	0,15	0,13	0,13
Bending strength	EN 310	N/mm^2	7,7	6,9	6	5,1	5,1
Modulus of elasticity in bending	EN 310	N/mm^2	600	560	510	470	470

Table 4.3.2.3.: Requirements for non load-bearing, general purpose MDF boards for use in dry conditions
(Source: European Standard EN 622-5:2006)

Property	Test method	Unit	Ranges of nominal thickness mm								
			1,8 to 2,5	> 2,5 to 4	> 4 to 6	> 6 to 9	> 9 to 12	> 12 to 19	> 19 to 30	> 30 to 45	> 45
Swelling in thickness 24 h	EN 317	%	45	35	30	17	15	12	10	8	6
Internal bond	EN 319	N/mm^2	0,65	0,65	0,65	0,65	0,60	0,55	0,55	0,50	0,50
Bending strength	EN 310	N/mm^2	23	23	23	23	22	20	18	17	15
Modulus of elasticity in bending	EN 310	N/mm^2	—	—	2 700	2 700	2 500	2 200	2 100	1 900	1 700

Table 4.3.2.4: Requirements for load-bearing, MDF boards for use in dry conditions
(Source: European Standard EN 622-5:2006)

Property	Test method	Unit	Ranges of nominal thickness mm								
			1,8 to 2,5	> 2,5 to 4	> 4 to 6	> 6 to 9	> 9 to 12	> 12 to 19	> 19 to 30	> 30 to 45	> 45
Swelling in thickness 24 h	EN 317	%	45	35	30	17	15	12	10	8	6
Internal bond	EN 319	N/mm^2	0,70	0,70	0,70	0,70	0,65	0,60	0,60	0,55	0,50
Bending strength	EN 310	N/mm^2	29	29	29	29	27	25	23	21	19
Modulus of elasticity in bending	EN 310	N/mm^2	3 000	3 000	3 000	3 000	2 800	2 500	2 300	2 100	1 900
If it is made known by the purchaser that the boards are intended for specific use in flooring, walls or roofing, the performance standard EN 12871 also has to be consulted. This may result in additional requirements having to be complied with.											

CHAPTER 5

CONCLUSION

5.1 Conclusion

As a conclusion, the first and second objectives in this research is achived. By using the waste biomass which is Oil Palm Frond mixed with waste LDPE composite and at the same time reducing the percentage of resin, we can produce the high quality fibre board which achieved the industrial requirement but strictly limited in its application. According to European Standard, this MDF can be use in dry condition for non load-bearing applications. The physical and mechanical properties of fibre board can be characterized.

5.2 Recomendation

Several step should be conduct in order to improve the mechanical and physical properties of MDF. The exact temperature, pressure and pressing time should be determine. By doing this, the frond fibre can perform better interaction with waste LDPE composites. In addition to that, the cost of manufacturing of MDF can be reduce.

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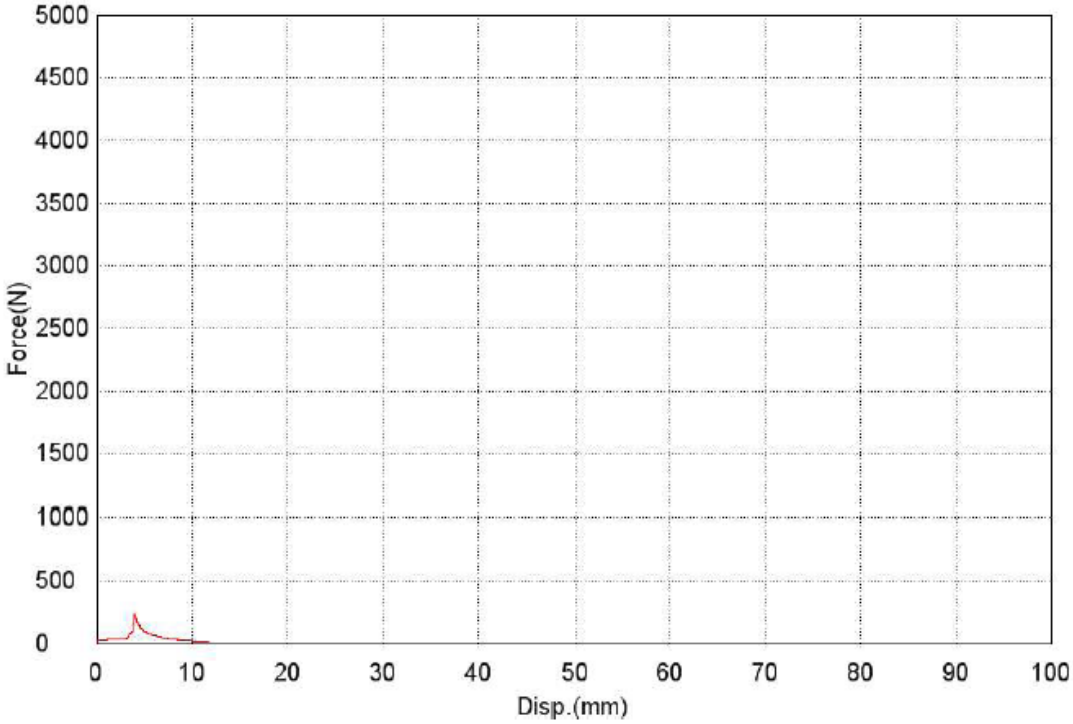
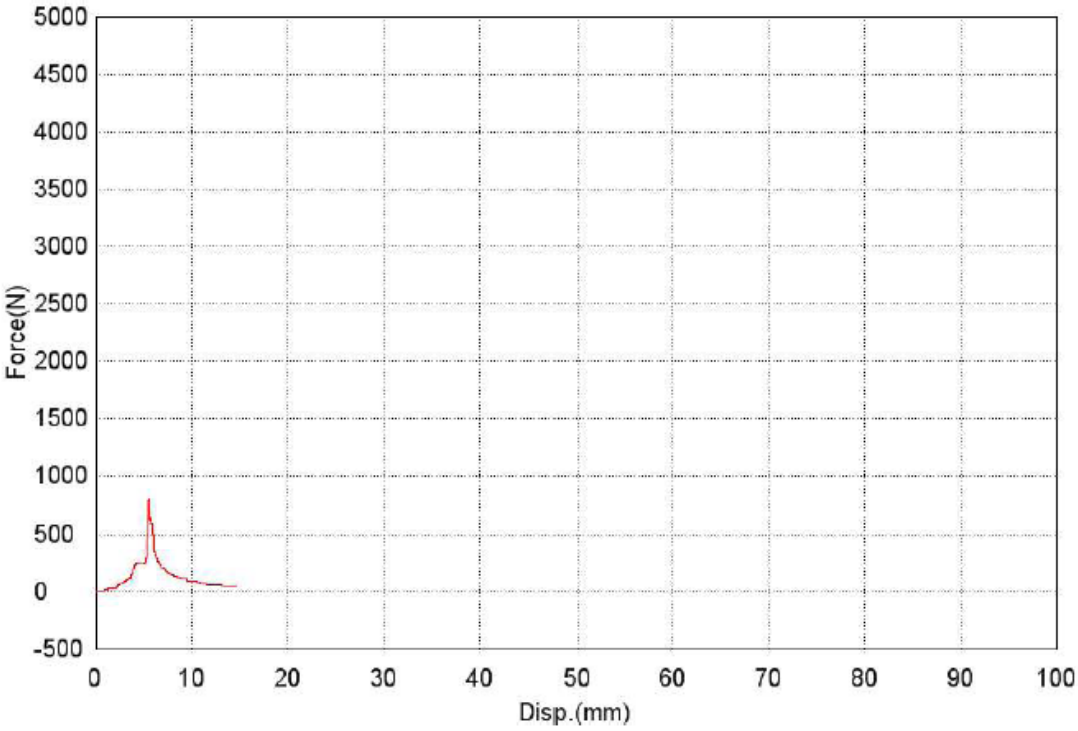
APPENDIX

Internal Bonding Test

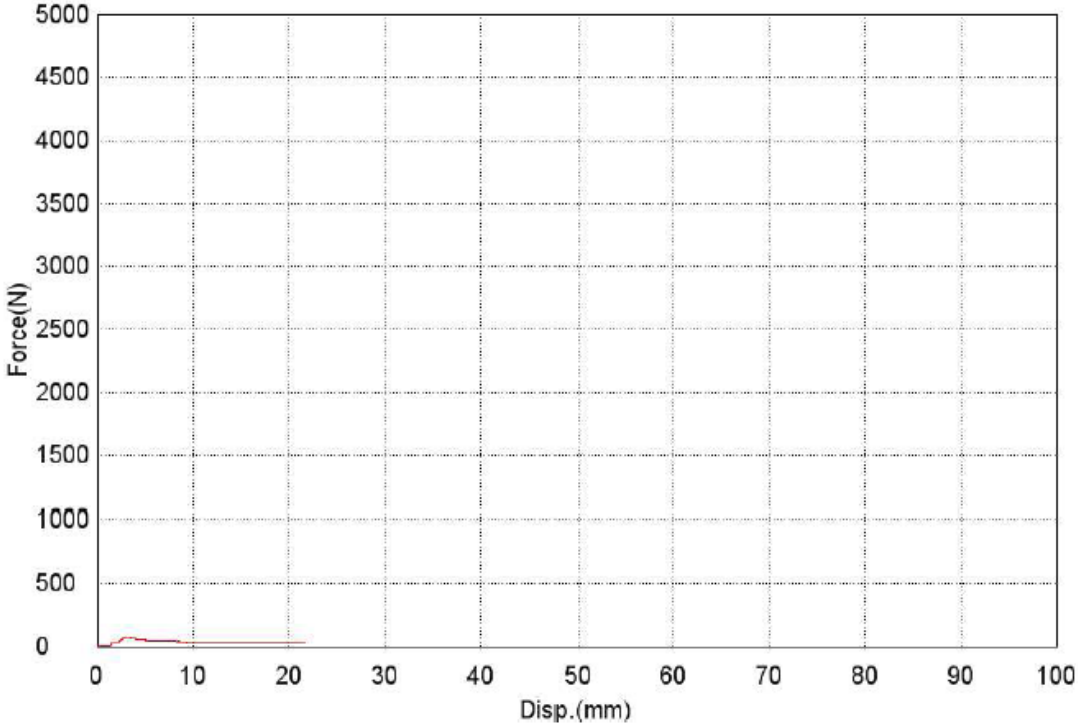
Sample A



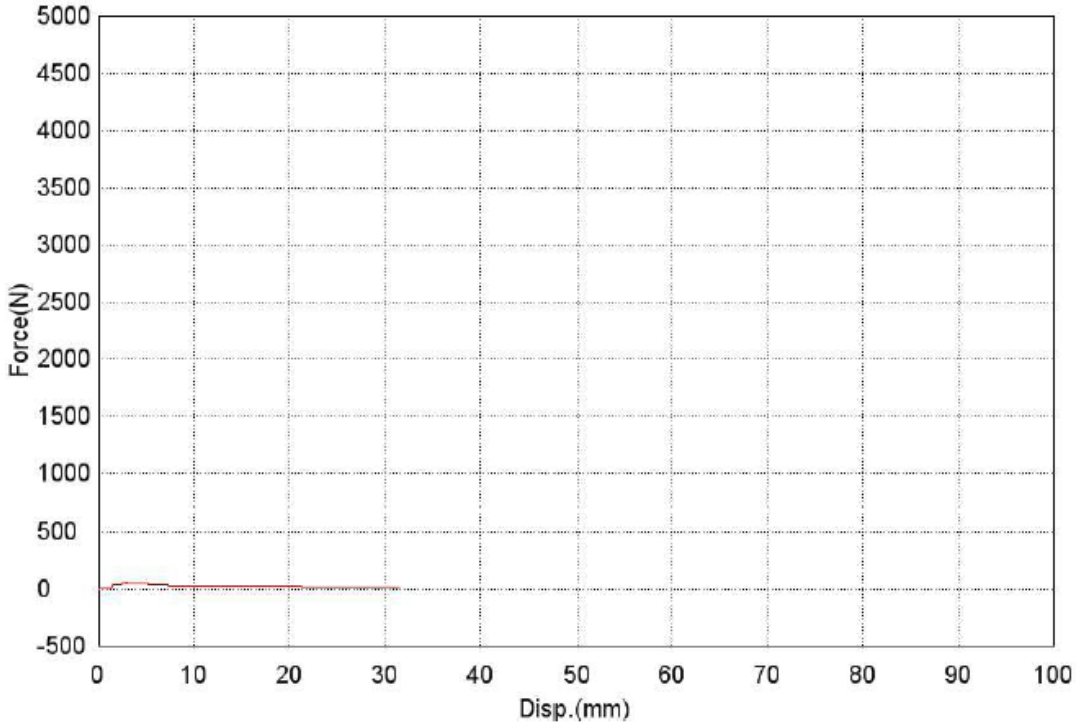
Sample B



Sample C

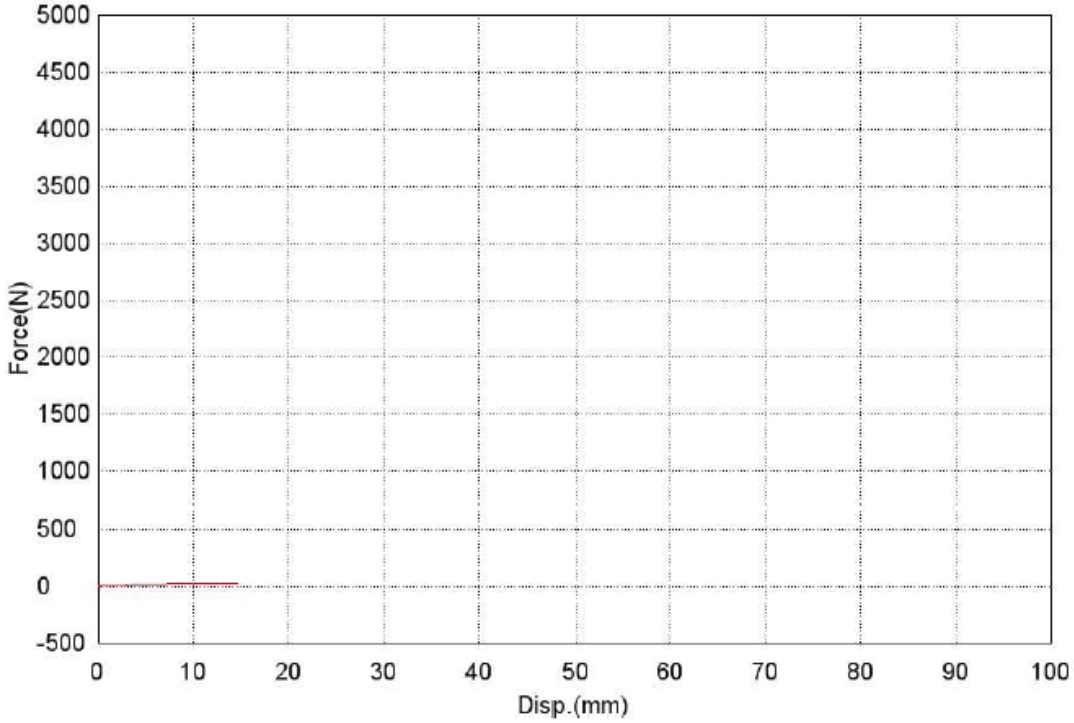


Sample D

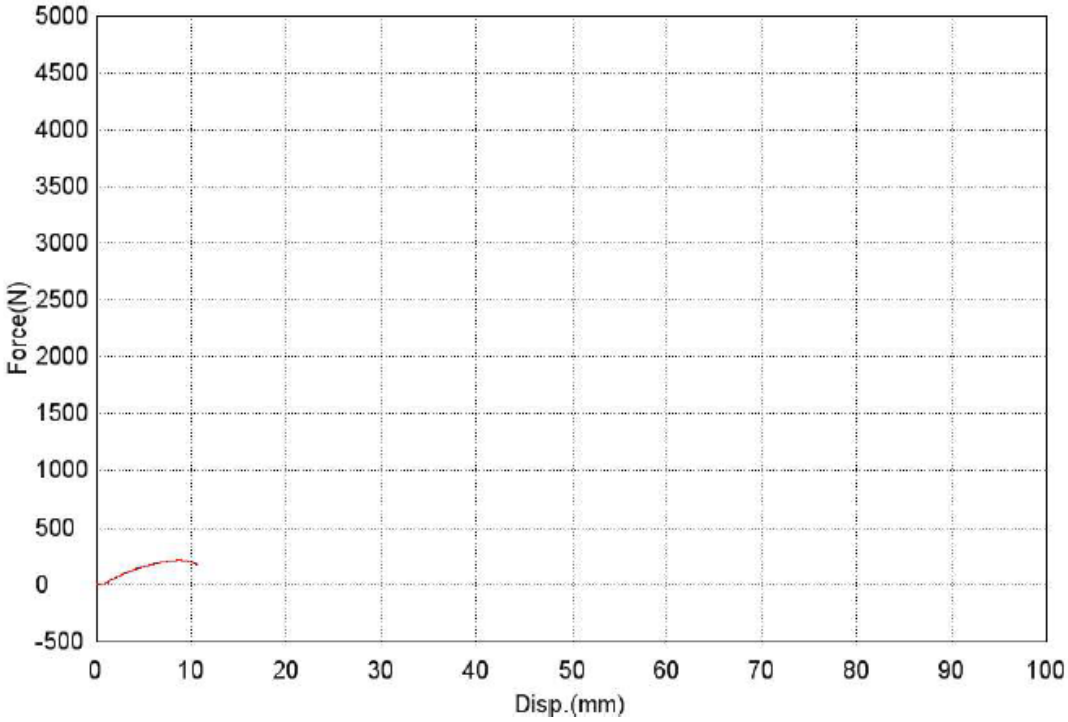


Modulus of Rupture Test

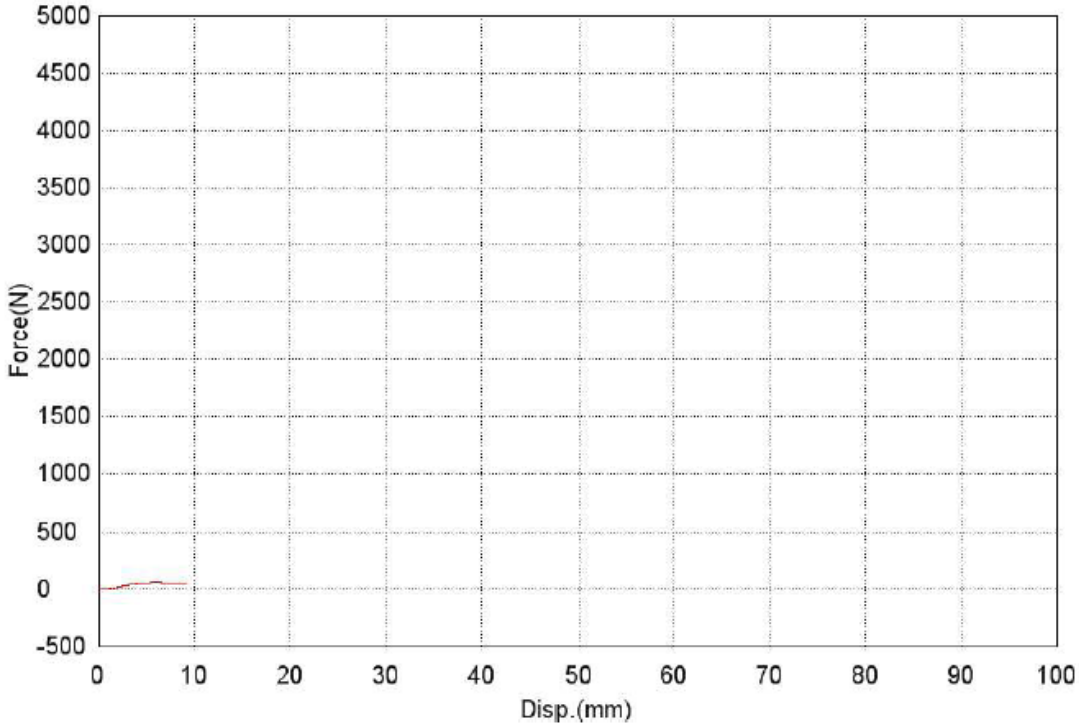
Sample A



Sample B



Sample C



Sample D