POSSIBILITY OF USING WASTE TIRE COMPOSITES REINFORCED WITH OIL PALM FROND AS CONSTRUCTION MATERIALS

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I hereby declare that the work in this thesis/project is my own except for the quotations and summaries which have been duly acknowledge. The thesis/project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Date:

DEDICATION

Dedicated to my beloved Father, mother

Brothers and sister

Professor and friends.....

Special Thanks for all of your Care, Love, Encouragement and Best Wishes.

ACKNOWLEDGEMENT

First and foremost, gratitude and praises goes to ALLAH, in whom I have put my trust and faith in. With the help and blesses from the Almighty, all the obstacles and problem have solved smoothly. I also would like to take this opportunity to express profound gratitude to my research supervisor, Assoc. Prof. Dr. Ghazi Faisal Najmuldeen for the noble guidance and valuable advices along the process to complete this research and also my study. His patience, time, thoughts and understanding are highly appreciated. I also would like to thank FKKSA laboratory for their cooperation and guidance along this research. For all my fellow colleagues, their help, support and understanding are really appreciated. Last but not least, I would like to thank my beloved family who always being supportive, helpful and listened to all my doubts and problems during my study. All of their helped will always be remembered.

ABSTRACT

Today, Malaysia is one of the largest countries planting palm tree worldwide. During the lifespan of this tree, there is abundance of fronds being trimmed and left there to biodegrade them by the nature which can affect the environment and the tree. Along with that, there is another waste produced result from the growth in technologies and transportation industries which is waste rubber tires. It seems that both wastes have limited application in industry nowadays. Therefore, this research proposed is to make use of both wastes to produce something worth which is a composite use for producing particle boards for construction purposes. The production methods used are fiber surface treatment with alkali solution and composite preparation using Hot and Cold Molding Press. The characteristics and properties of the particle board from palm fronds-rubber tires and palm fronds alone are studied and compared using Universal Testing Machine (UTM). It can be said that the particle board produced have comparable characteristics and properties especially its flexibility and flexural properties.

ABSTRAK

Dewasa kini, Malaysia merupakan salah satu negara terbesar yang menanam pokok sawit di dunia. Sepanjang jangka hayat pokok ini, terdapat banyak daun pelepah yang dipotong dan dibiarkan di kawasan sekitarnya untuk mengalami biodegradasi. Secara semula jadi, tetapi proses ini akan memberi kesan sampingan terhadap pokok sawit dan juga kawasan persekitarannya. Selain daripada itu, terdapat satu jenis hasil buangan lain yang terhasil kesan dari teknologi dalam industri pengangkutan iaitu tayar getah terpakai. Kedua-dua jenis hasil buangan ini mempunyai applikasi yang terhad dalam industri pada hari ini. Oleh itu, penyelidikan bertujuan untuk menghasilkan papan partikal daripada gentian pelepah sawit dan tayar terpakai untuk kegunaan pembinaan. Kaedah penghasilan papan partikal yang digunaakan terdiri daripada rawatan permukaan gentian dengan larutan alkali dan penyediaan komposit dengan menggunakan Mesin acuan bertekanan panas dan sejuk. Ciri-ciri dan sifat mekanikal papan partikal yang terhasil daripada gentian pelepah sawith dan tayar terpakai dianalisis menggunakan Mesin Ujian Universal (UTM). Secara keseluruhannya, ia boleh dikatakan bahawa papan partikal yang dihasilkan mempunyai ciri-ciri yang setanding dengan papan partikal dipasaran terutamanya sifat fleksibiliti dan lenturannya.

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LIST OF SYMBOLS

ρ	-	Density
ε	-	Strain
σ	-	Stress
%	-	Percentage

LIST OF ABBREVIATION

cm	-	centimeter
g	-	gram
IB	-	Internal Bonding
kg	-	kilogram
kg/m^3	-	kilogram per meter cube
mm	-	milimeter
MOE	-	Modulus of Elasticity
MOR	-	Modulus of Rupture
Mpa	-	Mega Pascal
NaOH	-	Sodium Hydroxide
N/mm^2	-	Newtown per millimeter square
OPF	-	Oil Palm Fronds
P	-	Pressure
T	-	Temperature
TS	-	Thickness Swelling
t	-	Time
UTM	-	Universal Testing Machine
vs	-	Versus
^0C	-	Degree Celcius

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Nowadays, the natural sources are more preferable than the synthetic materials. This also due to the wood-based industries and product that highly demand in the market based on diverse application for interior and exterior uses such as furniture, cabinets, millworks, construction materials, pool tables, floor underlayment and etc. But, there is shortage of the wood as the raw material, people start looking at other sources of lignocellulose materials that can replace the function of wood in this industry. In composite production such as plywood and particleboard, they start replacing the wood materials with agro-forest waste and agricultural residues which call as natural fibre.

Natural fibres that have been used in wood-based industries (plywood, particleboard, composites) is tea leaves waste, almond shells, flax shiv, wheat straw and corn pith, branch wood, decayed wood, durian peel and coconut coir, bamboo, kiwi pruning, tobacco, bagasse, oil palm empty fruit bunches, trunk and stem (Abdul Khalil, Nurul Fazita, Bhat, Jawaid & Nik Fuad, 2010; Nemli, Demirel, Gumuskaya, Aslan & Acar, 2009; Yang, Kim, Lee, Kim, Jeon & Kang, 2004). In addition, natural fibres usually have several advantages which are though they have poor strength properties due to low density; it can lead to high specific strength properties. They are abundantly available resources that having low cost, low energy consumption and non-toxic to work with (Satyanarayana, Sukumaran, Mukherjee, Pavithran & Pillai, 1990).

Natural fibre is one of the lignocellulose materials that have some characteristic like wood materials. Cellulose is a hydrophilic glycan polymer consisting of a linear chain of 1, 4-β anhydroglucose unit which contains alcoholic hydroxyl groups. Usually the absorption of the cellulosic material are depends on the purity of the cellulose (treated or untreated) and the degree of crystallinity of its structure (Mohd Aizuddin, 2010). All of the characteristic and properties of this cellulose are really important because it will affect the corporation when mixed with matrix.

For oil palm tree, it is produced in 42 countries worlwide on about 27 million acres. In Malaysia itself, the total planted area of palm tree increased to about 3.87 million hectares in 2004 (Abdul Khalil et al., 2010). Every year, production of oil palm will contribute around to 15.8 and 8.2 million tons of oil palm empty fruit bunches (EFB) and trunk (OPT). It is believe that the numbers of oil palm fronds (OPF) are much bigger than its empty fruit bunches and trunk that produce each year.

Other than that, the fast developments of the economy especially with broaden of technologies apply everyway. As this scenario interminable, the demand of the automobiles will keep increasing. The problem that occurs because of this demand is the abundance of the waste rubber tires while the sources of the rubber itself will decrease. Based on the statistic data that have been analyzed, approximately 1.5 billion tires are discarded every year worldwide (Jun, Xiang-min, Jian-min & Kai, 2008) that happen because the lifetime of each tires are quite short. Therefore, one of the biggest problems is how avoid environmental pollution that may cause by the waste rubber tires. Thereby, it is necessary to develop some methods for reused and recycling all the waste tires. Since most of the composition of the tires is rubber, it has properties such as high strength, resist abrasion, durable, elastic and anti-caustic that have high potential to be recycle as new raw materials.

1.2 PROBLEM STATEMENT

Malaysia has a large population of palm tree plant which has a life span of about 25 years. Yearly, there is abundance of oil palm fronds (OPF) that will be assemble around the palm tree after been trimmed. The OPF needs more than a month to be naturally degradable and along this process, it will promote the production of bacteria and fungus that may harm the soil and also the palm tree. Other than that, it also produce unpleasant odor to the surrounding.

Other than that, the number of waste rubber tire keeps increasing day to day. The application of it was subjected to producing rubber nuggets/buffing, as filler and it will be process back to produce metal and hydrocarbon (black carbon) or also been reused as a whole for application such garden decoration, tree guard, shock absorbent and fences. To abroad the application, this research proposes to make use the waste rubber tires as the reinforced composite to produce particle board when mixing with the OPF fibre.

1.3 OBJECTIVE

Objectives of this research are:

(i) To make use the waste of oil palm fronds (OPF) and rubber tires.
(ii) To produce particle boards of oil palm fronds (OPF) fibre and waste rubber tires.
(iii) To study the effect of alkali treatment to the physical and mechanical properties of the oil palm fronds (OPF) fibre particle board.
(iv) To study the effect of waste rubber tires composition to the physical and mechanical properties of the oil palm fronds (OPF) fibre-waste rubber tires particle board produced.
(v) To compare the characteristics and mechanical properties between oil palm fronds (OPF)-waste rubber tires particle board with palm fronds particle board.

1.4 SCOPE

In order to achieve the objectives of this research, the scope of the research will cover on the production of the particle board from both wastes which is trimmed oil palm fronds (OPF) and rubber tires. Different variables will be use during the experimental process such as the composition between trimmed oil palm fronds (OPF) and rubber tires, the alkali treatment of the trimmed oil palm fronds (OPF) and the pressure applied during cold and hot press. The data collected will be comparing between the particle board produce from trimmed oil palm fronds (OPF) fibre particle board and industrial grade particle board.

1.5 RATIONALE AND SIGNIFICANCE

Based on the objectives and scope that have been carried out, several rationales and significant of this research can be outline which is:

(i) The trimmed oil palm fronds, OPF (oil palm biomass) can be fully utilized.
(ii) The amount of waste rubber tires will decrease as it can be recycled to be raw materials in wood-based processes.
(iii) The environmental pollution will be lesser.
(iv) The physical and mechanical properties of the particle board produce will be comparable with the industrial particle board available (wood-based materials).

CHAPTER 2

LITERITURE REVIEW

2.1 INTRODUCTION

In this chapter, all information's regarding this research and study are briefly discussed, explained and supported with several reviews which extracted from several sources of journals, reference books and articles. There are five major topics that discussed in this chapter which is composites, natural fibre, oil palm fibres (OPF), rubber tires and conclusion.

2.2 COMPOSITES

Basically, all know that composites are the mixture or combination of fibre and adhesive as binder which pressed and bind together to yield strength and rigidity. In other words, composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix) (Taj, Munawar & Khan, 2007). It was really important to study the characteristics and properties of each of the fibre, matrix and adhesive used before mixed them together. The constituents of the composites will retain their individual, physical and chemical properties that produce combination qualities which they would be incapable of producing alone (Taj et al., 2007). With the development of wood-based industries and shortage of wood as raw materials, people start searching new sources that has lignocellulosic properties that can replace the wood as raw materials. Most of the sources are materials from agricultural residues and non-wood plant fibres.

2.3 NATURAL FIBRES

Natural fibres can be considered as naturally occurring composites consisting mainly of cellulose fibrils (fibres) embedded in lignin matrix (resin). These cellulose fibrils are aligned along the length of the fibre, irrespective of its origin, whether it is extracted from bark or stem, leaf or fruit (Satyanarayana, Sukumaran, Mukherjee, Pavithran & Pillai, 1990). There are many research has been carried out on wide variety of those materials from many different regions of the world: wheat straws, rice husks/straws, tobacco, bagasse, sunflower stalks, kenaf, bamboo, oil palm, maize husk and cob, kiwi pruning, paulownia, cotton carpel, durian peel and coconut coir, vineyard pruning, decayed wood, oil palm emptry fruit bunches, trunk and stem (Nemli et al., 2009; Tabarsa, Jahanshahi & Ashori, 2011).

The uses of natural fibres in wood-based industries have developed biodegradable composites which can be safely use without affecting the environmental conditions (Hamzah, 2009). Indirectly, the uses also can reduce current problem regarding environmental pollution and ecology problem. Other than that, it also economical compare to inorganic fibres that produce from synthetic materials. Realizing on the potential of many types of natural fibres that can be utilized, many reseach studies have been conducted to studies the properties and characteristic of natural fibre especially from agro-waste and biomass because it was low cost and low energy consumption.

There is a growing interest on natural fiber composites in various fields due to these advantages. Automotive giants such as Daimler chrysler use flax–sisal fiber mat embedded in an epoxy matrix for the door panels of Mercedes benz E-class model (John & Thomas, 2008). Coconut fibers bonded with natural rubber latex are being used in seats of the Mercedes benz A-class model. The Cambridge Industry (an automotive industry in MI, USA) is making flax fiber-reinforced polypropylene for Freightliner century COE C- 2 heavy trucks and also rear shelf trim panels of the 2000 model Chevrolet impala. Besides automotive industry, lignocellulosic fiber composites have also found their application in building and construction industries such as for panels, ceilings, and partition board (Hariharan & Khalil, 2005). Nowadays fiber-reinforced plastic composites find applications in fields such as aerospace, automotive parts, sports and recreation equipment, boats, office products, machinery, etc. (Sreekala, George, Kumaran & Thomas, 2002).

2.4 OIL PALM BIOMASS

Oil palm, Elaeis guineensis, is a tree whose fruits are used for extraction of edible oil (Kelly, Lee, Mohamed & Bhatia, 2007). Originated from South Africa, it is cultivated in all tropical areas of the world and it has become one of the main industrial crops. The reddish colored fruit grows in large bunches, each weighing at about 10–40 kg. Inside each fruit is a single seed, also known as the palm kernel, surrounded by the soft pulp. The oil extracted from the pulp is edible oil used as cooking, while that extracted from the kernel is used mainly in soap-manufacturing industries. (Kelly, Lee, Mohamed & Bhatia, 2007).

Oil palm is a multipurpose plantation and also a prolific producer of biomass as raw materials for value-added industries (Basiron & Simeh, 2005). For example, fresh fruit bunch contains only 21% palm oil, while the rest 6–7% palm kernel, 14–15% fiber, 6–7% shell and 23% empty fruit bunch (EFB) are left as biomass (Umikalsom, Ariff, Zulkifli, Tong, Hassan & Karim, 1997).

Nowadays, oil palm is now one of the major economic crops in a large number of countries, which triggered the expansion of plantation area around the world (Yusoff, 2006). This happen because the oil palm tree can grows well in wet, humid parts of tropical Asia. The data of estimation on the oil crops production in Asia for 2007 is 26,120,754 MT (DOA, 2009) while the total area of planted oil palms in Malaysia stood at 4.3 million hectares in 2007 taking Malaysia the largest producer of palm oil in the world.

Table 2.1: Land area of crops planting and annual production in Malaysia for year 2007

	Area of planting, Ha	**Production, MT**
Oil palm	4 304 914	26 1204 7
Rubber	1 229 940	1 119 553
Paddy	676 111	2 375 604
Fruits	287 327	1 871 262
Vegetables	42 832	694 811
Field crops	12 979	129 302
Herbs	495	890
Pepper	4 896	43 932
Flowers	1 895	154 974 350
Coconut	117 650	504 824
Coffee	7 100	30 550
Sugarcane	14 670	733 500
Tea	2 784	5 540

(Source: FAO, 2007)

Expectedly, large and abundant quantity of oil palm fronds (OPF) are naturally generated by this process, which presently are underutilized and are often buried in rows within the palm plantations.(Salman & Hameed, 2010). Effect from the development, Malaysia is ranked as the world's leading palm oil producer and exporter, accounting for 47% of global palm oil production and 89% of exports (Sumathi, Chai & Mohamed, 2008). In Malaysia, the production of palm oil is targeted to increase from 8.5 million tons in 2000 to 10.5 million tons by 2010. (Hanim, Azemi & Rosma,2011).

2.5 OIL PALM FRONDS, OPF

In Malaysia, oil palm industries are one of the bigger industries that have been developing such year. Each year, there will be abundance of biomass produced from the production of these industries. This make the potential to utilized all the biomass become wider especially when the sources of cellulose materials been use to replace the function of wood in wood-based industries. Loh, Paridah, Hoong, Bakar, Anis and Hamdan (2011) stated that stem of oil palm trees are one of the most potential residues available in Malaysia. Being a monocot, the oil palm stem differ with wood in term of cell types and arrangement. It is very hygroscopic in which it shrink and swells easily upon the loss and gain of water respectively. Cellulose, hemicellulose, and lignin made up the cell wall and are responsible for most physical and chemical properties exhibited by lignocellulose materials.

Based on all journals available, the replacement of wood raw materials with oil palm biomass in producing composite and plywood have improved some properties such as bending strength, screw withdrawal and shear strength. It also eventually increased the added value of these residues (oil palm biomass) for use as interiors and exteriors. Furthermore, the treated oil palm biomass will also enhance the mechanical and physical properties of the composites produced. This has been discovered by Loh et al. (2011) that oil palm stem that soaked in low molecular weight phenol formaldehyde for 20 seconds before drying will yield better properties compared to untreated oil palm stem.

Oil palm frond (OPF) is a suitable raw material because it is an abundant waste material produced by the palm oil industry in Malaysia (Goh, Lee & Bhatia, 2010). As the world's second largest palm oil producer, Malaysia generated approximately 38,256 dry kton of oil palm lignocellulosic biomass in the year 2007, of which OPF comprised 44% (Goh et al., 2010).

Oil palm biomass including oil palm fronds are generally consists of cellulose, hemicellulose and lignin, and composition varies according to plant species. Cellulose with a molecular weight of about 100,000 is essentially a polymer with linear chains of glucopyranose units linked to each other by its 1, 4 in the a configuration (Kelly-Yong et. al, 2007). Hemicellulose is a complex mixture of several polysaccharides such as mannose, glucose, xylose, arabinose, methylglucoronic and galaturonic acids. Its average molecular weight is of about 30,000, and it is a component of the cell wall. Lignin is a mononuclear aromatic polymer also found in the cell wall. Due to the near position of hemicellulose and lignin in the cell wall, adjacent to each other, both these compounds can form a complex termed as lignocellulose (Goyal, Seal & Saxena, 2006). The data in Table 2.2 below shows the oil palm generation and chemical components including OPF:

Table 2.2: Oil palm generation and chemical components

Types of biomass residues	Quantity generated yearly, $tha^{-1}y^{-1}$	Chemical components, %				
		Cellulose	Hemi-cellulose	Lignin	Extractives	Ash
Empty fruit bunch	4.420	38.3	35.3	22.1	2.7	1.6
Palm kernel shells	1.100	20.8	22.7	50.7	4.8	1.0
Palm kernel trunks	2.515	34.5	31.8	25.7	3.7	4.3
Fronds	10.880	30.4	40.4	21.7	1.7	5.8
Mesocarp fibers	2.710	33.9	26.1	27.7	6.9	3.5
total	21.625					

Source: Saka (2005), Singh, Huan, Leng and Kow (1999) and Yang, Yan, Chen, Lee, Liang and Zheng (2004)

2.6 RUBBER TIRES

Other effect of technology and development in economy worldwide is the increasing demand of automobiles and vehicles. With increasing of the automobiles demand, people will confront with a severe problem which is the dilemma between environmental pollution from waste tires and the shortage of rubber resources (Jun et al., 2008). It is believe that from 2008, there will be more than 3 billion tires discarded every year around the world. This also may occur because of the short life span of the tires. Therefore, it is necessary for the academia and researchers to develop methods and ways to minimizes and recycling the waste tires because the proportion of these waste tires being recycled are remains negligible (Yang, Kim, Lee, Kim, Jeon & Kang, 2004). Jun et al. (2008) stated that waste tire rubber is an ideal raw material for the functional composite panel because it possesses some unique properties: excellent energy absorption, characteristically large elastic deformation, better sound insulation, and durability and abrasion resistance, anti-caustic and anti-rot.

Several researches have been done to study the potential and the characteristics of composite that produced from waste tire rubber. Yang et al. (2004) recovered that rice straw-waste tire particle composite boards had better flexural properties than wood particleboard, insulation board, fiberboard, plywood and various other construction materials. They also stated that this composite are suitable as sound absorbing insulation boards and as flexural material for construction such as flexural insulating materials for curved walls. Research by Jun et al. (2008) is conducted to determine the feasibility of manufacturing of wood-rubber composites. This research also yield the improvement in properties of the composites produced.

2.7 CONCLUSION

Based on all researches and journals available, there are many fibres have been used to replace the role of wood raw materials in composite production. This also solves the environmental pollution that cause by those materials. Numbers of study have utilized the oil palm biomass which is its empty fruit bunches (EFB), trunk (OPT) and stem but none of it have mentioned about the trimmed oil palm fronds (OPF). There is abundance of trimmed OPF been produced yearly and it has high potential to be used in wood-based industries.

Other than that, none of the researched mixed the waste rubber tires with other than rice straw fibres. That is why this research also purpose mix the OPF fibre with waste rubber tires in particle board because of its properties that stated by Jun et al. (2008). In conclusion, this research will produce particle boards from trimmed OPF fibre and waste tire rubber that will help to decrease the number waste OPF and waste rubber tires which produce yearly in Malaysia and might be in the whole world.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

On the previous chapter, all the previous journals and articles have been reviewed. Based on the information available, the methodology that will be used in this research such as the materials, fibre surface treatment, preparation of the composite, mechanical and physical testing are adopted.

3.2 MATERIALS

Waste of rubber tires and oil palm fronds are acquired from nearest oil palm plant with University Malaysia Pahang, Gambang. Other chemicals that required in this research was sodium hydroxide, benzene, toluene, phenolic resin and urea formaldehyde are supplied from University Malaysia Pahang.

3.3 PREPARATION OF OIL PALM FRONDS (OPF) FIBRE

Oil palm fronds (OPF) which been cut from the oil palm tree are cut into pieces to an approximately around 15cm × 6cm × 6cm dimensions in average. Then the pices are rinse with the deionized water and dried in drying oven at temperature of 60-70°C for one day. After that, the pieces are grinded into smaller pieces (6mm × 1mm × 1mm dimensions in average). The grinded OPF fibre then are dried in drying oven back at temperature of 60°C for 3 hours for achieve less than 6-10% of moisture content.

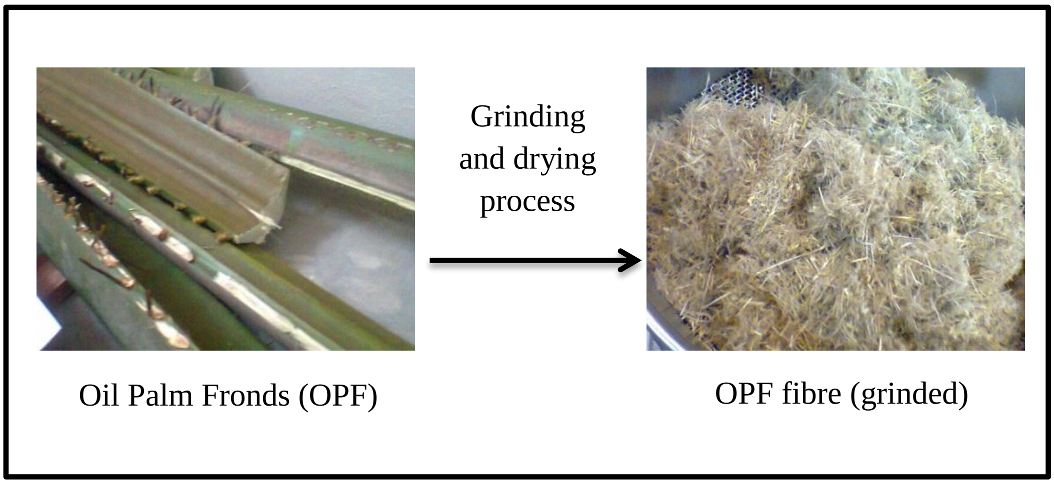

Figure 3.1: Preparation of OPF fibre

3.4 FIBRE SURFACE TREATMENT

The untreated dried OPF fibres are immersed in 7-10% of NaOH (sodium hydroxide) solution. The total volume of the NaOH solution is 10 times the weight of the OPF fibre (example: 2 kg of OPF fibre in 20 litres of NaOH solution). The fibres are kept in the solution at ambient temperature of 28°C for 24 hours. It was then thoroughly washed in running deionized water and then been dry back in the drying oven at the temperature of 75°C for 2 days to have approximately 6-10% moisture content. The alkali treatment is applied to polish and improve the interfacial bonding between the fibres and matrix.

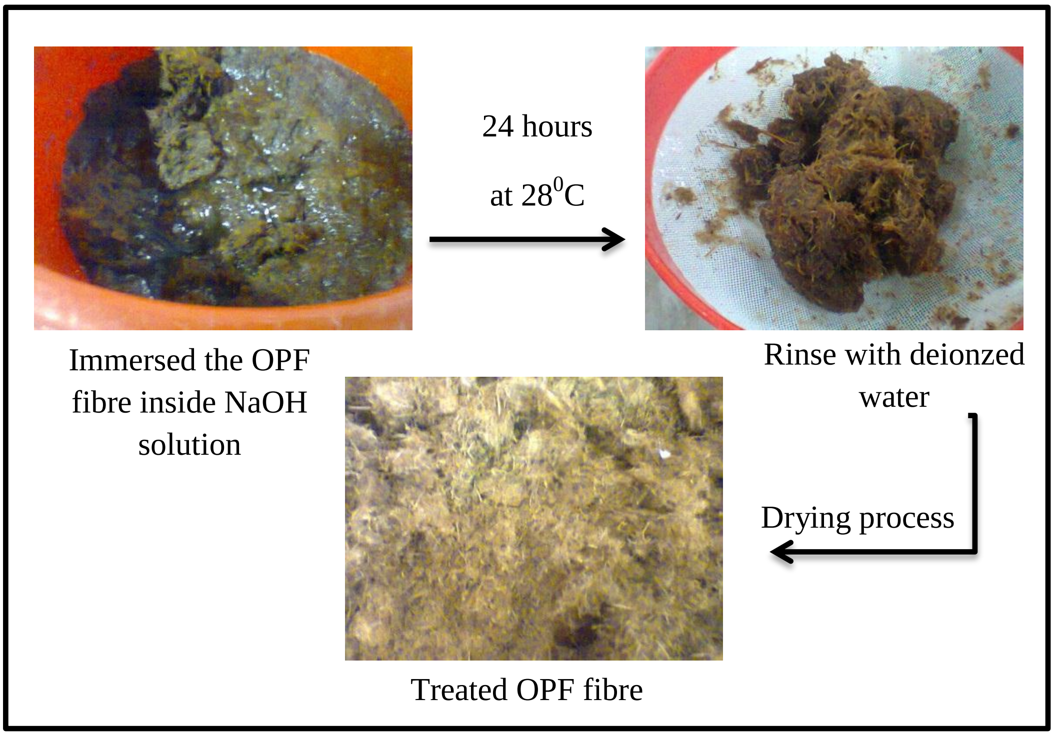

Figure 3.2: Process of fibre surface treatment

3.5 PREPARATION OF THE RUBBER TIRE PARTICLE

The waste rubber tires are cut into small particles with dimensions of 2.5 mm × 2.5mm × 2.5 mm approximately (average). The small particle are screened using sieve shaker to obtain an homogenous size/dimension.

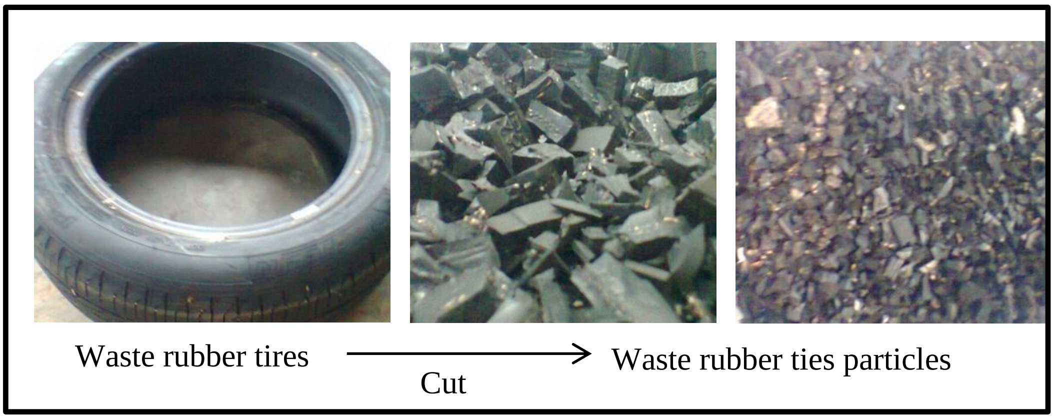

Figure 3.3: Preparation of waste rubber tires particles

3.6 PREPARATION OF THE PARTICLE BOARD

Placed the OPF (either treated or untreated) fibre into the drum blender and slowly add the solution of the adhesive, urea formaldehyde with weight percentage of 10% from the total particle board weight. For sample with different composition of waste tire particle, composition of 60-40% and 80-20% ratio of OPF fibre to waste tires are prepared. The 10% of urea formaldehyde is also mix inside the mixture. Then, the sample are pre-pressed or cold pressed the mixture at pressure of 0.5 MPa for 2 min and after that hot pressed it at pressure of 5 Mpa and temperature of 120-150°C for 8 min using Hot and Cold Moulding Press. The particle boards produced with dimension of 20cm × 20cm × 6mm are placed at ambient condition (room temperature) for a week before testing it properties.

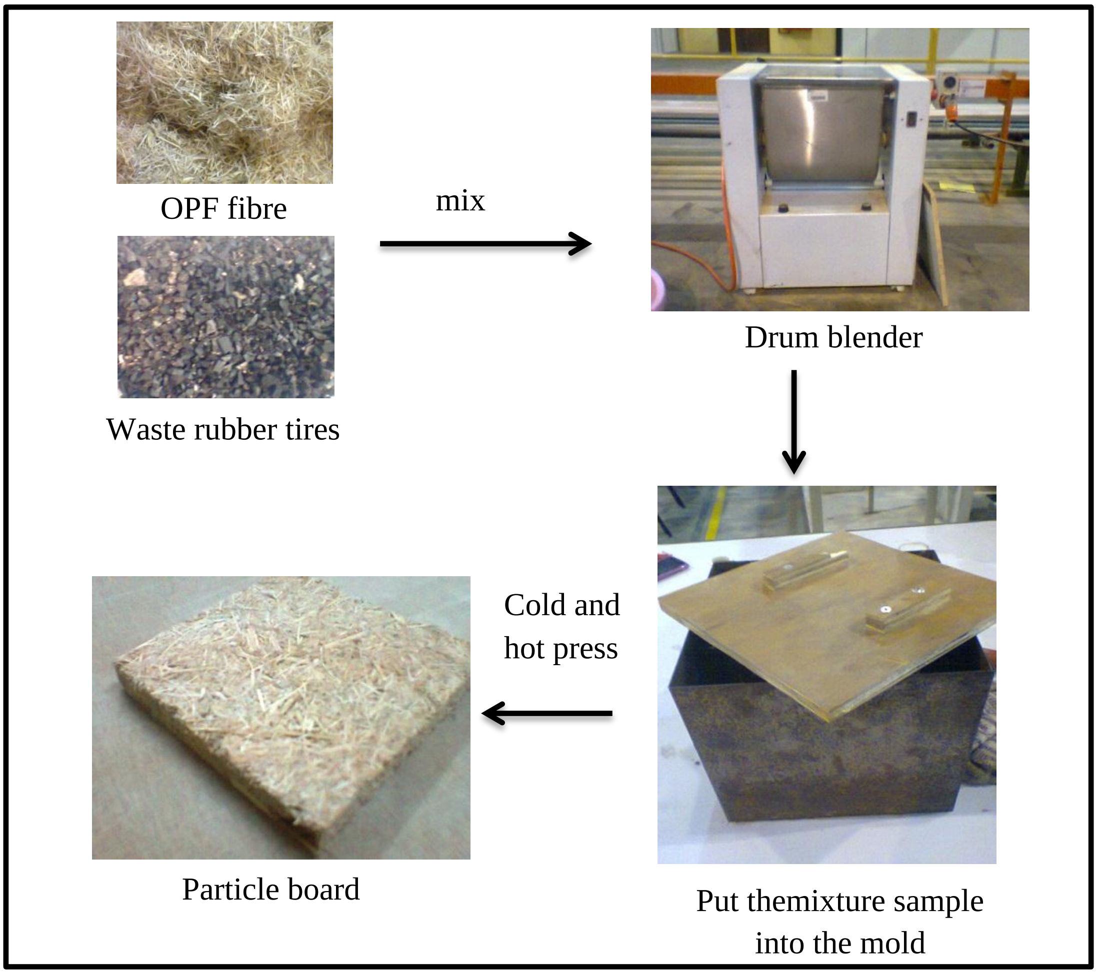

Figure 3.4: Preparation of the particle board

Figure 3.5: Hot and Cold Moulding Press Machine

3.7 PHYSICAL TESTING

Physical properties that are considered are the density and the thickness swelling, TS. The density of the particle boards are determined by measuring the mass volume of each sample. Each sample weighed to an accuracy of 0.01g using analytical balance. The volume of each samples are obtained by calculate each volume of the specimen by using mathematical formula of volume equal to length × width × thickness. For the TS, the percentages of swelling thickness are measure after 1 and 12 hours immersed in water bath.

3.8 MECHANICAL TESTING

Two types of mechanical testing are conducted in this research which is bending/ hardness test and internal bonding (IB) test. All of the tests are conducted using Universal Testing Machine (UTM). For the bending/hardness test, sample of the particle board with 15cm × 5cm × 0.6cm dimensions are used while for internal bonding (IB) test, sample of particle board with dimension of 5cm × 5cm × 0.6cm are used. Bending/hardness test are used to calculate the modulus of rupture (MOR) and modulus of elasticity (MOE) while internal bonding (IB) test are used to determine the amount of internal bonding (IB) strength.

Figure 3.6: Universal Testing Machine (UTM)

Figure 3.7: Attachment for Internal Bonding Test

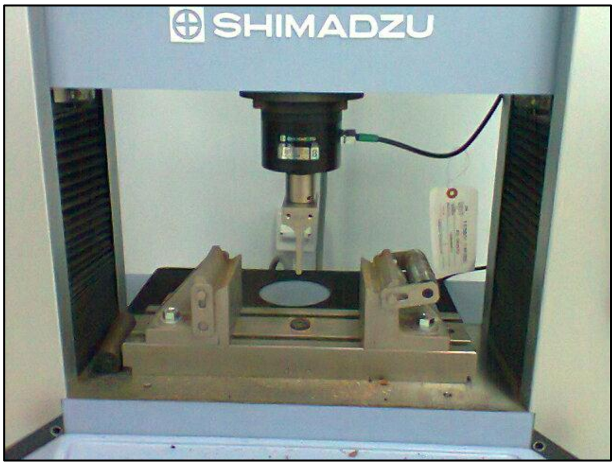

Figure 3.8: Attachment for Bending Test

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

Based on the data collected from all tests that has been conducted, it can be classify two major categories which are based on the physical properties and mechanical properties. The physical properties consists the amount of particle boards density and it's percentage of thickness swelling based on the particle board's composition and its condition. While for the mechanical properties, it consists of the amount of modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding strength (IB Strength) depending on the value of particle board composition and its condition.

4.2 PHYSICAL PROPERTIES

Physical properties are the properties that are measureable whose value describes a physical system's state. In this research, two properties are being considered which is density and percentage of thickness swelling (%TS) at time t of the particle board.

Table 4.1: Physical properties of the palm fronds fibre-waste tires particle board

No.	**OPF fibre condition**	**composition, %**		**physical properties, (average)**		
		OPF fibre	**waste tires**	**Density,kg/m³**	**%TS, 1hr**	**%TS, 12 hrs.**
1	untreated	100	0	673.75	28.471	40.036
2	treated	100	0	653.08	90.407	110.64
3	treated	80	20	657.49	45.161	52.957
4	treated	60	40	689.56	34.573	40.155
5	Industrial standard	ANSI M-2*(1)		672.78-720.83	-	-
6	Industrial standard	ANSI M-S*(1)		640.74-688.80	-	-
7	Industrial standard	SierraPine Particleboard*(2)		720.83	-	-

*(1) from Duraflake® Particleboard Specification

(2) SierraPine Particleboard testing based on ASTM D1037

4.2.1 Density of the particle boards

Based on the result shown in Table 4.1, it can be seen that the density of the treated OPF fibre particle board are less than the density for the untreated OPF fibre particle board which is 653.08kg/m^3 and 673.75kg/m^3. But this value are comparable with the industrial grade value which ANSI M-2, ANSI M-S and SierraPine Particleboard standard which in range of 664.77-720.83kg/m^3.

For the treated OPF fibre-waste tires particle board, the density increase as the amount of waste tires composition increase. The amount of waste tire composition increase from 0%, 20% to 40% of weight percentages while the density increase from 653.08kg/m^3, 657.49 kg/m^3 to 689.56 kg/m^3 respectively. These value are also comparable with the industrial grade value which ANSI M-2, ANSI M-S and SierraPine Particleboard standard which in range of 664.77-720.83kg/m^3.The results are represented in Figure 4.1 and Figure 4.2 for clearer understanding. The target density of the particle board is 750 kg/m^3 and the errors yield on the different value of the particle board produce is 12.95% - 8.06%. These errors might cause from the mass loss during the experimental procedures.

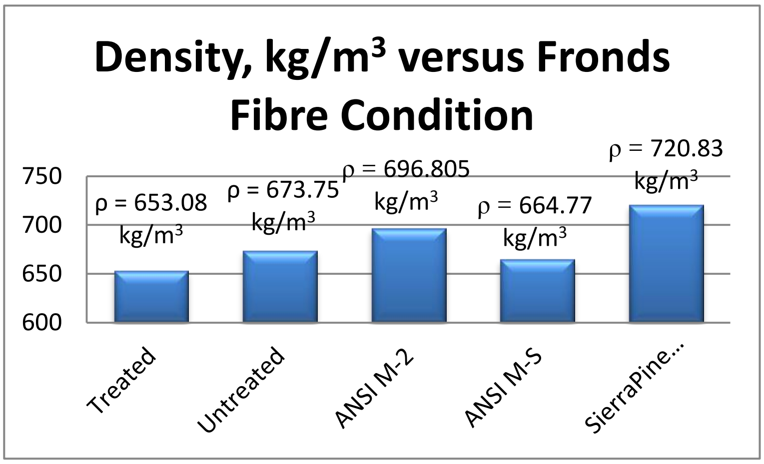

Figure 4.1: Density of particle board depending on the OPF fibre condition

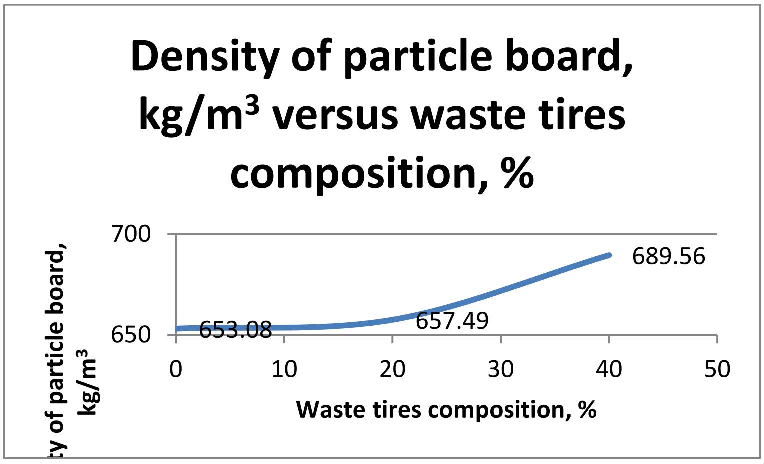

Figure 4.2: Density of particle board depending on the waste tires composition

4.2.2 Thickness Swelling

Thickness swelling amount of the OPF fibre-waste tires particle board are studied based on two major parameters which is the OPF fibre condition and waste tires composition amount. Both of this parameter effects are observed for twice which is for one hour and 12 hours. The swelling took place because of the particle hygroscopity, spring back (the release of built in compressive force brought about during manufacturing) and the water absorption affinity of the binding material (adhesive).

The result yield for thickness swelling affected by the OPF fibre condition whether it is treated or untreated for one hour is 28.471% and 90.407% respectively while for 12 hours is 40.036% and 110.64% respectively. This percentages shows that the untreated OPF fibre are better than the treated OPF fibre which it absorb less amount of water and swelled less than the treated sample.

The result yield for thickness swelling affected by the waste tires composition amount of 0%, 20% and 40 % for one hour is 90.407%, 45.161% and 34.573% respectively while for 12 hours is 110.64%, 52.957% and 40.155% respectively. This shows that as the waste tires composition increases, the amount of thickness swelled is decreases. This might cause by the tires characteristic which it low value of water and solvent absorption.

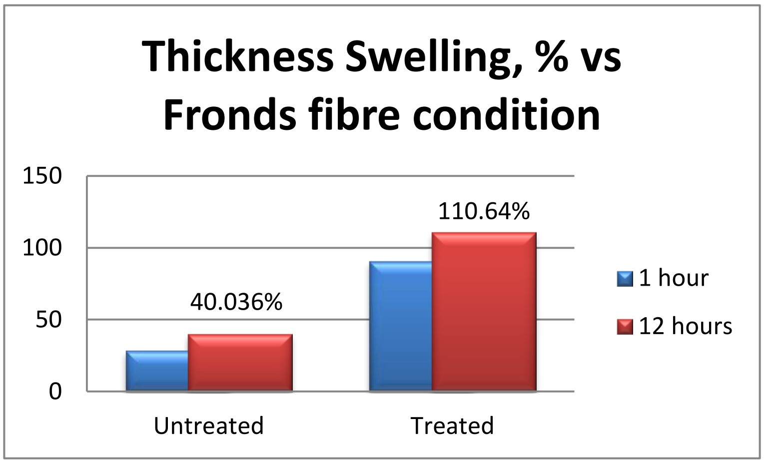

Figure 4.3: Thickness Swelling depending on the OPF fibre condition

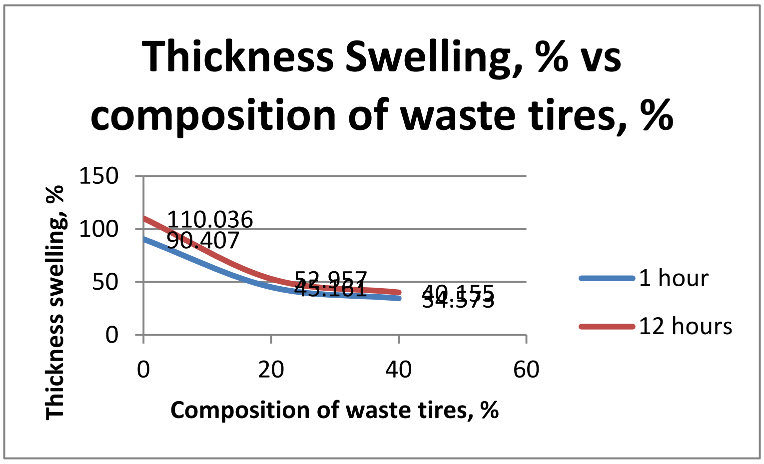

Figure 4.4: Thickness Swelling depending on the waste tires composition

4.3 MECHANICAL PROPERTIES

Mechanical properties are the properties which represent the materials behavior at certain situation and condition. Usually, strength, hardness, toughness, elasticity, plasticity, brittleness, ductility and malleability are the mechanical properties used as the measurement on how materials behave under a load. In this research, three properties are being considered to study the behavior of the palm OPF fibre-waste tires particle board under certain load which is Modulus of Rupture (MOR), Modulus of Elasticity (MOE) and Internal Bonding (IB) Strength.

The data collected are compared with the commercial or industrial standard consists of ANSI M-2, ANSI M-S and SierraPine Particleboard standard testing based on ASTM D1037. All the properties measured in unit N/mm^2 and tabulated in Table 4.2 below:

Table 4.2: Physical properties of the OPF fibre-waste tires particle board

No.	**OPF fibre condition**	**composition, %**		**physical properties (average)**		
		OPF fibre	**waste tires**	**MOR, N/mm^2**	**MOE, N/mm^2**	**IB strength, N/mm^2**
1	untreated	100	0	14.2998	1607.489	0.3816
2	treated	100	0	3.0141	340.624	0.0635
3	treated	80	20	2.072	249.8449	0.026
4	treated	60	40	1.2116	149.3019	0.0166
5	Industrial standard	ANSI M-2*(1)		12.997	2000.24	0.3999
6	Industrial standard	ANSI M-S*(1)		10.998	1700.307	0.359
7	Industrial standard	SierraPine Particleboard*(2)		13.1005	1999.55	0.448

*(1) from Duraflake® Particleboard Specification

(2) SierraPine Particleboard testing based on ASTM D1037

4.3.1 Modulus of Rupture, MOR

Modulus of rupture (MOR) is also known as flexural strength, bend strength and fracture strength. It was a mechanical parameter for brittle material and defined as the materials ability to resists deformation under load. Based on the data and result collected in Table 4.2, MOR for untreated OPF fibre are higher than the treated OPF fibre which is 14.2998 N/mm^2 and 3.0141 N/mm^2 respectively. While for the different composition of waste tires which is 0%, 20% and 40%, the yield MOR is 3.0141 N/mm^2, 2.072 N/mm^2 and 1.2116 N/mm^2.

This shows that as the amount or composition of the waste tires increase, the amount of MOR will be decrease. Comparing the MOR value with the industrial standard, the amount are quite lower for treated and OPF fibre-waste tires particle board. But the amount yield for untreated OPF fibre particle board was higher than the industrial standard values.

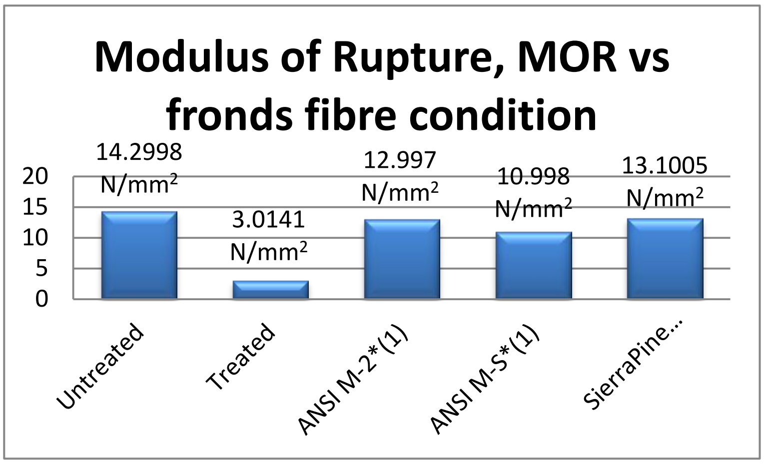

Figure 4.5: Modulus of rupture (MOR) depending on the OPF fibre condition

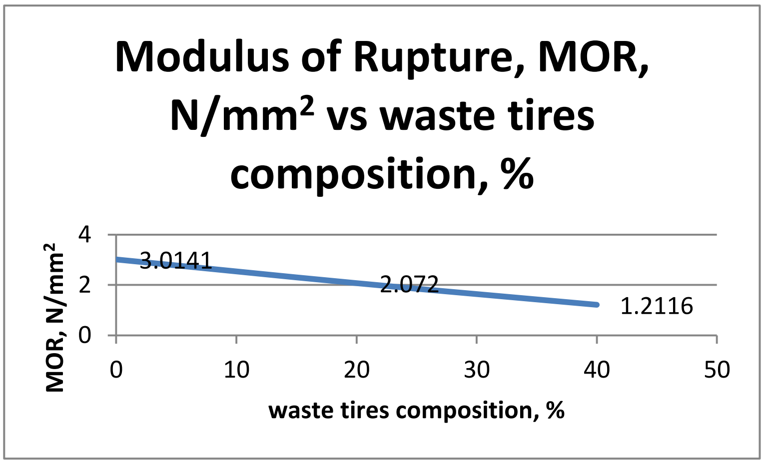

Figure 4.6: Modulus of Rupture (MOR) depending on the waste tires composition inside the particle board

4.3.2 Modulus of Elasticity, MOE

Modulus of elasticity or elastic modulus is mechanical properties defined as the substance tendency to be deformed elastically or non-permanently when force applied to it. Often, it is determine as the slope of the stress-strain curve in the elastic deformation region. Based on the data and result collected, it can be said that the untreated OPF fibre particle board are more elastic than the treated OPF fibre particle board. The value of MOE for untreated and treated particle board is 1607.489 N/mm^2 and 340.624 N/mm^2 respectively.

While value of MOE for the particle board with different waste tires composition of 0%, 20%, 40% is 340.624 N/mm^2, 249.8449 N/mm^2 and 149.3019 N/mm^2 respectively. It can be conclude that as the amount of waste tires composition increases, the value of MOE yield for the particle board is decreases. Based on values of MOE yield, the mount of MOE for untreated OPF fibre are comparable with the industrial standard which is 1700.307-2000.24 N/mm^2. All the data are represented in figures below:

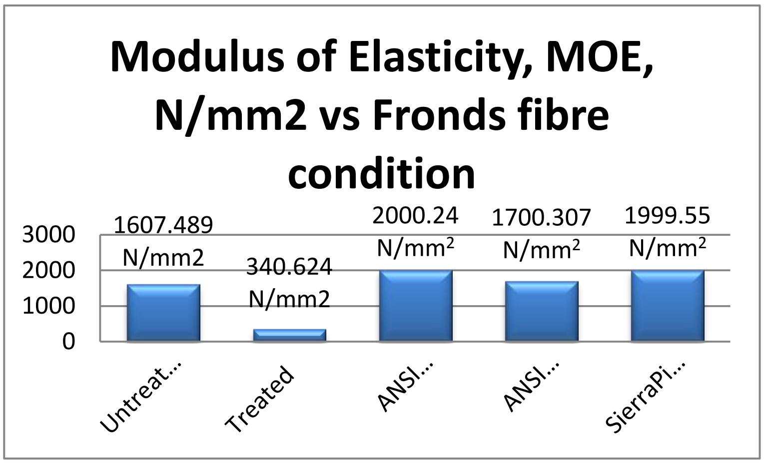

Figure 4.7: Modulus of elasticity (MOE) depending on the OPF fibre condition

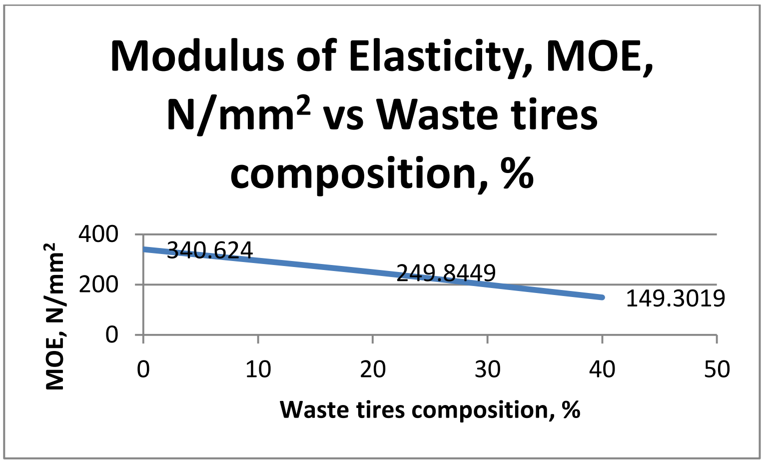

Figure 4.8: Modulus of elasticity (MOE) depending on the waste tires composition inside the particle board

4.3.3 Internal Bonding Strength, IB Strength

Internal bonding (IB) strength is the strength of the bond produce between the OPF fibre particle and the adhesive (urea formaldehyde) in the particle board. Based on the data and result observed for the particle board of untreated and treated OPF fibre, the internal (IB) strength is 0.3816 N/mm^2 and 0.0635 N/mm^2 respectively. It happens to be that the internal bonding between the untreated OPF fibres is higher than treated OPF fibre and it seem that the untreated OPF fibres particle board yield IB strength in range with the industrial standard.

Other than that, the amount of internal bonding (IB) strength yield for the particle board with different amount of waste tires composition of 0%, 20% and 40% is 0.0635 N/mm^2, 0.026 N/mm^2 and 0.0166 N/mm^2 respectively. This shows that as the amount of the waste tires composition inside the particle board increases, the amount of the internal bonding (IB) strength is decreases.

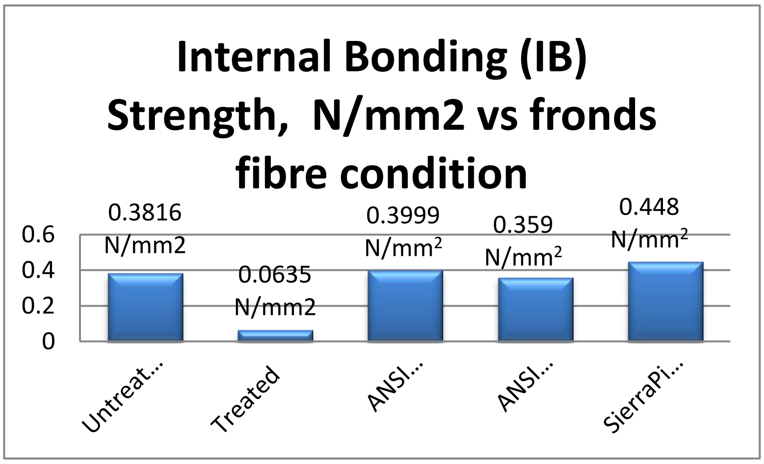

Figure 4.9: Internal Bonding (IB) strength depending on the OPF fibre condition

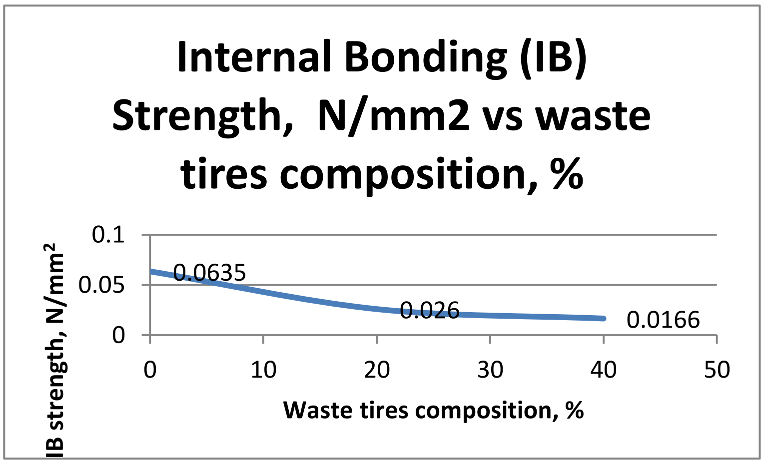

Figure 4.10: Internal bonding (IB) strength depending on the waste tires composition inside the particle board

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In this chapter, a concrete conclusion is being described based on the results and discussions which are discussed on the previous chapter. The conclusion are compared the performance and properties of all the particle boards produced which is untreated OPF fibre particle board, treated OPF fibre particle board, treated OPF fibre-waste tires particle boards with composition of 8:2 and 6:4 (OPF fibre: waste tires). It also compared with the standard specification of industrial/commercial particle boards.

5.2 CONCLUSION

In this research, the major objective is to make use the waste of OPF and rubber tires which is to produce particle board. Four types of particle board are produced successfully and the physical and mechanical properties of all the particle board have been studied and compare. As the conclusion, it can be conclude that the particle board produced from untreated OPF fibre has the best physical and mechanical properties. It was the steadiest reading of the density which is 673.75kg/m^3, the smallest percentage of the thickness swelling which is 28.471% for one hour and 40.036% for 12 hours; it has the highest value of MOR, MOE and IB strength which is 14.2998 N/mm^2, 1607.489 N/mm^2 and 0.3816 N/mm^2 respectively.

Other than that, based on the result, discussion and chart than have been studied in previous chapter, it can also be conclude that as the composition of waste rubber tires inside the particle board increases, the value of density will be increases, the percentages of thickness swelling will be decreases and the values of MOR, MOE and IB strength will be decreases.

However, the value of MOE yield for untreated OPF fibre is slightly lower than the industrial standard value which is 1607.489 N/mm^2 and 1700.307-2000.24 N/mm^2 respectively. This limitation can be preventing by applying some improvements in the production process of the particle boards.

5.3 RECOMMENDATIONS

As stated previously, there are several limitations of the particle boards produce. Thus, some recommendations are suggested such as decreased the size of both, OPF fibre and waste tires particles. When the size decreases, the amount of total surface area will be increase and therefore the amount of contact area also increases which it can improves the physical and mechanical properties of the particle boards including the internal bonding (IB) strength, MOR, MOE, and TS.

Other than that, it also suggested to increase the thickness of the particle board. With increases of the thickness, the particle board can become tougher and also can be used in heavy duty applications such construction materials.

It also recommended reducing the concentration of the sodium hydroxide, NaOH solution used in the surface treatment process. It seems that the concentrations of 7-10% are not suitable to OPF fibre and it has destroyed the mechanical properties of the OPF fibre. Therefore, concentration below than 7% should be used to do the surface treatment process of the OPF fibre in order to polish the OPF fibre and maintain its properties.

Lastly, it also recommended melting the waste tires into solution. This can improve it internal bonding which can improve its physical and mechanical properties. Other than improve the properties, it also can acts as adhesive materials and replace the function of urea formaldehyde inside the particle board. The melting process can be done by using heavy oil and high boiling point temperature of solvents. Therefore, it is relevance to precede this topic to future research to improve the data and yield optimum result.

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APPENDIX A

CALCULATION OF PARTICLE BOARD DENSITY AND AMOUNT OF UREA FORMALDEHYDE AS WOOD ADHESIVE

CALCULATION

Producing medium density particle board:

Density = 0.75 g/cm^3 = 750 Kg/cm^3

Dimension of board = 20 cm x 20 cm x 6 mm

= 240 cm^3

Weight for each sample:

W = density x volume

= 0.75 g/cm^3 x 240 cm^3

= 180 g

Table A.1: Summary table for sample weight:

Sample	Palm fronds fibre condition	Composition, %		Weight, g	
		Palm fronds fibre	Waste tires	Palm fronds fibre	Waste tires
1	Untreated	100	0	180	0
2	Treated	100	0	180	0
3	Treated	80	20	144	36
4	Treated	60	40	108	72

Amount of urea formaldehyde, UF adhesive needed:

$$M_{UF} = 10\% \times \text{board weight}$$

$$= 10\% \times 180 \text{ g}$$

$$= 18 \text{ g}$$

Total amount needed = 18 x 4 x 5 = 360 g

APPENDIX B

RESULT FOR BENDING TEST OBTAIN FROM UNIVERSAL TESTING MACHINE

B.1 UNTREATED OPF FIBRE PARTICLE BOARD

Title

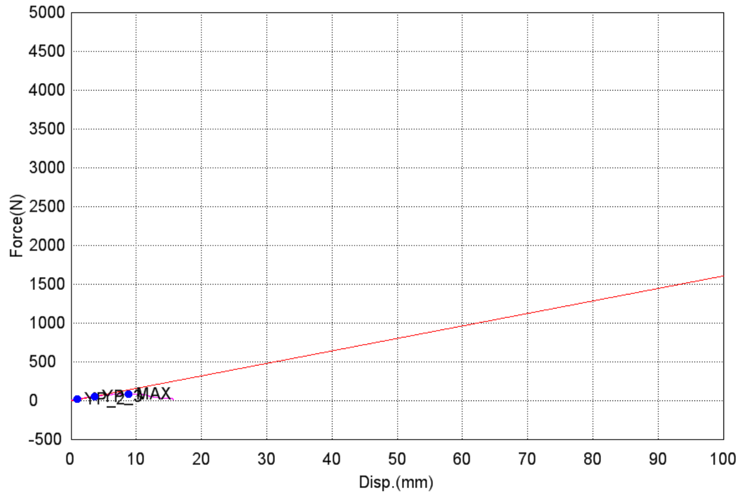
Key Word		**Product Name**	
Test File Name		**Method File Name**	standard test nas.xmak
Report Date	2006/12/05	**Test Date**	2006/12/05
Test Mode	Single	**Test Type**	3 Point Bend
Speed	10mm/min	**Shape**	Plate
No of Batches:	1	**Qty/Batch:**	7

Name	Break_Force	Elastic	Max_Force	YP(Disp.)_Force
Parameters	Sensitivity: 1	Force 1 - 20 N	Calc. At Entire Are	Stroke 1 mm
Unit	N	N/mm2	N	N
1-1	-.-	2535.47	78.6400	5.38747
1-2	35.8804	2717.74	107.237	7.05163
1-3	28.7533	2978.19	119.176	5.28654
1-4	19.5114	2995.87	92.4444	20.0756
1-5	-.-	3084.25	115.506	1.19209
1-6	92.1170	2841.61	117.743	17.6748
1-7	-.-	2172.58	81.0281	15.4797
Average	44.0655	2760.82	101.682	10.3068
Standard Deviation	23.1420	319.452	17.4586	7.29786
Maximum	92.1170	3084.25	119.176	20.0756
Minimum	19.5114	2172.58	78.6400	1.19209

Range	72.6056	911.670	40.5360	18.8835
Median	32.3169	2841.61	107.237	7.05163
Name	YP(Points)_Force	Tangent	Secant	Max_Slope
Parameters	3 Points	Force 5 N	Force 5 N	2 Points
Unit	N	N/mm2	N/mm2	N/mm2
1-1	58.5254	2126.28	690.714	15707.0
1-2	64.2935	3397.40	759.570	14050.8
1-3	73.3789	3744.41	686.428	18557.5
1-4	81.2197	2536.65	2042.12	20222.6
1-5	80.1651	4430.83	583.285	49029.1
1-6	59.1246	3223.37	1583.99	54262.3
1-7	51.8537	3037.47	1888.03	20662.2
Average	66.9373	3213.77	1176.31	27498.8
Standard Deviation	11.4511	760.355	635.546	16730.0
Maximum	81.2197	4430.83	2042.12	54262.3
Minimum	51.8537	2126.28	583.285	14050.8
Range	29.3660	2304.55	1458.84	40211.5
Median	64.2935	3223.37	759.570	20222.6
Name	Max_Stress	Max_Strain	Thickness	Width
Parameters	Calc. At Entire Are	Calc. At Entire Are		
Unit	N/mm2	%		
1-1	14.1552	1.03348	5.0000	50.0000
1-2	19.3026	1.24170	5.0000	50.0000
1-3	21.4517	1.21303	5.0000	50.0000
1-4	16.6400	0.83703	5.0000	50.0000
1-5	20.7911	1.33280	5.0000	50.0000
1-6	21.1937	1.20146	5.0000	50.0000
1-7	14.5851	1.16881	5.0000	50.0000
Average	18.3028	1.14690	5.0000	50.0000

Standard Deviation	3.14253	0.16343	0.00000	0.00000
Maximum	21.4517	1.33280	5.0000	50.0000
Minimum	14.1552	0.83703	5.0000	50.0000
Range	7.29650	0.49577	0.00000	0.00000
Median	19.3026	1.20146	5.0000	50.0000

Name	Lower_Support	Slope_Tangent
Parameters		Force 5 N
Unit		N/mm
1-1	150.0000	15.7502
1-2	150.0000	25.1659
1-3	150.0000	27.7364
1-4	150.0000	18.7900
1-5	150.0000	32.8209
1-6	150.0000	23.8768
1-7	150.0000	22.4998
Average	150.0000	23.8057
Standard Deviation	0.00000	5.63225
Maximum	150.0000	32.8209
Minimum	150.0000	15.7502
Range	0.00000	17.0707
Median	150.0000	23.8768



B.2 TREATED OPF FIBRE PARTICLE BOARD

Title

Key Word		**Product Name**	
Test File Name		**Method File Name**	standard test nas.xmak
Report Date	2006/12/05	**Test Date**	2006/12/05
Test Mode	Single	**Test Type**	3 Point Bend
Speed	10mm/min	**Shape**	Plate
No of Batches:	1	**Qty/Batch:**	7

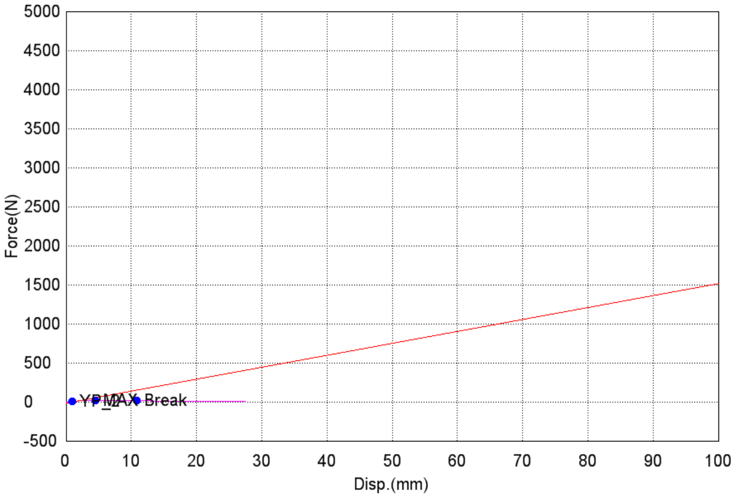
Name	Break_Force	Elastic	Max_Force	YP(Disp.)_Force
Parameters	Sensitivity: 1	Force 1 - 20 N	Calc. at Entire Are	Stroke 1 mm
Unit	N	N/mm2	N	N
2-1	-.-	1016.49	24.7558	6.79493
2-2	-.-	-.-	9.01143	4.37816
2-3	-.-	976.264	21.3591	2.68062
2-4	-.-	-.-	16.8459	1.77304
2-5	-.-	-.-	17.7272	4.53790
2-6	31.6660	51.9899	33.8697	7.48714
2-7	13.1830	-.-	18.2613	4.95990
Average	22.4245	681.581	20.2615	4.65881
Standard Deviation	5.33558	545.613	7.69459	2.04073
Maximum	31.6660	1016.49	33.8697	7.48714
Minimum	13.1830	51.9899	9.01143	1.77304
Range	18.4830	964.500	24.8583	5.71410
Median	22.4245	976.264	18.2613	4.53790

Name	YP(Points)_Force	Tangent	Secant	Max_Slope
Parameters	3 Points	Force 5 N	Force 5 N	2 Points
Unit	N	N/mm2	N/mm2	N/mm2

2-1	-.-	1208.39	859.828	12748.9
2-2	-.-	2424.73	579.026	22500.0
2-3	-.-	1749.03	524.070	18552.6
2-4	-.-	1767.10	409.923	18338.5
2-5	-.-	270.650	590.610	59040.2
2-6	-.-	1117.09	1047.17	22461.3
2-7	-.-	2064.37	671.681	16415.1
Average	-.-	1514.48	668.901	24293.8
Standard Deviation	-.-	712.798	216.718	15693.3
Maximum	-.-	2424.73	1047.17	59040.2
Minimum	-.-	270.650	409.923	12748.9
Range	-.-	2154.08	637.247	46291.3
Median	-.-	1749.03	590.610	18552.6

Name	Max_Stress	Max_Strain	Thickness	Width
Parameters	Calc. at Entire Are	Calc. at Entire Are		
Unit	N/mm2	%		
2-1	4.45604	0.65527	5.0000	50.0000
2-2	1.62206	3.80816	5.0000	50.0000
2-3	3.84464	0.73725	5.0000	50.0000
2-4	3.03226	0.96439	5.0000	50.0000
2-5	3.19090	2.14238	5.0000	50.0000
2-6	6.09655	4.95505	5.0000	50.0000
2-7	3.28703	0.59348	5.0000	50.0000
Average	3.64707	1.97943	5.0000	50.0000
Standard Deviation	1.38503	1.75465	0.00000	0.00000
Maximum	6.09655	4.95505	5.0000	50.0000
Minimum	1.62206	0.59348	5.0000	50.0000
Range	4.47449	4.36157	0.00000	0.00000
Median	3.28703	0.96439	5.0000	50.0000

Name	Lower_Support	Slope_Tangent
Parameters		Force 5 N
Unit		N/mm
2-1	150.0000	8.95103
2-2	150.0000	17.9610
2-3	150.0000	12.9558
2-4	150.0000	13.0897
2-5	150.0000	2.00481
2-6	150.0000	8.27477
2-7	150.0000	15.2916
Average	150.0000	11.2184
Standard Deviation	0.00000	5.28000
Maximum	150.0000	17.9610
Minimum	150.0000	2.00481
Range	0.00000	15.9562
Median	150.0000	12.9558



Comment

B.3 TREATED OPF FIBRE-WASTE TIRE (20%) PARTICLE BOARD

Title

Key Word **Product Name**

Test File Name **Method File Name** standard test nas.xmak

Report Date 2006/12/05 **Test Date**2006/12/05

Test Mode Single **Test Type** 3 Point Bend

Speed 10mm/min **Shape** Plate

No of Batches: 1 **Qty/Batch:** 7

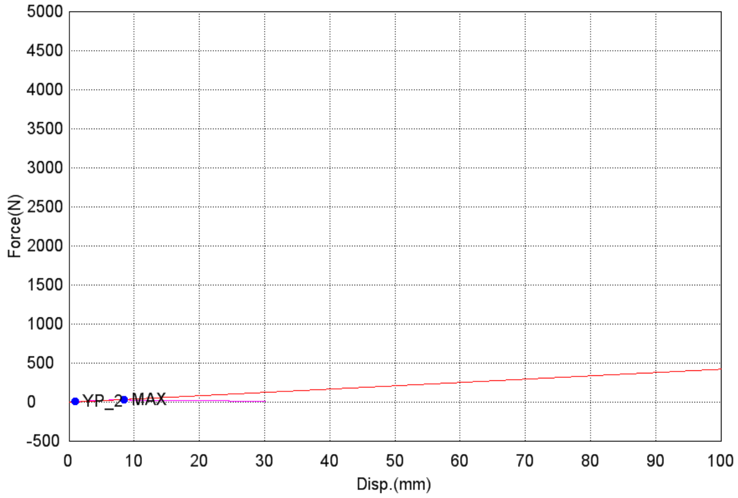
Name	Break_Force	Elastic	Max_Force	YP(Disp.)_Force
Parameters	Sensitivity: 1	Force 1 - 20 N	Calc. at Entire Are	Stroke 1 mm
Unit	N	N/mm2	N	N
3-1	-.-	-.-	9.48509	0.01192
3-2	-.-	-.-	4.04199	0.00397
3-3	-.-	-.-	12.3723	1.52429
3-4	-.-	-.-	15.7929	2.40485
3-5	-.-	-.-	14.0357	0.00795
3-6	-.-	955.968	29.7562	5.92232
3-7	-.-	573.310	23.3913	1.82788
Average	-.-	764.639	15.5536	1.67188
Standard Deviation	-.-	270.580	8.61171	2.11958
Maximum	-.-	955.968	29.7562	5.92232
Minimum	-.-	573.310	4.04199	0.00397
Range	-.-	382.658	25.7142	5.91835
Median	-.-	764.639	14.0357	1.52429

Name	YP(Points)_Force	Tangent	Secant	Max_Slope
Parameters	3 Points	Force 5 N	Force 5 N	2 Points
Unit	N	N/mm2	N/mm2	N/mm2

3-1	-.-	514.421	178.548	19955.7
3-2	-.-	-.-	-.-	20286.1
3-3	-.-	1926.04	309.363	18861.3
3-4	-.-	1121.70	350.278	15072.8
3-5	-.-	761.869	269.722	19183.2
3-6	-.-	1781.68	765.599	15015.2
3-7	-.-	1273.61	392.051	26625.6
Average	-.-	1229.89	377.594	19285.7
Standard Deviation	-.-	553.833	203.673	3905.13
Maximum	-.-	1926.04	765.599	26625.6
Minimum	-.-	514.421	178.548	15015.2
Range	-.-	1411.62	587.051	11610.4
Median	-.-	1197.66	329.821	19183.2

Name	Max_Stress	Max_Strain	Thickness	Width
Parameters	Calc. at Entire Are	Calc. at Entire Are		
Unit	N/mm2	%		
3-1	1.70732	1.53747	5.0000	50.0000
3-2	0.72756	1.02970	5.0000	50.0000
3-3	2.22702	1.17905	5.0000	50.0000
3-4	2.84271	1.59214	5.0000	50.0000
3-5	2.52643	1.15105	5.0000	50.0000
3-6	5.35612	0.88705	5.0000	50.0000
3-7	4.21042	1.11837	5.0000	50.0000
Average	2.79965	1.21355	5.0000	50.0000
Standard Deviation	1.55011	0.25911	0.00000	0.00000
Maximum	5.35612	1.59214	5.0000	50.0000
Minimum	0.72756	0.88705	5.0000	50.0000
Range	4.62856	0.70509	0.00000	0.00000
Median	2.52643	1.15105	5.0000	50.0000

Name	Lower_Support	Slope_Tangent
Parameters		Force 5 N
Unit		N/mm
3-1	150.0000	3.81053
3-2	150.0000	-.-
3-3	150.0000	14.2670
3-4	150.0000	8.30889
3-5	150.0000	5.64347
3-6	150.0000	13.1976
3-7	150.0000	9.43411
Average	150.0000	9.11027
Standard Deviation	0.00000	4.10247
Maximum	150.0000	14.2670
Minimum	150.0000	3.81053
Range	0.00000	10.4565
Median	150.0000	8.87150



Comment

B.4 TREATED OPF FIBRE-WASTE TIRES (40%) PARTICLE BOARD

Title

Key Word		**Product Name**	
Test File Name		**Method File Name**	standard test nas.xmak
Report Date	2006/12/05	**Test Date**	2006/12/05
Test Mode	Single	**Test Type**	3 Point Bend
Speed	10mm/min	**Shape**	Plate
No of Batches:	1	**Qty/Batch:**	7

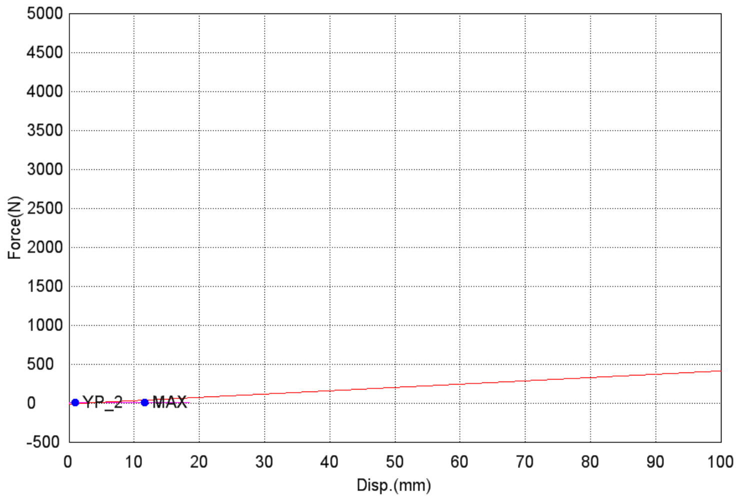
Name	Break_Force	Elastic	Max_Force	YP(Disp.)_Force
Parameters	Sensitivity: 1	Force 1 - 20 N	Calc. at Entire Are	Stroke 1 mm
Pass/Fail		1 - 100		
Unit	N	N/mm2	N	N
4-1	-.-	-.-	6.01451	0.01033
4-2	-.-	-.-	7.48952	2.25703
4-3	-.-	-.-	7.79470	1.16507
4-4	-.-	-.-	12.2937	3.28461
4-5	-.-	-.-	8.35419	0.00636
4-6	2.73307	-.-	10.5413	0.00397
4-7	-.-	-.-	8.47181	2.31822
Average	2.73307	-.-	8.70853	1.29223
Standard Deviation	-.-	-.-	2.08058	1.34942
Maximum	2.73307	-.-	12.2937	3.28461
Minimum	2.73307	-.-	6.01451	0.00397
Range	0.00000	-.-	6.27919	3.28064
Median	2.73307	-.-	8.35419	1.16507
Name	YP(Points)_Force	Tangent	Secant	Max_Slope
Parameters	3 Points	Force 5 N	Force 5 N	2 Points

Pass/Fail				
Unit	N	N/mm2	N/mm2	N/mm2
4-1	-.-	2284.49	176.674	13732.7
4-2	-.-	2268.83	164.675	24590.5
4-3	-.-	808.063	139.405	10943.4
4-4	-.-	1634.43	438.778	16373.8
4-5	-.-	50.3166	193.556	22806.0
4-6	-.-	1551.32	175.698	13798.4
4-7	-.-	572.140	232.803	14507.5
Average	-.-	1309.94	217.370	16678.9
Standard Deviation	-.-	857.871	101.714	5079.64
Maximum	-.-	2284.49	438.778	24590.5
Minimum	-.-	50.3166	139.405	10943.4
Range	-.-	2234.17	299.373	13647.1
Median	-.-	1551.32	176.674	14507.5

Name	Max_Stress	Max_Strain	Thickness	Width
Parameters	Calc. at Entire Are	Calc. at Entire Are		
Pass/Fail				
Unit	N/mm2	%		
4-1	1.08261	0.68570	5.0000	50.0000
4-2	1.34811	1.76814	5.0000	50.0000
4-3	1.40305	1.81594	5.0000	50.0000
4-4	2.21286	0.71348	5.0000	50.0000
4-5	1.50375	0.93814	5.0000	50.0000
4-6	1.89743	1.15149	5.0000	50.0000
4-7	1.52493	1.54814	5.0000	50.0000
Average	1.56753	1.23158	5.0000	50.0000
Standard Deviation	0.37450	0.48106	0.00000	0.00000
Maximum	2.21286	1.81594	5.0000	50.0000

Minimum	1.08261	0.68570	5.0000	50.0000
Range	1.13025	1.13024	0.00000	0.00000
Median	1.50375	1.15149	5.0000	50.0000

Name	Lower_Support	Slope_Tangent
Parameters		Force 5 N
Pass/Fail		
Unit		N/mm
4-1	150.0000	16.9221
4-2	150.0000	16.8061
4-3	150.0000	5.98565
4-4	150.0000	12.1069
4-5	150.0000	0.37272
4-6	150.0000	11.4912
4-7	150.0000	4.23807
Average	150.0000	9.70325
Standard Deviation	0.00000	6.35458
Maximum	150.0000	16.9221
Minimum	150.0000	0.37272
Range	0.00000	16.5494
Median	150.0000	11.4912



APPENDIX C

RESULT FOR INTERNAL BONDING TEST OBTAIN FROM UNIVERSAL TESTING MACHINE

C.1 UNTREATED OPF FIBRE PARTICLE BOARD

Title

Key Word **Product Name**

Test File NameIB-1.xtak **Method File Name** standared test nas IB.x

Report Date2006/11/30 **Test Date**2006/11/30

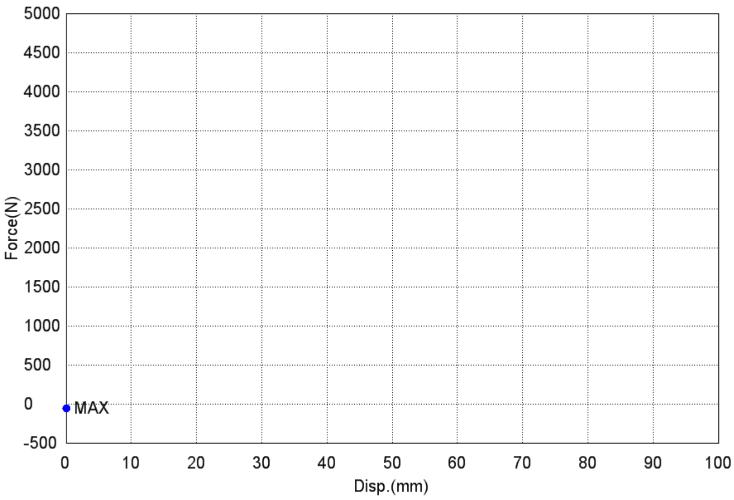
Test Mode Single **Test Type** Tensile

Speed 1mm/min **Shape** Plate

No of Batches:1 **Qty/Batch:** 7

Name	Elastic	Slope_Standard	Tangent	Max_Force
Parameters	Force 10 - 20 N	Force 10 - 20 N	Force 10 N	Calc. at Entire Are
Unit	N/mm2	N/mm	N/mm2	N
1-1	4057.32	40.5732	51913.9	1263.60
1-2	242.253	2.42253	18251.5	1409.84
1-3	418.040	4.18040	7483.76	559.263
1-4	4191.62	41.9162	-5166.4	1345.71
1-5	2838.88	28.3888	-12955	1145.27
1-6	1644.99	16.4499	44980.7	1153.22
1-7	325.223	3.25223	-1301.8	678.743
1 _ 7_N	-.-	-.-	-.-	-56.364
Average	1959.76	19.5976	14743.8	937.410
Standard Deviation	1744.10	17.4410	25106.4	504.773
Maximum	4191.62	41.9162	51913.9	1409.84

Minimum	242.253	2.42253	-12955	-56.364
Name	Break_Force	Break_Stress	YP(%FS)_Force	YP(Disp.)_Force
Parameters	Sensitivity: 10	Sensitivity: 10	0.1 %	Stroke 1 mm
Unit	N	N/mm2	N	N
1-1	-.-	-.-	-.-	224.412
1-2	-.-	-.-	-.-	10.2894
1-3	-.-	-.-	-.-	63.8485
1-4	-.-	-.-	-.-	11.7294
1-5	-.-	-.-	-.-	19.3405
1-6	-.-	-.-	-.-	33.7338
1-7	-.-	-.-	-.-	4.94957
1 _ 7_N	-.-	-.-	-.-	-.-
Average	-.-	-.-	-.-	52.6147
Standard Deviation	-.-	-.-	-.-	72.5447
Maximum	-.-	-.-	-.-	224.412
Minimum	-.-	-.-	-.-	4.94957



Comment

C.2 TREATED OPF FIBRE PARTICLE BOARD

Title

Key Word **Product Name**

Test File Name **Method File Name** standared test nas IB.x

Report Date2006/11/30 **Test Date**2006/11/30

Test Mode Single **Test Type** Tensile

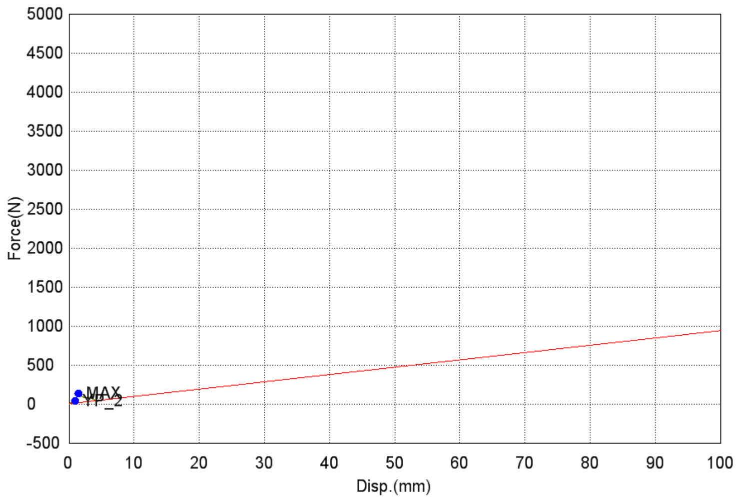
Speed 1mm/min **Shape** Plate

No of Batches:1 **Qty/Batch:** 7

Name	Elastic	Slope_Standard	Tangent	Max_Force
Parameters	Force 10 - 20 N	Force 10 - 20 N	Force 10 N	Calc. at Entire Are
Unit	N/mm2	N/mm	N/mm2	N
2-1	6043.00	60.4300	10946.0	146.816
2-2	7514.71	75.1471	12141.1	127.876
2-3	656.585	6.56585	47055.6	284.292
2-4	124.098	1.24098	-41280	168.304
2-5	537.858	5.37858	7495.77	141.717
2-6	937.129	9.37129	39197.9	136.823
Average	2635.56	26.3556	12592.7	167.638
Standard Deviation	3253.48	32.5348	31069.9	58.7276
Maximum	7514.71	75.1471	47055.6	284.292
Minimum	124.098	1.24098	-41280	127.876

Name	Break_Force	Break_Stress	YP(%FS)_Force	YP(Disp.)_Force
Parameters	Sensitivity: 10	Sensitivity: 10	0.1 %	Stroke 1 mm
Unit	N	N/mm2	N	N
2-1	-.-	-.-	-.-	89.7678
2-2	-.-	-.-	-.-	36.7951
2-3	-.-	-.-	-.-	6.12497

2-4	-.-	-.-	-.-	7.54198
2-5	-.-	-.-	-.-	66.2581
2-6	-.-	-.-	-.-	34.3323
Average	-.-	-.-	-.-	40.1367
Standard Deviation	-.-	-.-	-.-	32.8927
Maximum	-.-	-.-	-.-	89.7678
Minimum	-.-	-.-	-.-	6.12497



Comment

C.3 TREATED OPF FIBRE-WASTE TIRES (20%) PARTICLE BOARD

Title

Key Word **Product Name**

Test File NameIB-3.xtak **Method File Name** standared test nas IB.x

Report Date2006/11/30 **Test Date**2006/12/01

Test Mode Single **Test Type** Tensile

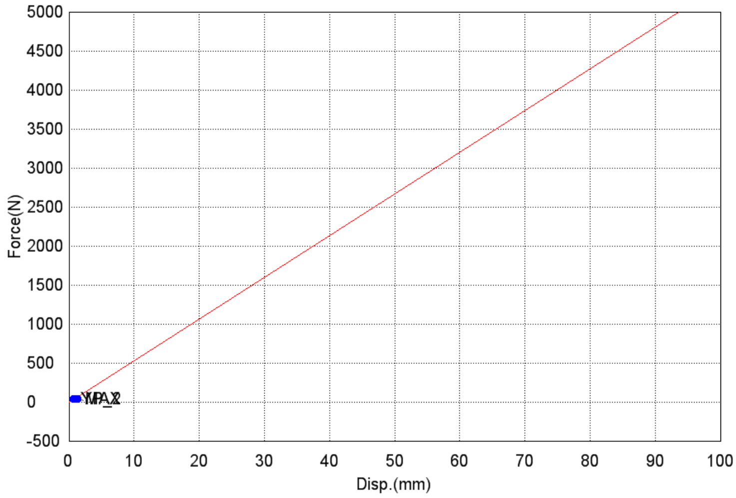
Speed 1mm/min **Shape** Plate

No of Batches:1 **Qty/Batch:** 7

Name	Elastic	Slope_Standard	Tangent	Max_Force
Parameters	Force 10 - 20 N	Force 10 - 20 N	Force 10 N	Calc. at Entire Are
Unit	N/mm2	N/mm	N/mm2	N
3-3	327.153	3.27153	9116.14	20.7464
3-3(2)	2934.59	29.3459	10900.2	39.3335
3-4	31780.7	317.807	36193.8	117.439
3-5	16255.3	162.553	37203.2	77.0020
3-6	265.852	2.65852	6710.27	172.504
3-7	5345.61	53.4561	23672.3	37.3666
Average	9484.87	94.8487	20632.7	77.3986
Standard Deviation	12424.5	124.245	13763.4	58.1540
Maximum	31780.7	317.807	37203.2	172.504
Minimum	265.852	2.65852	6710.27	20.7464

Name	Break_Force	Break_Stress	YP(%FS)_Force	YP(Disp.)_Force
Parameters	Sensitivity: 10	Sensitivity: 10	0.1 %	Stroke 1 mm
Unit	N	N/mm2	N	N
3-3	-.-	-.-	-.-	10.7416
3-3(2)	-.-	-.-	-.-	38.4347
3-4	-.-	-.-	-.-	117.439

3-5	-.-	-.-	-.-	77.0020
3-6	-.-	-.-	-.-	16.1958
3-7	-.-	-.-	-.-	36.9000
Average	-.-	-.-	-.-	49.4522
Standard Deviation	-.-	-.-	-.-	40.6562
Maximum	-.-	-.-	-.-	117.439
Minimum	-.-	-.-	-.-	10.7416



Comment

C.4 TREATED OPF FIBRE-WASTE TIRES (40%) PARTICLE BOARD

Title

Key Word **Product Name**

Test File NameIB-4.xtak **Method File Name** standared test nas IB.x

Report Date2006/11/30 **Test Date**2006/11/30

Test Mode Single **Test Type** Tensile

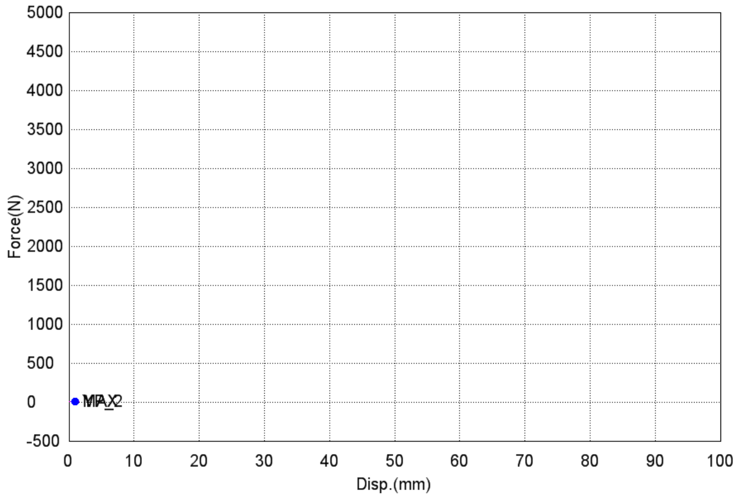
Speed 1mm/min **Shape** Plate

No of Batches:1 **Qty/Batch:** 7

Name	Elastic	Slope_Standard	Tangent	Max_Force
Parameters	Force 10 - 20 N	Force 10 - 20 N	Force 10 N	Calc. at Entire Are
Unit	N/mm2	N/mm	N/mm2	N
4-1	353.854	3.53854	3024.08	21.9472
4-2	566.252	5.66252	1847.11	23.5399
4-3	5406.49	54.0649	23583.9	66.0380
4-4	261.960	2.61960	6714.78	36.6346
4-5	315.825	3.15825	11262.9	85.5128
4-6	279.713	2.79713	1021.09	40.5884
4-7	-.-	-.-	-.-	2.79506
Average	1197.35	11.9735	7908.98	39.5794
Standard Deviation	2064.98	20.6498	8560.72	28.1095
Maximum	5406.49	54.0649	23583.9	85.5128
Minimum	261.960	2.61960	1021.09	2.79506

Name	Break_Force	Break_Stress	YP(%FS)_Force	YP(Disp.)_Force
Parameters	Sensitivity: 10	Sensitivity: 10	0.1 %	Stroke 1 mm
Unit	N	N/mm2	N	N
4-1	-.-	-.-	-.-	15.8382
4-2	-.-	-.-	-.-	8.10862

4-3	-.-	-.-	-.-	25.9773
4-4	-.-	-.-	-.-	10.4825
4-5	-.-	-.-	-.-	13.2505
4-6	-.-	-.-	-.-	6.34035
4-7	-.-	-.-	-.-	2.79506
Average	-.-	-.-	-.-	11.8275
Standard Deviation	-.-	-.-	-.-	7.59013
Maximum	-.-	-.-	-.-	25.9773
Minimum	-.-	-.-	-.-	2.79506



Comment