STUDY ON TENSILE AND FLEXURAL PROPERTIES OF RECYCLED HIGH DENSITY POLYETHELENE/SAWDUST COMPOSITES

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

Study on Tensile and Flexural Properties of Recycled High Density Polyethylene/Sawdust Composites

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Aimi Nurliyana Bt Johar

A project dissertation submitted to the
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May 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AIMI NURLIYANA BT JOHAR

ABSTRACT

Plastic lumber is a wood plastic composite and usually made from recycled material. It is composed of recycled High Density Polyethylene (r-HDPE) and wood waste known as saw dust. The goal for this project is to evaluate the tensile and flexural properties of r-HDPE/sawdust composites with various compositions. The sawdust was ranging from 0 wt% to 50 wt%. Sawdust is commonly available at furniture factories whereas r-HDPE was collected from milk and yoghurt bottles. Twin-screw extruder and hot press compression moulding machines were used to produce this polymer composite. Study of the mechanical properties of the loading sawdust content showed that tensile strength of the composites is decreased with increasing of sawdust content. The best tensile strength was achieved with 10 wt % of sawdust, which translated to reductions of 14.3% compared to pure r-HDPE. For flexural strength and modulus, the performance is increased by increasing of sawdust content. The maximum flexural strength and modulus were obtained with 40 wt% of sawdust content, which were 46.0% and 58.9% improvement. Scanning electron microscopy (SEM) images of the fractured surfaces from tensile testing had been done to investigate the interfacial bonding between sawdust and r-HDPE matrix

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The use of plastic lumber for the outdoor application is well known and widely practiced especially in landscaping and decking. Most of plastic lumber in industry are made from recycled High Density Polyethylene (r-HDPE) and wood waste. Plastic lumber appeared in the market in the market in the late of 1980s and since then, it has grown and undergone research and development to improve the performance. Figure 1.1 shows the applications for this r-HDPE/sawdust composite which are suitable for outdoor and building application. This plastic lumber offers great advantages in durability to absorb moisture and biological attack [1]. It also has lower maintenance cost compared to real wood as it does not required surface coating. In addition, plastic lumber is very cheap compared to real wood, so it is not surprising this wood composite is more attractive than real wood [2]. The usage of recycled HDPE as the composite matrix manages to reduce the plastic pollution. Previous studies show that material properties of the recycled HDPE were not largely different from virgin HDPE. Also recycled HDPE is cheaper than the virgin HDPE [3].

Figure 1.1: Applications of r-HDPE/sawdust composite.

1.2 Problem Statement

Currently solid wood has been widely used in building product, marine structure, and automobile parts around the world. However, there are attempts to substitute solid woods with plastic lumber because of concerning in effect of wood treatment process to the environment. Without any treatment or surface coating, wood products have high potential to damage, especially in climate like Malaysia, which is rich in humid and hot. Figure 1.2 shows the damaged wood products attacked by climate and fungus/bacteria. The moisture that builds inside the wood becomes an ideal place for the growth of bacteria. By combining the r-HDPE (hydrophobic polymer matrix) and sawdust (hydrophilic fiber), it helped in improving its durability against the moisture absorption.

Recent research found that colour in wood-based materials has a significant influence on consumer preferences [4]. Therefore, it is important to improve their long-term weather-ability, durability, and color stability.

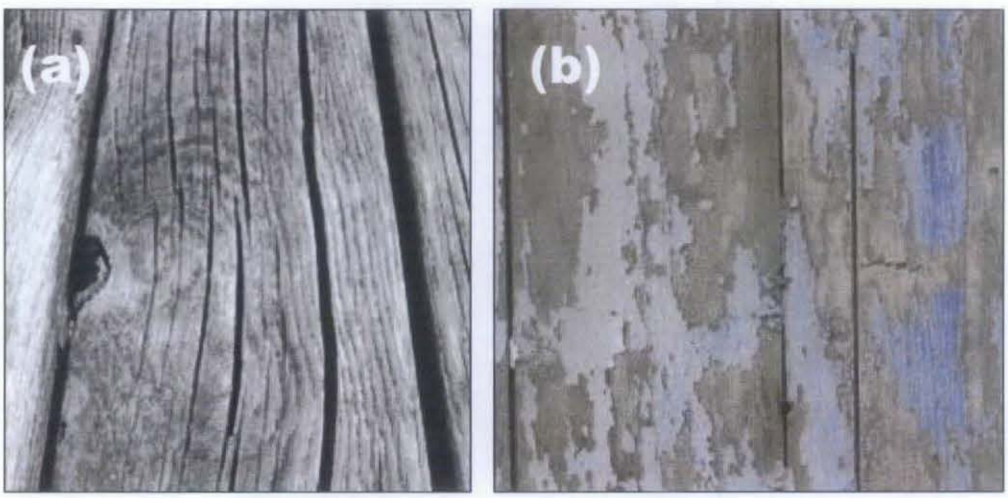

Figure 1.2: Wood product damaged due to (a) wear and tear (b) fungus attacked.

The increasing amount of plastic waste from our daily usage also contributed in pollution to the environment. Today plastic pollution has become one of serious global problems because increasing amount of plastic product and it takes long time to degrade, hence it can contaminate the earth. In 2000, the amount of plastics waste in Municipal Solid Waste reached 24.7 million tons in United States.

As shown in Figure 1.3 low density polyethylene (LDPE) /linear low density polyethylene (LLDPE) is the largest waste component, followed by high density polyethylene (HDPE), polypropylene (PP), polyethylene terephtalate (PET), and polystyrene (PS) [5].

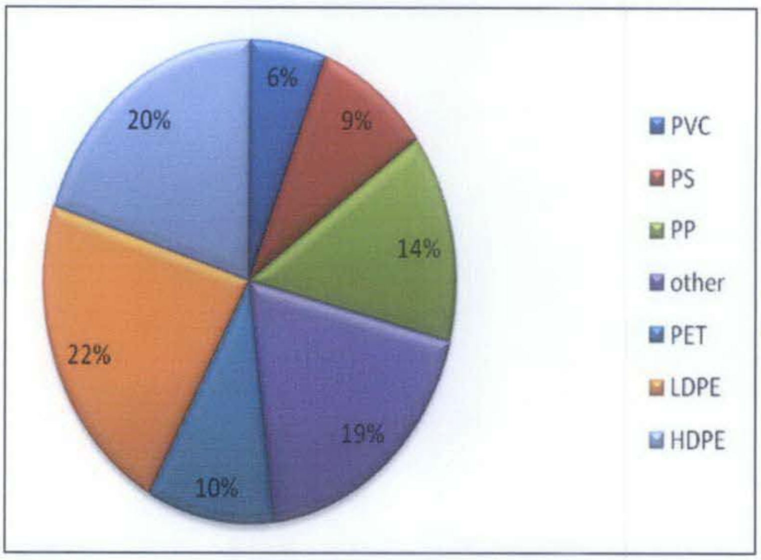

Figure 1.3: Plastics in the US municipal solid waste stream in 2000 [5].

Realizing this, an action should be taken to recycle the post–consumer plastics in order to reduce the pollution and consumption of virgin plastic. Plastic waste can be categorized as the fastest growing part of the waste stream and the most expensive waste to manage because it is not biodegradable. Increasing of waste wood (sawdust) in wood industry also becomes another major concern and usually such waste is disposed at landfill. Due to those problems, plastic lumber has been seen as the new environmental friendly material because it is composed of recycled plastic and nature fiber (saw dust). Hence, this plastic lumber helps reducing waste disposal problems and lowering production costs by increasing usage of the recycled plastics and waste wood.

Producing this plastic lumber involves few challenges. Material preparation process required the sawdust to be dried well before compounding with polymer matrix to avoid degradation and voids. Increased moisture content in the composites may reduce its mechanical properties, dimensional stability, and tends to lead to biodegradation [6]. However, the effectiveness of additives like maleated coupling agents has shown to be capable of improving the water resistant and mechanical properties through improved the compatibility between the hydrophilic wood filler and hydrophobic polymer matrix [6-7]. Furthermore, uncontrolled temperature during extrusion process can burned the saw dust and degraded the r-HDPE.

1.3 Objective and Scope of Study

The objective of this project is to study the tensile and flexural properties of recycled High Density Polyethylene/sawdust composites with various compositions.

The scopes of this project include:

- Grinding and sieving the sawdust to get the desired size.
- Cutting and granulate the recycled HDPE to get the suitable size.
- Fabricate the composite with various compositions by ranging the sawdust content from 0 wt% to 50 wt%.
- Investigate tensile and flexural properties of different composition of the plastic lumber.

1.4 Relevancy and Feasibility of Project

This project is relevant because it provides knowledge and information for next student to do continue in this plastic lumber research. As this plastic lumber is getting high demand in market so it will be a great opportunity for UTP (University Teknologi PETRONAS) to start doing research in this field because UTP is well equipped to produce this plastic lumber. This project is carried out over two academic semesters, the processes involve in this project are guided by the time line in Appendix A-1and A-2.

CHAPTER 2

LITERATURE REVIEW/THEORY

2.1 Overview

Plastic lumber, also known as wood plastic composite, is a 100% recyclable material lumber made from recycled plastic and saw dust with addition of additives. As the plastic lumber has been used for outdoor application, addition of coupling agent (MAPE or acetylation) can improve adhesion between the fibers and matrix [6]. Meanwhile addition of UV stabilizer can increase the lifespan because it protects plastic lumber from UV ray exposure which can cause degradation to the plastic lumber. In industries, several companies are producing plastic lumber because of the stability and fungal resistance compared to original wood composite [7]. To produce plastic lumber, twin-screw extruder machine will be used to compound sawdust and recycled HDPE. Those materials will melt under heat and pressure inside the twin-screw extruder. Then, the extruded material will be injection molded to produce samples for tensile and flexural tests.

2.2 Composites

Composites are usually made of two or more parts, one parts as fillers or reinforcement and others as matrix. The fiber can be glass, carbon fiber, or natural fiber (sawdust). The matrix holds the reinforcement together and it has lower strength than the reinforcements. So, the fillers are embedded in the matrix in order to make the matrix stronger. Figure 2.1 illustrated a close-up on what a composite look like. The reinforcing fibers are the main load-carrying component in the composites. It provides high strength and stiffness as well as resistance to bending and breaking under the applied stress. Stress is transfer from the matrix into the fillers across the interface bonding between them. The interface adhesion between the polymer matrix and wood fillers can be improved using coupling agents. The coupling agents will form a bond between the fibers and the matrix and improved compatibility (wet ability) and developing a bonding. Short fiber composites have tensile strength that is more sensitive to polymer matrix properties; however elastic modulus is more dependently on fiber properties [8]. Natural fiber reinforced polyester composites have the prospects of such composites in building applications [6].

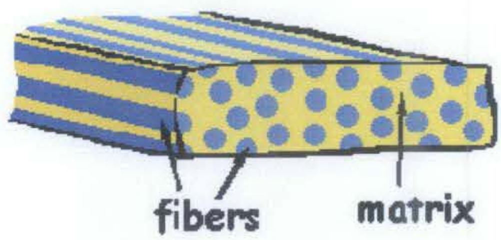

Figure 2.1: Close up on what a composite look like.

2.3 Recycled HDPE as a Matrix

Recycled HDPE has been chosen as the matrix in this wood plastic composite. The functions of the matrix in composite are to bind the fibers together and to hold them aligned in the important stress direction. HDPE is under thermoplastic category which has one or two dimensional molecular structure and softens at high temperature [9]. Only thermoplastic is applicable in this plastic lumber which can be processed at temperature below 200°C. This temperature is due to limited thermal stability of wood [10]. The process of softening or melting can be reversed to regain its properties.

Besides that, HDPE has a greater proportion of crystalline regions than low density polyethylene (LDPE). Higher proportion of crystalline gives greater density and strength. Meanwhile, lesser proportion of crystalline like LDPE has a greater flexibility but less strength [9]. Its tensile strength is two to three times greater than LDPE. It has good compressive strength. Due to that property, HDPE is selected as the matrix. Recycled HDPE pallets and flakes are 31–34% less expensive than the virgin high density polyethylene (v-HDPE) [3].

Previous studies shows that the properties of the recycled HDPE (r-HDPE) obtained from the post-consumer milk bottles were not largely different from those of virgin resin and thus could be used for various applications [11]. A study by Jayaraman *et al.* shows that the tensile strengths of plastic lumber made from wood fibers (pine) and recycled HDPE are about 25% higher than those of the entirely virgin HDPE panel [12-13].

The comparison of tensile strength and tensile modulus is presented in Figure 2.2. As can be seen, performance of composites made from recycled HDPE was as good as that of composites made from virgin HDPE. In most cases, differences between the recycled and virgin HDPE composites were not statistically significant [14].

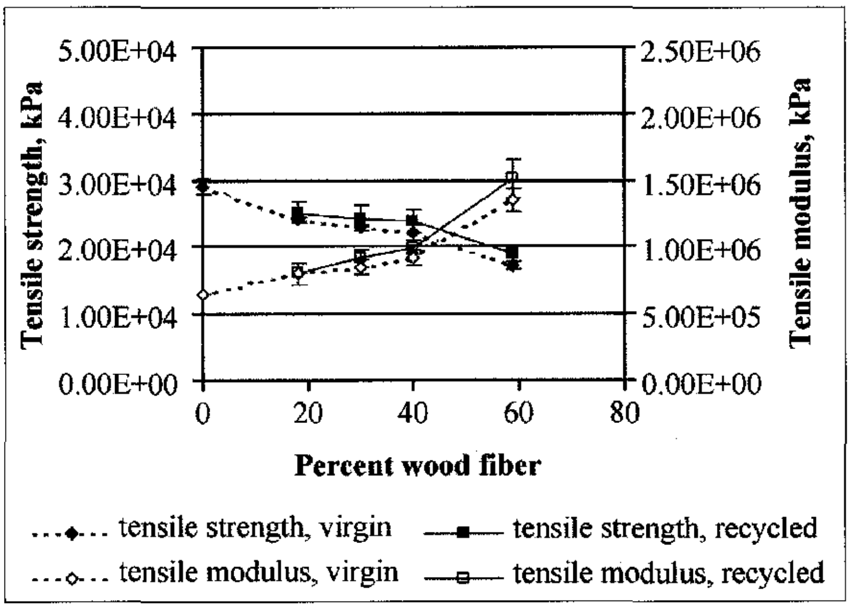

Figure 2.2: Comparison of tensile strength and young modulus of composites of virgin and recycle HDPE with wood fiber [14].

The problem in achieving true reinforcement for wood plastic composites is the inherent incompatibility between the hydrophilic fibers and the hydrophobic polymers. Poor composite strength results from poor adhesion and poor ability to transfer stress from the matrix to the reinforcing fibers [15]. So, the best method to solve this problem is by adding coupling agent (cross linking agent) to this composite. MAPE (malefic anhydride) be used as the coupling agent for plastic lumber that made from HDPE matrix. Function of coupling agent is to improve the adhesion between the cellulose chains in the fiber and the polymer matrix [7].

A study by Kamal *et. al* [14], proved that the composite material becomes stiffer with the addition of wood flour as shown in Figure 2.3. However, the corresponding strain at failure decreases with the increases of wood flour. In case of non-coupled composites, lack of intimate bonding between wood flour and HDPE lead to numerous irregularly shaped micro-voids or micro-flaws, resulting in poor transfer of stress from the matrix to the fibers.

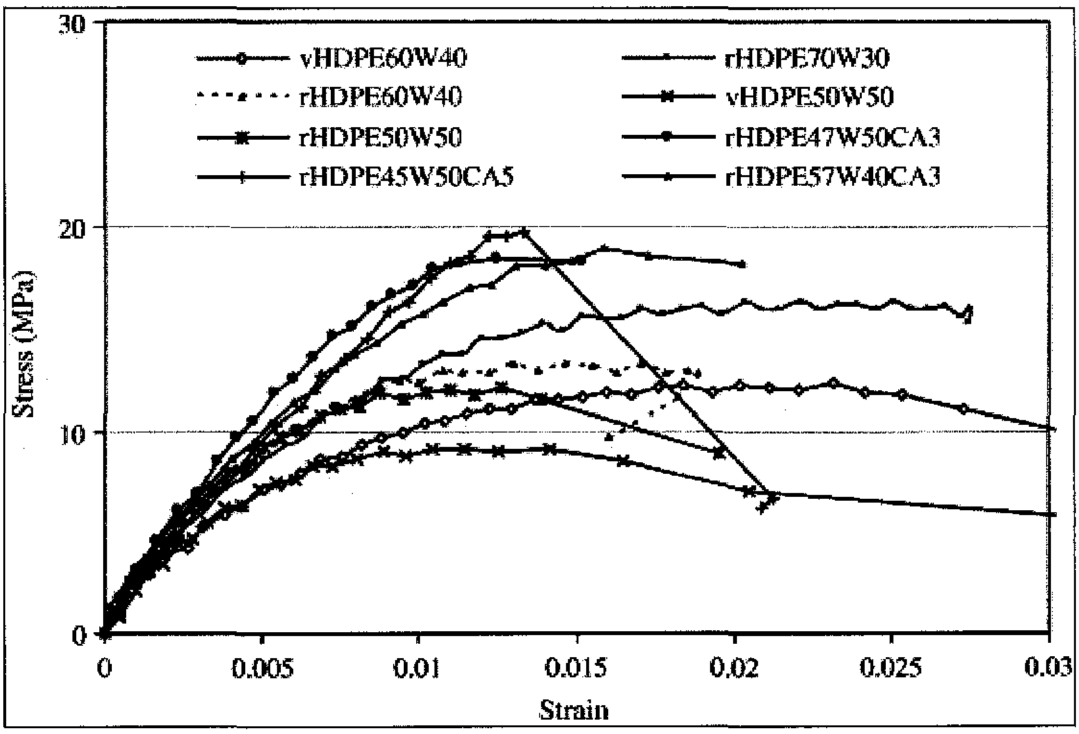

Figure 2.3: Tensile stress–strain curves of HDPE–wood flour composites [14]

2.4 Sawdust as Fiber

Natural-fiber reinforcement is the most important factor that natural affecting the composite mechanical properties. All cellulose based fillers for plastic lumber like sawdust are natural materials which containing cellulose, hemicelluloses, and lignin, shown in Figure 2.4. These three compositions can be explained as follows:

- Cellulose is highly regular structures, crystalline polymer, made up of thousand of glucose residues covalently bound "head to tail".
- Hemicelluloses form much shorter branched chain consisting of five and six carbon ring sugar. These chains play a role of amorphous soft fillers, wrapping cellulose regions.
- Lignin is phenol propane based amorphous solidified resin, filling the spaces between the polysaccharide fibers.

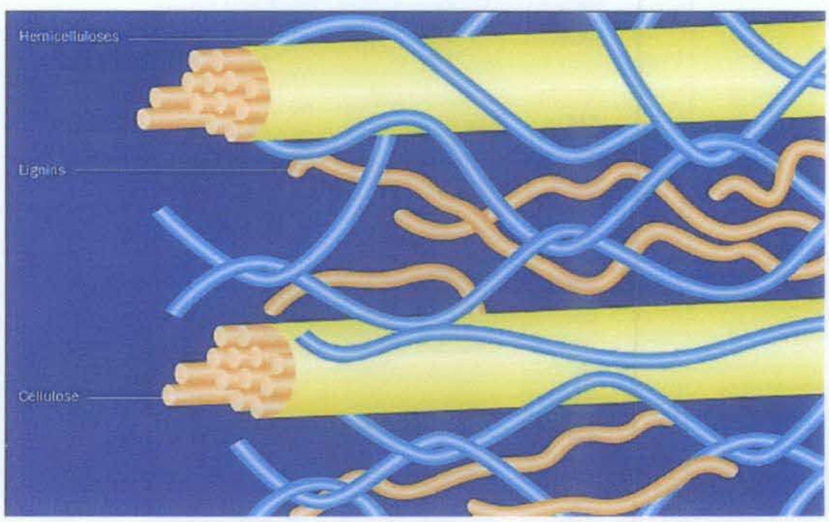

Figure 2.4: Schematic diagram of cellulose, hemicelluloses, and lignin.

Effect on mechanical properties of composite material, cellulose is the main components of wood flour that contributing to mechanical properties of wood plastic composites. Table 2.2 shows the flexural and tensile strengths as well as flexural and tensile moduli of various PP/wood flour compositions [16]. Flexural and tensile strength reached the maximum at 40% of wood flour.

Table 2.1: Flexural and tensile properties of polypropylene composites, filled with 40 mesh wood flour [16].

Wood flour in composite (%)	Flexural		Tensile	
	Strength (MPa)	Modulus (GPa)	Strength (MPa)	Modulus (GPa)
0	393.52	0.999	27.99	1.3
20	41.98	1.640	25.09	2.0
30	42.98	2.599	24.99	3.2
40	43.98	3.199	25.51	3.8
50	42.05	3.750	22.99	4.2
60	37.99	4.102	19.99	4.6

Lignin is a highly polymeric material, cross linked, highly aromatic structure. Lignin is considered to be largely responsible for strength and durability of wood [10]. In fact, trees stand upright because of lignin support their integrity. Typically, wood begins to undergo some dehydration at temperatures at the HDPE melting point of 110°C to 130°C. Lignin begins to thermally degraded at about 150°C and hemicelluloses degraded at 160°C [10]. All these process releases volatiles, which increase porosity and reduce density of the resulting composite material, unless vented extruders are used.

Saw dust is a recycled wood wastes which act as the reinforcement for this wood plastic composite. Selection of wood species like softwood or hardwood has a significant influence on the microstructure and properties of plastic lumber [17]. There are several distinct differences in the chemical composition of hardwood and softwood, as shown in Table 2.3 [18].

Table 2.3: Chemical composition of both softwoods and hardwoods [18].

Tree Type	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Hardwood	40-44	15-35	18-25
Softwood	40-44	20-32	25-35

However, for plastic lumber fabrication the sawdust should be ground to fine flour. When fine sawdust is used, the sawdust reinforcement to the plastic is not through individual fiber but through particulates consisting of broken fiber bundles of wood. [18]. A study done on hot-press moulded composites based on a combination of v-HDPE and r-HDPE, and pine wood flakes found that the initial particle geometry of HDPE played an important role in the quality of the composites [19]. Previous study on construction wood plastic composites proved that smaller size wood particles improved water absorption and thickness swelling [19].

2.5 Extrusion Process

Twin screw extruder is widely used in industries due to its high capacity and good performance. Measuring polymer melt temperature in polymer processing equipment is not an easy task due to the fact that the mechanism of flow and heat transfer are very complex, and they affected by one another [20]. The barrel temperature and speed of the screw need to be controlled since high temperature can burn the saw dust and degraded the HDPE [21], [22]. The barrel is equipped with a twin screw that blends the pallets convey them through the barrel towards the die. The internal friction from the mechanical action of the screw heats the pallets and liquifies them [22]. The screw has three distinct sections that are feed section, melt section and metering or pumping section

CHAPTER 3

METHODOLOGY

3.1 Project Planning

The project planning can be generally divided into two parts, namely first semester and second semester. The literature review, experiment process preparation were the primary objectives for the first semester. Experimentation, testing, data collection and analysis were done in the second semester. The general project flow chart is illustrated in Figure 3.1. Milestone of the project is shown in Figure 3.2 and details of the timeline activities can be referred to Gantt chart in Appendix A1 and Appendix A 2.

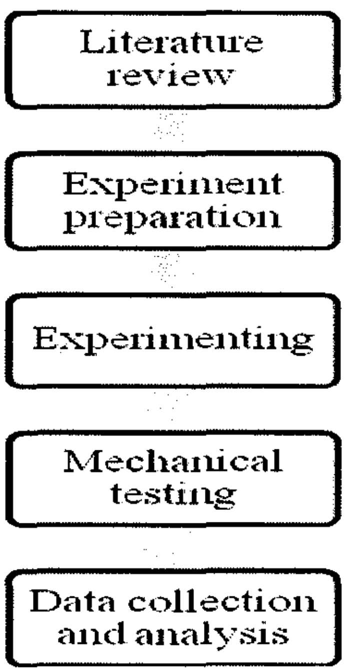

Figure 3.1: Overall project flow chart.

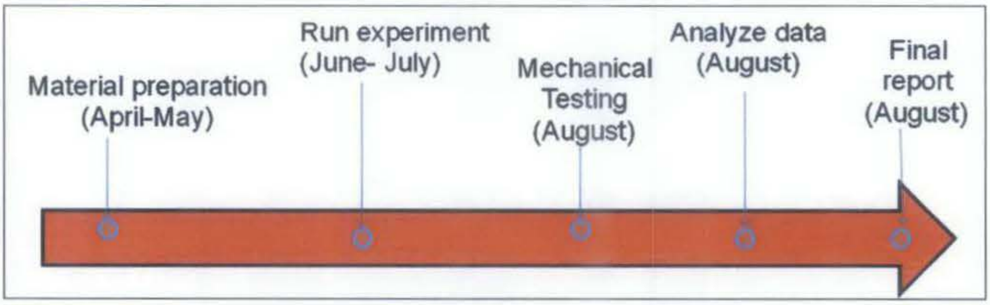

Figure 3.2: Milestone of the project.

3.2 Experiment

In this study, six different compositions were used. The composite fabrication was made through extrusion process and compression moulding. Then, the composite samples were tested for their mechanical performance referring to American Standard Testing and Materials (ASTM) standards.

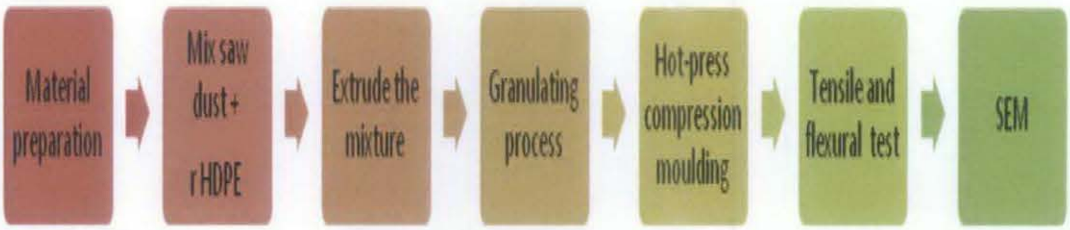

Figure 3.3: Flow chart of the experiment.

3.2.1 Material Preparation: Sawdust

Sawdust was collected from the local furniture factory. Then, the sawdust need to dry at 102°C for 24 hours in an oven. Before going through dry process, saw dust will be ground to fine flour by using grinder machine. After that, the sawdust been sieved and found that the size of the wood particles are in range between 63μm and 600 μm. Figure 3.4 shows the distribution size of wood particles from the sieved analysis. This sieved process also able to eliminate any unwanted particles like wood piece.

Dry process is to remove the moisture content because moisture in wood can create voids in the final product and thus adverse the mechanical properties affect. The average moisture content is between 2% - 3%.

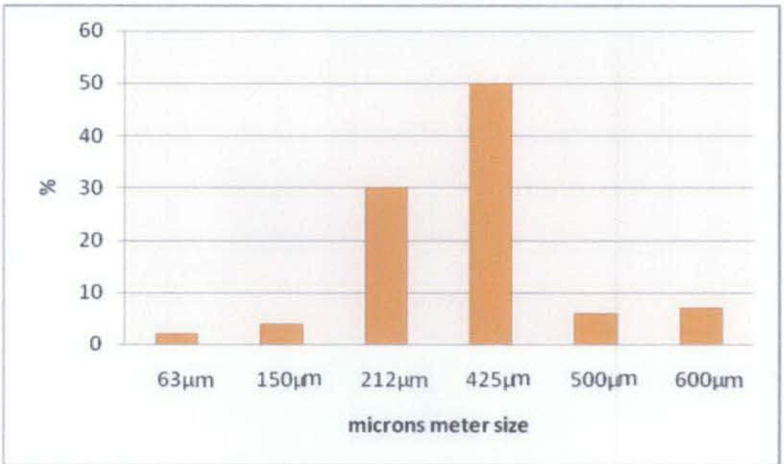

Figure 3.4: Size distribution of the sawdust.

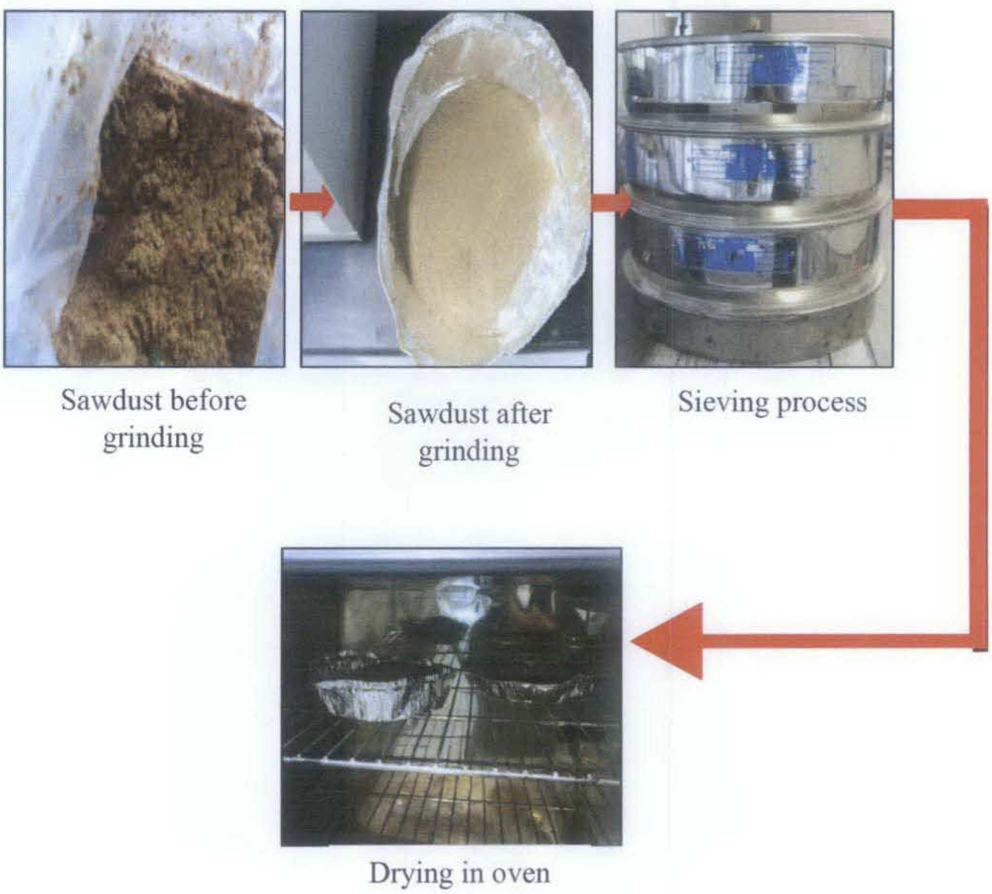

Figure 3.5: Flow of sawdust preparation.

3.2.2 Material Preparation: r-HDPE

Recycled HDPE that had been used in this experiment is from post-consumer bottles and collected around the campus. The recycled HDPE bottles were cut into small shape before granulating them by using granulator machine. They were thoroughly cleaned, washed, and dried at 65°C for 12 hours before mixing and compounding with sawdust in a twin-screw extruder.

r-HDPE drink bottles | Cut into small, washed, and dried | Granulated r-HDPE

Figure 3.6: Flow of r-HDPE preparation.

3.2.3 Extrusion Process for Composite Processing

After the sawdust and the r-HDPE had been dried, both materials were mixed in a plastic bag. Then, the mixture was compounded in the twin screw extruder (Leistritz ZSE-40) with screw diameter of 40 mm. The temperature profile ranged between 160°C and 180°C with screw speed 50 rpm. The extruded strand was palletized using Scheer palletizer machine. The formulations of the composition are given in Table 3.1.

Table 3.1: r-HDPE/sawdust composite formulations.

Composition sample	r HDPE content (wt%)	Sawdust (sw) content (wt%)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50

Figure 3.7: Flow of extrusion process.

The processing parameter also played an important role in determining the quality of the product and ultimately its properties. Table 3.2 is the best parameter found for the extruder machine. Figure 3.8 shows initial profiles obtained when the temperature parameter is insufficient cooling of the extrudate upon exiting the die which results into improper shapes. Meanwhile, Figure 3.9 shows profiles from the best parameter.

Table 3.2: Parameter at twin-screw extruder machine.

Parameter	
Melt temperature - zone 1& 2 (°C)	180
Melt temperature- Barrel 3, 4 5,6 & 7 (°C)	170
Melt temperature - flange & die (°C)	160
Screw speed (RPM)	50

Figure 3.8: Initial profile obtained.

Figure 3.9: Profile from the best parameter.

3.2.4 Compression Moulding For Composite Panel

Next, the compounded pallets were dried again at 100°C in oven for at least 12 hours to remove remaining moisture prior to compression moulding. The pallets were moulded in an electrically heated platen press by using an aluminium mould. The temperature for the upper and lower heater was set at 205°C, before placing the pallet-filled mould on the bottom platen. After the hot press, the mould with panel was moved to a cold press manually. Finally, the compression panels samples were cut according to specimen size for the tensile and flexural tests.

Figure 3.10: Flow of compression process.

3.2.5 Mechanical properties

Tensile tests were performed according to ASTM D638 with a crosshead speed of 5 mm/min. Five replicates were tested for each composite formulation. Figure 3.11 shows specimen type IV that was used for the test.

Figure 3.11 : Specimen type IV.

Flexural test were done according to ASTM D790 with a crosshead speed of 2.8 mm/min. Five replicates were also been tested and Figure 3.12 shows the shape of specimen for flexural test.

Figure 3.12: Specimen for flexural testing.

3.2.6 Scanning electron microscopy (SEM)

The fracture surfaces of the tensile test specimens were characterized with high resolution field emission scanning electron microscopy (FESEM). The FESEM was operated at an accelerating voltage of 2 kV. The scanning data were analyzed at magnifications of 100X. Approximately about 2 SEM images were taken and analyzed for each composite formulation.

3.3 Tools/Equipment required

The tools and equipment required in this study are cutting tools, digital humidity device, granulator machine, twin-screw extruder machine, grinder machine, compression moulding, universal testing machine, FESEM (refer to appendix B).

CHAPTER 4

RESULTS AND DISCUSSION

The effects of the sawdust loadings, mechanical properties and microstructure were investigated. The test results for the r-HDPE based composite were presented and discussed in this chapter.

4.1 Mechanical Properties

4.1.1 Tensile strength

Figure 4.1 shows the tensile strength of r-HDPE/sawdust composite. The graph shows a decreasing trend of tensile strength with increasing of sawdust content. At 10 wt% of sawdust, tensile strength was reducing by 14.3% compared to pure r-HDPE, while reduction of 23.5% was observed at 20 wt%.

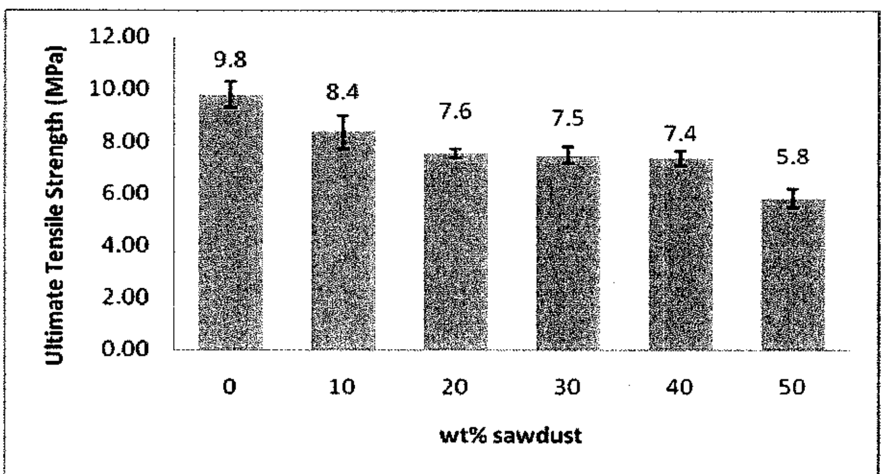

Figure 4.1: Ultimate tensile strength of the sawdust-HDPE composites.

Figure 4.2 (a) suggests that sawdust was fully bound by r-HDPE. The short fracture sawdust fiber for 10 wt% indicates that there is a strong interfacial bonding between sawdust and r-HDPE. However, fibers pull-out are quite visible with 20 wt% suggesting that the interfacial bonding between the reinforcement and matrix is weaken as shown in Figure 4.2 (b).

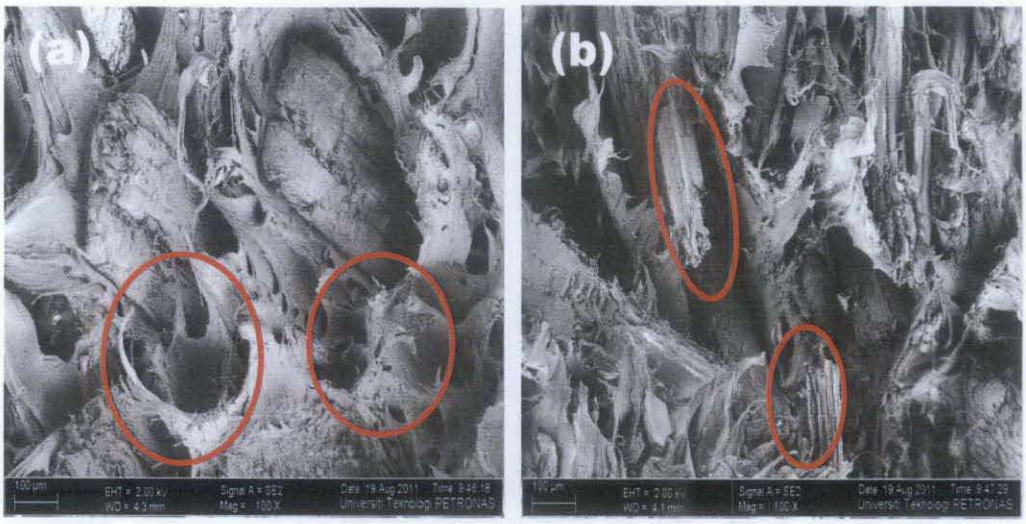

Figure 4.2: SEM image for (a) 10 wt% of sawdust , (b) 20 wt% of sawdust.

At 20 wt% to 40 wt%, the tensile strength reduction was quite constant, which can be explained by the similarity of SEM images of Figures 4.2 (b) and 4.3 (a). Further reduction of 40% was observed for 50 wt% of sawdust. Figure 4.3 (b) suggests that sawdust was not fully bound by the matrix, resulting in poor tensile strength. Therefore, the tensile strength trend is influenced by the interfacial bonding between sawdust and r-HDPE. The poor bonding between hydrophilic sawdust (fiber) and hydrophobic r-HDPE (polymer) obstructs the stress propagation and causes the tensile strength to decrease as the sawdust loadings increase [15], [23]. In addition, poor dispersion causes the agglomeration of fiber as well as decreasing the tensile strength [23].

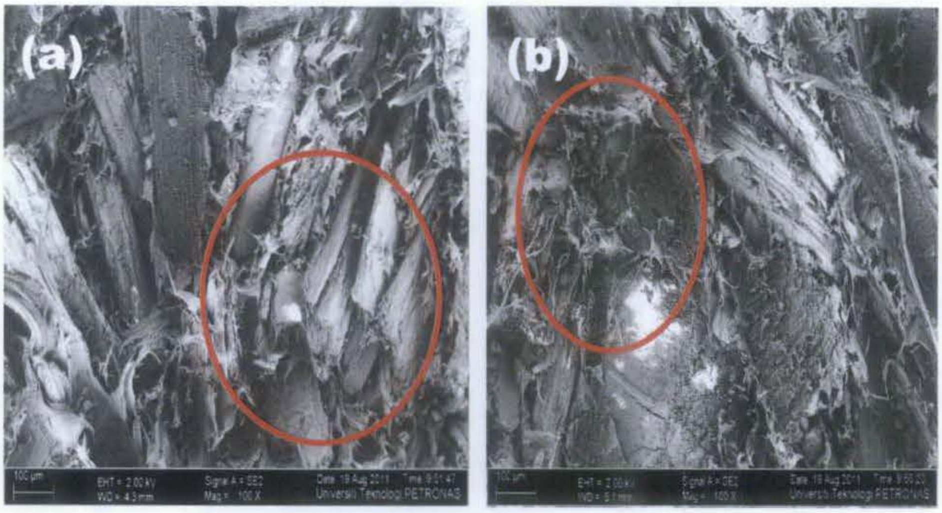

Figure 4.3: SEM image for (a) 40 wt% of sawdust , (b) 50 wt% of sawdust.

From the results gathered, the mechanical properties are governed by the bonding of r-HDPE and sawdust.Weak bonding between these two materials can be improved by using an appropriate coupling agent. This coupling agent will act as a bridge or glue between cellulose filler and polymer matrix. Providing better mechanical properties of the composite.

4.1.2 Flexural Properties

Figures 4.4 and 4.5 illustrate the flexural strength and modulus of r-HDPE/sawdust composites. The graphs show increasing trends of flexural strength and modulus with the increase of sawdust content. The maximum flexural strength and modulus were achieved at 40 wt% of sawdust, which were 46.0% and 58.9% improvements, respectively. Improvements in flexural properties suggest that the presence of sawdust as fillers has reduced the ductility of the composite and increased the stiffness.

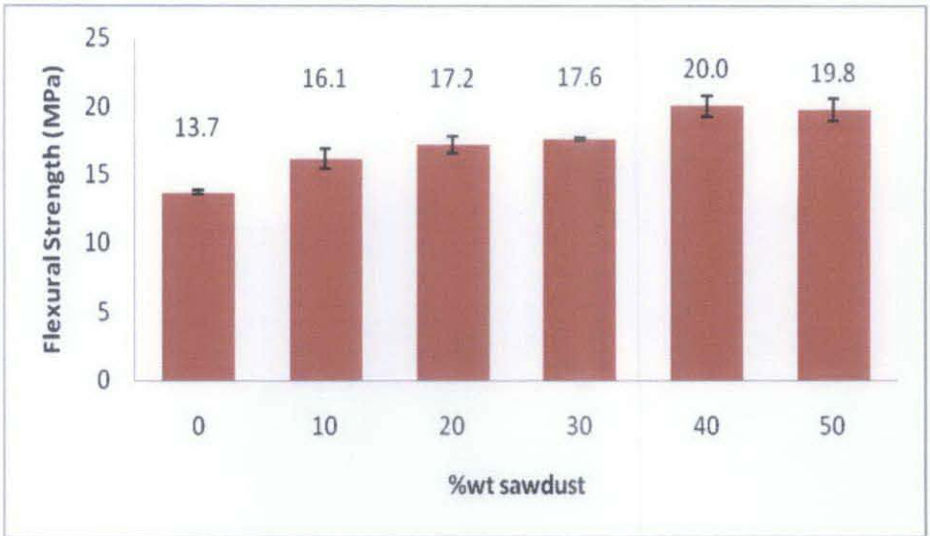

Figure 4.4: Flexural strength of the r-HDPE/sawdust composites.

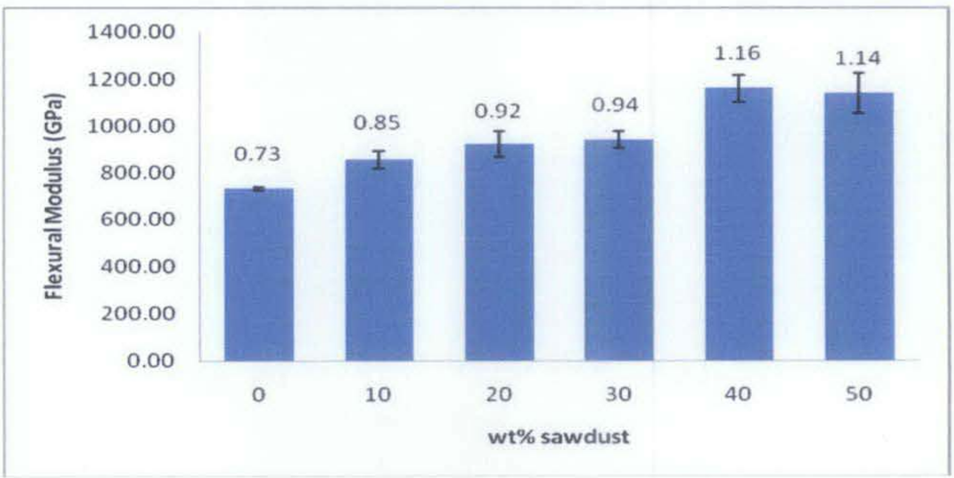

Figure 4.5: Flexural modulus of the r-HDPE/sawdust composites

Trend of these flexural properties is similar to the findings of Stark *et al.* [16] (please refer to Table 2.1 at Section 2.3). These fillers were added to restrain the movement of polymer chain, thereby increased the modulus. Higher in flexural strength proved the ability of this composite beam or slab to resist failure in bending.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn from this study:

- Plastic lumber was successfully fabricated by mixing recycled HDPE and sawdust.
- The effects of sawdust loadings on tensile and flexural properties of the composites were evaluated.
- The tensile strength trend decreased with the increase of sawdust loadings.
- However, an opposite trend for flexural strength and modulus of the composite was observed. Flexural strength and modulus of the composite increased with the increase of sawdust content.
- The best tensile strength was achieved with 10 wt% of sawdust, which translated to a reduction of 14.3% compared to pure r-HDPE.
- The maximum flexural strength and modulus were obtained with 40 wt% of sawdust content, which were 46.0% and 58.9% improvements, respectively.

5.2 Recommendations

As mentioned earlier, coupling agent like MAPE can be used to improve interfacial bonding between sawdust and r-HDPE, leading to mechanical property improvement. A study on the influence of MAPE on mechanical properties is recommended.

Another potential method to improve the mechanical properties of r-HDPE/sawdust composite is through fiber surface treatment. Three methods of fiber surface treatment consists of alkaline method (AM), silane method (SM), and alkaline followed by silane method (ASM) can be used to modify the wood fibers. Previous study [24] suggested that, wood plastic composite treated by the alkaline followed by silane surface treatment together with coupling agent (MAPE) gave the best mechanical properties among the three surface treatment method mentioned.

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Time line for Final Year Project I

No.	Detail/ Week	1	2	3	4	5	6	7	8	9		10	11	12	13	14
1	**Selection of Project Topic**										Mid-semester break					
2	**Preliminary Research Work**															
	- Preliminary report preparation															
3	**Submission of Preliminary Report**															
4	**Project Work**															
	- Conceptual study															
	- Design & drawing						Fri	Fri								
	- Progress report preparation															
5	**Submission of Progress Report**															
6	**Seminar (compulsory)**															
7	**Project work continues**															
	- Study the parameters influence															
	- Fabrication planning															
	- Material & tools preparation															
	- Interim report preparation															
8	**Submission of Interim Report Final Draft**															
	- Presentation preparation															
9	**Oral Presentation**															
	Final Semester Break															

● Mile stone — Preparation

Process — Done

APPENDIX A-1

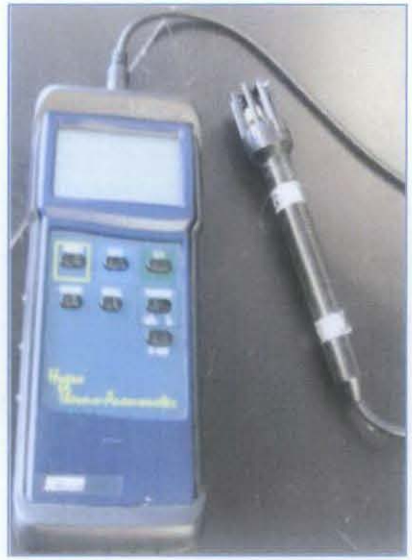
Time line for Final Year Project II

No.	Detail/ Week	1	2	3	4	5	6	7	8	9		10	11	12	13	14
1	**Design & Fabrication process**										Mid-semester break					
3	**Submission of Progress Report 1**															
4	**Testing & Experiment process**															
	- Experiment															
	- Data Gather															
	- Discussion															
5	**Submission of Progress Report 2**															
6	**Seminar (compulsory)**															
7	**Poster submission**															
8	**Work Cont. & Dissertation draft**															
9	**Oral Presentation**															
Final Semester Break																

APPENDIX A-2

APPENDIX B-1

Plastic scissor



Humidity device

Granulator

APPENDIX B-2

		
Grinder	Sieve plate	Oven

APPENDIX B-3

Twin screw extruder machine

Hot press- compression moulding