RICE HUSK FILLED THERMOPLASTIC COMPOSITE

By

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DEDICATION

DEAREST ALLAH....

HELP ME.......

To live this day......
Quietly, Easily

To lean upon Thy great strength.....
Trustfully, Restfully

To wait for the unfolding of Thy will....
Patiently, Serenely

To meet others....
Peacefully, Joyfully

To face tomorrow....
Confidently, Courageously

AMIN....!!!!

ACKNOWLEDGEMENTS

With the grace of ALLAH and his Messenger Prophet Muhammad S.A.W., may we always be under the guidance of the Almighty Allah S.W.T. and his Beloved Prophet Muhammad S.A.W. I would like to express my highest gratitude to ALLAH S.W.T.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BS	British Standard
df	Degree of Freedom
Elong	Elongation
IMP	Industrial Master Plan
MAPP	Maleated Anhydride Polypropylene
MIFF	Malaysian International Furniture Fair
MOE	Modulus of Elasticity
MOR	Modulus of Rapture
MPa	Mega Pascal
p	Probability
PP	Polypropylene
r	Correlation Coefficient
RH	Rice Husk
rpm	Revolution per Minute
SPSS	Statistical Package for Special Science
TEN	Tensile Strength
TMOE	Tensile Modulus of Elasticity
WA	Water Absorption

RICE HUSK FILLED THERMOPLASTIC COMPOSITE

By

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October 1999

A study was conducted on rice husk obtained from Bernas Kuala Selangor, to determine its suitability for thermoplastic manufactured and to determine its physical and mechanical properties. The rice husk and Polypropylene (PP) were blended in a Dispersion Mixer and then moulded into a composite in a mould, with the rice husk weight fractions varying from 10 to 50%. A maleated anhydride polypropylene was used to improve the interaction or poor bonding and adhesion between hydrophobic or non-polar matrix plastic and the polar or hydrophilic lignocellulosic fibers. Form the result; rice husk loading affected the physical and mechanical properties of the composite. Higher amount of rice husk decreased the strength and elongation, while the modulus of elasticity and water absorption properties increased significantly. Present of MAPP increased the strength, modulus of elasticity and elongation but decreased the water absorption significantly. There was little difference in the properties observed between composite with 1% and 3% MAPP (by weight). These results suggest that rice husk is a suitable material to be use in the manufacture of thermoplastic composite.

KOMPOSIT TERMOPLASTIK DARIPADA SEKAM PADI

Oleh

ARIFF MOHAMED

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Kajian yang telah dijalankan ke atas sekam padi yang diperolehi daripada Bernas Kuala Selangor untuk mementukan kesesuaian serta sifat-sifat fizikal dan mekanikal dalam komposit termoplastik. Sekam padi dan Polipropilena (PP) telah dicampur di dalam mesin penggaul dispersion dan kemudian komposit dihasilkan dengan menggunakan acuan, dengan berat sekam padi daripada 10 hingga 50%. Polipropelina anhidrid termalaet (MAPP) telah digunakan untuk meningkatkan tindak balas dalaman atau ikatan yang lemah dan perekatan diantara plastik yang takut air atau tak berpolar dan fiber yang berpolar atau suka air. Daripada keputusan, penambahan sekam padi memberi kesan kepada sifat fizikal dan mekanikal komposit. Penambahan sekam padi menurunkan kekuatan dan pemanjangan, manakala modulus kekenyalan dan kadar penyerapan air bertambah dengan ketara. Kehadiran MAPP menaikkan kekuatan, modulus kekenyalan dan pemanjangan tetapi menurunkan kadar penyerapan air dengan jelas. Keputusan mendedahkan bahawa sedikit perbezaan dalam sifat komposit diantara 1% dan 3% MAPP (berdasarkan berat). Keputusan ini menunjukkan bahawa sekam padi sesuai untuk digunakan dalam pembuatan komposit termoplastik.

CHAPTER I

INTRODUCTION

The fast maturing Malaysian furniture industry expands vigorously every year. It has been identified as a 'target industry' under the government's second Industrial Master Plan (IMP) for the period 1998 to 2005. The annual exports of the industry are targeted to hit RM6 billion (Anonymous, 1997).

For the past decade, the annual exports of Malaysian furniture rose from RM 27 million to more than RM 2 billion (Anonymous, 1997). Furniture industry is one of the major industries in Malaysia. In the year 1995, Malaysia exports about RM 2.288 billion worth of furniture and furniture parts. In 1998, the exported furniture and furniture parts increases to RM 4.362. This significant growth shows that the furniture industry is becoming important to Malaysian economy (Anonymous, 1999). Majority of furniture plant in Malaysia used solid wood or wood-based panel as the raw material. With the increasing number of furniture being produced, the volume of timber utilized also increases. It is forecast that the export will grow between 10-15% from 1996 to the year 2005. Malaysia is still about three-quarter covered by forest. Its forest resources allow for more growth, opportunities and accelerated development of the downstream industries.

Furniture manufactures invest RM300 million in research and development each year, assisted by tax incentives and protective regulations. The industry utilise the latest production technology and hence change its focus to produce higher quality and value added products catering to the medium and higher-end markets.

Malaysia is now ranked among the top exporting furniture nations in both the USA and Japan. The furniture makers of Malaysia can be assured that the increasing demand of locally produced furniture range determines that buyers are satisfied with the quality and value.

Supply of raw material for Malaysian furniture industries are depleting. Therefore development and research on new alternative raw materials and should be emphasized. Using low cost and non-commercial sources such as combination of plastic with lignocellulosic material (rice husk) to produce thermoplastic composite might provide alternative material for future manufacturing in the next millennium.

Technology, research and development can make this product more advantageous because of the enhanced properties both fibre and plastic. Direct or indirectly it can increase the number of product varieties in the Malaysia furniture industries.

The study was conducted with the following objectives;

i) To utilise rice husk as a raw material for polypropylene-rice husk thermoplastic composite

ii) To determine the effects of plastic ratio and MAPP addition on the physical and mechanical properties of rice husk thermoplastic composite.

iii) To develop products that can utilise recycled materials and have the products themselves be recyclable.

CHAPTER II

LITERATURE REVIEW

Research on Rice Husk

General Characteristics of Paddy in Malaysia

Paddy is in the same family with grass and wheat. The scientific name is *Oriza sativa*. Generally, the strip can reach six feet in height, straight, cylinder in shape, thin and have a hole in the middle. The strip can achieve more than 15 millimetres (Abdul Rahim, 1981).

Paddy is a crop suitable to be plated in tropical country (Abdul Rahim, 1981). The temperature must be more than 70^0F and the rain must be more than 60 inch per year. Besides then that, the sun plays an important growth for the paddy to grow and ripe. The weather in Malaysia is suitable with its high temperature and heavy rain.

There are two kinds of paddy commonly found in Malaysia that is lowland paddy and hill paddy. There are about 12 types of modern paddy. Nine officially released rice varieties, two popularly grown varieties and one semi-traditional variety (Husain, 1984). They differ widely with respect to physical, chemical, cooking and eating qualities (Husain, 1984). With these varieties of paddy, indirectly the rice husks volume increase from time to time. Rice growing environments in Malaysia consists of three types; upland, rain fed lowland, and irrigated lowland (Abdullah et al., 1991).

Today, Malaysia introduced two season of paddy plantation, the main season and the off- season. Main season is the period when paddy grown without depending wholly on any irrigation system. For administrative purposes, main season paddy is, which has a commencement date of planting between 1st August, and until 28/29 February of the following year. While, off-season is the dry period and paddy planting normally depends on an irrigation system. Off-season paddy is, which has the commencement date of planting 1st March until 31st July of the year (Anonymous, 1996). Now, the plantation of paddy is done continuously so indirectly the supply of rice husk is available all year round.

Rice and Rice Husk Production

In Malaysia, area of paddy plantation more than 0.6 hectares planted with paddy (Abdullah et al., 1991). In 1996 area of paddy field is 685, 468 hectares with production yield of about 2, 228, 489 metric tonnes producing 1, 438, 794 metric tonnes rice (Anonymous, 1996). With production mean of 3,251 kg/ha it can produce 650.2 kg/ha rice husks and in one year Malaysia can get 445,698 metric tonnes rice husk. Table 1 shows overall planted area, average yield, production of paddy, rice and rice husk in Malaysia.

Table 1: Overall Planted Area of Average Yield, Production of Paddy, Rice, and Rice Husk (1987-1996).

Year	**Area planted** (*Hectares*)	**Average yield** (*kg/ha*)	**Paddy production** (*Metric Tonnes*)	**Rice production** (*Metric Tonnes*)	**Rice husk** (*Metric Tonnes*)
1987	658,954	2,469	1,626,699	1,046,467	325,340
1988	671,755	2,525	1,696,239	1,091,478	339,248
1989	664,137	2,625	1,743,444	1,122,617	348,689
1990	680,647	2,769	1,884,984	1,215,065	376,997
1991	683,640	2,818	1,926,354	1,241,796	385,271
1992	672,753	2,992	2,012,732	1,297,914	402,546
1993	693,434	3,035	2,104,447	1,357,432	420,889
1994	698,624	3,061	2,138,788	1,378,945	427,758
1995	672,787	3,162	2,127,271	1,372,584	425,454
1996	685,468	3,251	2,228,489	1,438,794	445,698

Source: Paddy Statistic of Malaysia 1996

Rice Husk

Rice husks are agricultural residues that are available in fairly large quantities in one area and it is one of by products of the rice milling industry. Sustainable forest management is a continuous global challenge. The unassuming rice husk that has protected the staple food of more than half of the world's population could well be the answer to preserving the world's fast depleting forests in the years to come (Anonymous, 1998). Although national trade on this product is relatively minor, nevertheless rice husk is an important constituent of feedstuff (Ajimilah et al., 1985). The rice husk is the outer covering for the caryopsis (Marshall & Wadsworth, 1994). Rice husk are the larger milling by products of rice, constituting one-fifth of the paddy by weight (Beagle, 1978) and it comprises 18-20% by weight of the rough rice (Marshall, 1994).

Malaysia milling product of the local rice varieties constitute of 20-25% rice husk (Husain, 1984). Rice husks are a notable exception because those are stored ion the grain. The colour change when matured and green before mature. In this country, the sizes of rice husk fully depend on size of paddy and the mean of rice husk more than 5.2mm and sometime it can achieve more than 6.2mm.

Every year starting from late 1980's until now, the production of rice husk in Malaysia was over 300,000 million tonnes per annum. In early 1992 production of rice husk increase over 400,000 million tonnes until now. This statistics proof that this annual grass waste was sufficient as a raw material to produced composite board.

Rice husk comes to the mill at about an 8% moisture content level (Rowell et al., 1997). Rice husks are quite fibrous by nature and little energy input is required to prepare the husks for board manufacture. Rice husks have high silica content and to make quality boards, the inner and outer husks were separated and broken at their spine (Rowell et al., 1997).

Physical and Chemical Characteristic of Rice Husk

Generally rice is difficult to handle because of their silica-cellulose structural arrangements, which imparts peculiarities different from those of any other plant offal (Beagle, 1978). The physical peculiarities of rice husk make them difficult to store in outdoor piles. Rice husk is easily to drift by wind, and soaked by rain soaked and when decomposed, the piles can be set afire by spontaneous combustion. Dry storage is expensive because rice husk is of low density, and storage cost is very expensive. The size and shape of the rice husk also permit fluidity and ease of bulk handling. Table 2 shows the composition of rice husk.

Table 2: Composition of Rice Husk (% by weight)

Investigator	**Moisture**	**Ash**	**Protein**	**Fat**	**Fiber**	**Insoluble**
Borasio	10.30	18.20	3.10	0.90	42.80	17.20
Browne	8.97	18.29	3.50	0.49	41.89	17.24
Fraps	8.49	18.59	3.56	0.93	39.05	17.52
Grist	9.02	17.14	3.27	1.18	35.68	-
Joachim	11.35	17.43	3.90	1.26	40.22	-
Morrison	-	19.1	3.0	0.8	40.7	-
Morse	7.08	25.51	2.37	0.24	42.23	-
Possenti	10.3	18.2	-	-	-	-
Reed	7.91	19.54	2.66	0.80	41.29	-
Ross	8.27	13.85	2.89	0.85	38.15	-
Wise	6.62	18.70	2.56	0.50	35.99	-

***Source*:** Beagle. E. C. 1978. Rice-Husk Conversion to Energy.

Usage of Rice Husk

Rice husk reported to be suitable for making ceiling boards (Ajiwe et al, 1998), rice husk particleboard (Anonymous, 1998), cement board and other products (Beagle, 1978; Rowell et al., 1997; Anonymous, 1998). They are also used in oil extraction particularly in Japan and India (Ajimilah et al, 1985), and in Malaysia it is used as fuel for process steam for parboiling.

Thermoplastic Composite

Introduction

Composite materials now play an important role in the daily lives of most people in industrialised societies. Several billion pounds of fillers and reinforcement were used annually in the plastic industry (Sanadi et al., 1997). Plastics were still evolving, still changing and improving as the 21st century approaches. Plastic are rigid and will maintain their shape under load at use temperature, but flow viscously during fabrication (Grulke, 1994). A thermoplastic can defined as any material that softens when heated and hardness when cooled. The composite material can be defined as a microscopic combination of two or more distinct materials (Reinhart & Clements, 1984) or it can be defines as any combination of two or more materials, in any form, and any use (English et al., 1994) or combinations of two or more materials with properties that the component materials do not have by themselves (Rosato, 1993).

Thermoplastic selected for use with lignocellulosics must melt at or below the degradation point of the lignocellulosic component, normally 200-220^{0}C (Sanadi et al., 1997). Processing temperatures (>200^{0}C) reduces viscosity and do not facilitate good mixing cannot be used; however it is possible to use higher temperature for short periods. Thermoplastic matrices were normally used with short fibre reinforcement for applications in products made by injection moulding (Hull, 1981). The feedstock is usually in the form of pellets that contain the short fibres, typically 1-3 mm long, intimately mixed and dispersed in the matrix.

The use of annual growth lignocellulosic material as a reinforcing fillers is appealing, both because of the properties of the resultant polyolefin composites and because of the environmental viewpoint (Sanadi, 1994). The objective of composite development is to produce a product with performance characteristics that combine the positive attributes of each constituent component (English et al., 1994).

Thermoplastic composite can be divided into two classes. The first class is the long established group of mainly particulate-filled polymers in which the filler is present primarily as diluents, to reduce cost without too serious an effect on useful properties. Second class of composite is that of the reinforced engineering thermoplastic.

Advantages Uses of Annual Growth Lignocellulosic in Plastic

Material cost savings due to the incorporation of the relatively low cost agro-fibres and the higher filling levels possible, coupled with the advantages of being non-abrasive to the mixing and moulding equipment, were benefits that were not likely to be ignored by the plastics industry for use in the automotive, building, appliance and other applications (Sanadi et al., 1997).

The advantages of annual growth can divide into two primary advantages. The first situation is property advantages such as (1) low densities, (2) non-abrasiveness, (3) high filling levels possible resulting in high stiffness properties, (4) high specific properties, (5) easily recyclable, (6) unlike brittle fibres, the fibres will not fracture when processing over sharp curvatures, (7) generation of rural/agricultural-based economy (Sanadi et al., 1997 & Sanadi et al., 1995).

The second advantage is environmental and sosio-economic like (1) low cost, (2) low energy consumption, (3) low energy utilisation, (4) non food agricultural/farm based economy, (5) generates rural jobs, (6) biodegradable and (7) wide variety of fibres available throughout the world.

The use of some annual growth agricultural crop fibres has resulted in significant property advantages as compared to typical wood-based fillers/fibers such as wood flour, wood fibers, and recycled newspaper (Sanadi et al., 1997).

Potential Uses of Thermoplastic Composite

Fibre technology, high performance adhesives, and fibre modification can be used to manufacture structural lignocellulosic composite with uniform densities, durability in adverse environments, and high strength (Rowell et al., 1997). Plywood, hardboard, paper, particleboard, MDF, and chipboard were just a few examples of conventional composite products while non-conventional composite that combine wood fibers, flakes, particles, or lumber with other materials like plastic, cement, and gypsum. Combination of lignocellulosic/composite creates enormous opportunities to match product performance to end-use requirements (Youngquist, 1995).

Composites also find wide spread use in the industrial and agricultural sectors in term of tanks and pipes while in the electrical sector, composites were used for the manufacture of switch casings, junction boxes, cable and distribution cabinets etc. (Bowen, 1989). Thermoplastic composite also found use as filters, geotextiles, sorbents, packaging, non-structural composite, fibre products, building, appliance, automotive, exterior construction, toys, house wares, coatings and door application (Sanadi et al., 1997; Rowell, 1997; Youngquist, 1995; Grulke, 1994; Ulrich, 1993).

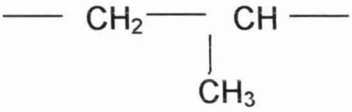
All types of agricultural residues like paper, yard waste, industrial fibre residues, residential fibre waste, and many other forms of waste lignocellulosic fibre can also be used to make property enhanced composite (Rowell et al., 1997).

Polypropylene as a Binder

The world annual consumption of Polypropylene is more than 7 million t/a (Domininghous, 1993) and the average rate increase in consumption is 7 to 8% per annum. G. Natta (1954) discovered Polypropylene and the first commercial production of polypropylene stared in

1959 (Roff et al., 1971; Ulrich, 1993; Domininghous, 1993). Polypropylene is the lightest of the major plastic, with a specific gravity of 0.90 g/cm^3 and a melting range of 165 to 170^{0}C. Polypropylene is made entirely by low-pressure processes, using Ziegler-Natta catalysts (aluminium alkyls and titanium halides) (Ulrich, 1993).

The basic structure is



$$-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-$$

Two types of polymers are made; by polymerisation of propylene, called homopolymers and those made by polymerisation of a mixture of propylene with small amount of ethylene, called copolymers. Copolymers have greater impact strength than homopolymers at low temperature. PP have many advantages; (1) lower density, (2) higher glass transaction temperature, (3) higher melting range, (4) propylene homopolymers is brittle in the cold but copolymers with ethylene are resistant to impact, (5) scarcely any tendency to stress cracking, (6) less resistance to oxidation, and (6) low cost (Domininghous, 1993; Ulrich, 1993).

Polypropylene is a visco elastic material and its mechanical properties depend on the basic parameters; temperature, stress, and time (Domininghous, 1993). PP with its non-polar nature is resistant to acids (except oxidizing acids), alkalis, salt solution, solvents, alcohol, water, fruit juice, milk, oil and fat at room temperature, and detergents. It has much less tendency to stress-crack formation compare other plastic like Polyurethane, however PP is not resistant to aromatic or chlorinated hydrocarbons such as benzene, and ligroin. PP does not serve as a nutrient for microorganisms and is consequently not attacked by them. Inherent advantages of polypropylene are the excellent chemical resistance, high melting point, good stiffness, adaptability to many converting methods, and low cost. Furthermore PP is easier to bond than PE.

Nowadays, the largest applications of PP are primary and secondary woven and non-woven uses, carpet backing face yarns, indoor and outdoor constructions, automotive interior mats and trunk linings and synthetic turf (Hanna, 1990). PP is a versatile material and because of that the end uses are divided into four categories, (i) injection moulded components such as automobile parts, sanitary equipment, domestic appliances, soil pipe systems, hospital equipment, footwear, storage trays, etc.; (ii) blow moulded articles, made from copolymers such as expansion tanks in sealed engine cooling systems, air ducts, tanks for chemical plant; (iii) extruded products such as sheets for chemical plant an lining tank, pipes for hot water, (iv) fibers like cordage, netting, blankets, carpets, brushes; (v) films such as packaging, unoriented, and biaxial oriented (Roff et al., 1971; Ulrich, 1993; Domininghous, 1993).

Maleated Anhydride Polypropylene as Compatibilizer

The adhesion between the plastic matrix and lignocellulosic fibers is important because it determines the properties of the composite. Several different types of coupling agents are used to improve the dispersion and the interaction between cellulosic-based fibers and plastic matrix (Sanadi et al., 1993; Krzysik and Youngquist, 1991; Sanadi et al., 1995).

Maleic anhydride (MA)-grafted polypropylene (MAPP) is the effective compatibilizer for lignocellulosic-PP system. Maleic anhydride (MA) was also important for obtaining strengthened composites (Shiraishi et al., 1989). The interactions between non-polar thermoplastic (PP) and coupling agents MAPP were predominantly chain entanglement (Sanadi et al, 1997). The MAPP also improved the water-resistant property (Krzysik and Youngquist, 1991).

The addition of coupling agents and compatibilizer helps in internal bonding or improve the inherently poor bonding between the hydrophilic wood filler and the hydrophobic polymer matrix and can help recover some of the impact strength (Youngquist, 1995). Normally, the level of MAPP is between 1 to 3%. A small amount of the MAPP (0.5% by weight) improved the flexural and tensile strength, tensile energy adsorption, failure strain, and un-notched impact strength (Sanadi et al., 1997; Sanadi et al, 1995; Krzysik, 1991; Kishi et al., 1988; Seong Han et al., 1989).

CHAPTER III

MATERIALS AND METHODS

Source of Materials

The rice husk from Paddy (Oriza sativa) was more than 5.2mm in length and was obtained from BERNAS (Beras Negara), Kuala Selangor. Thermoplastic material used was high-density polypropylene (HDPP) obtained from Titan PP Polymers (M) Sdn. Bhd. with a melting temperature of 190^0C. A maleic anhydride grafted polypropylene (MAPP) was used as a compatibilizer.

Methods

Processing of Thermoplastic Composite

The flow chart on the making of the thermoplastic can point is shown in figure 1. The rice husk moisture content was approximately about 8 percent. The rice husk was blended or compounded into PP using the Dispersion Mixture machine model 8038 twin screw at a temperature 190^0C. The dispersion mixer was run at a speed of 145 rpm for front rotor and 105 rpm for rear rotor. The power voltage used was 400V. Table 3 shows the ratio between rice husks, polypropylene, MAPP and table 4 shows the ratio for control test.

Table 3: The Ratio Between Rice Husk, Polypropylene and MAPP

Rice Husk (%)	Polypropylene (%)	MAPP (%)
10	90	0
30	70	0
50	50	0
10	90	1
30	70	1
50	50	1
10	90	3
30	71	3
50	50	3
0	100*	0

***Note**:* ** Control sample 100 PP*

Table 4: The Ratio for Control Test (control test)

Rice Husk (g)	Polypropylene (g)	MAPP (g)
100	900	0
300	700	0
500	500	0
100	900	10
300	700	10
500	500	10
100	900	30
300	700	30
500	500	30

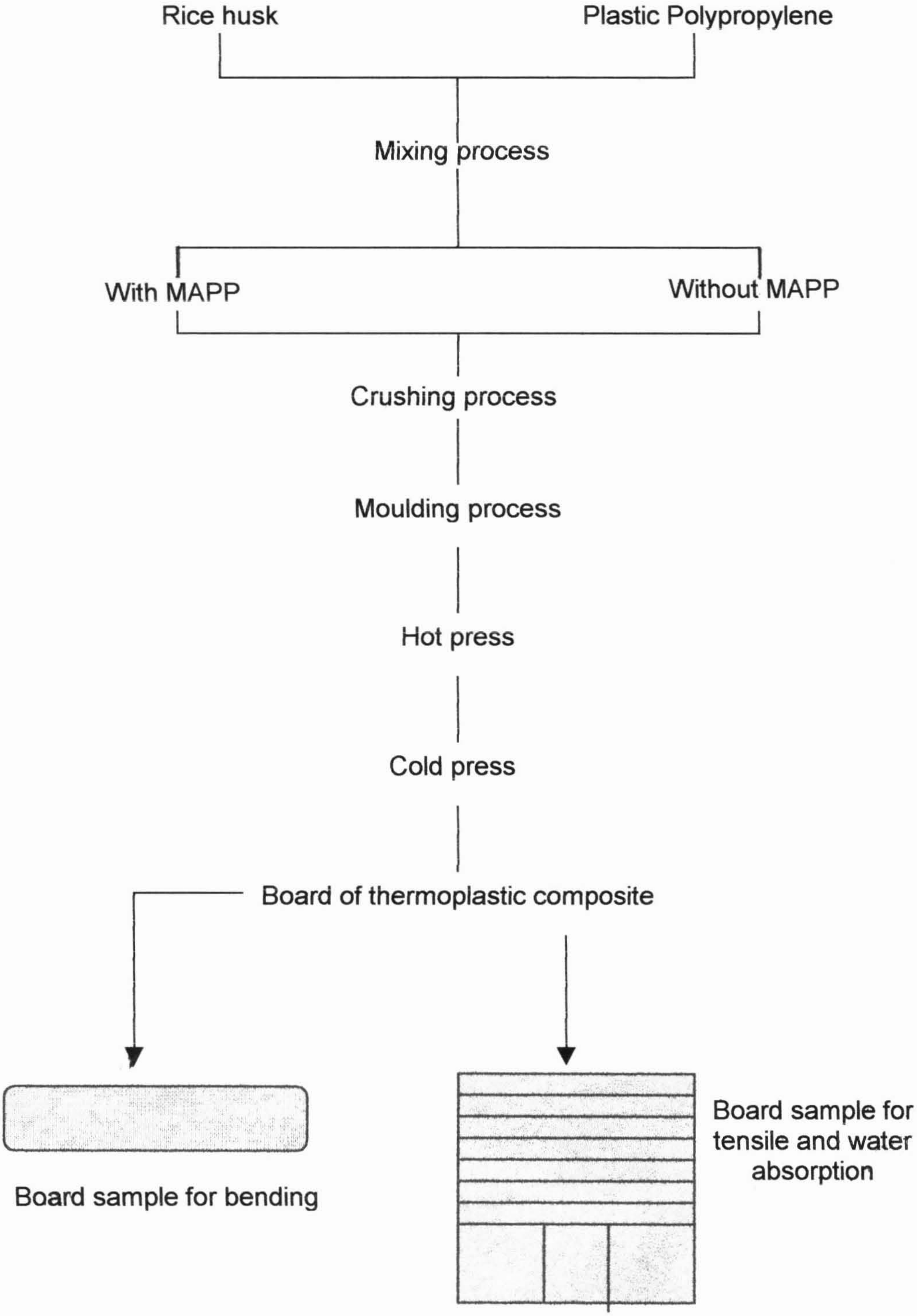


Figure 1: Flow Chart Making of Rice Husk Thermoplastic Composite

The polypropylene was first melted in the dispersion mixer. It was conducted for 35 minutes until they melted before the mixing process between PP and rice husk. For composite with compatibilizer, the coupling agent (MAPP) powder was first mixed with polypropylene before blending with rice husk. The purpose is to achieve an even consistency. Then the rice husk was put in the dispersion mixer. The mixing process was continued for an additional 30 minutes to make sure all rice husk mix completely with PP.

The temperature was maintained at $190^0C - 195^0C$ to ensure the PP pellets melted. Plate 1 shows the mixing process using Dispersion Mixer machine and table 5 and 6 shows overall mixing parameters and moulding parameters.

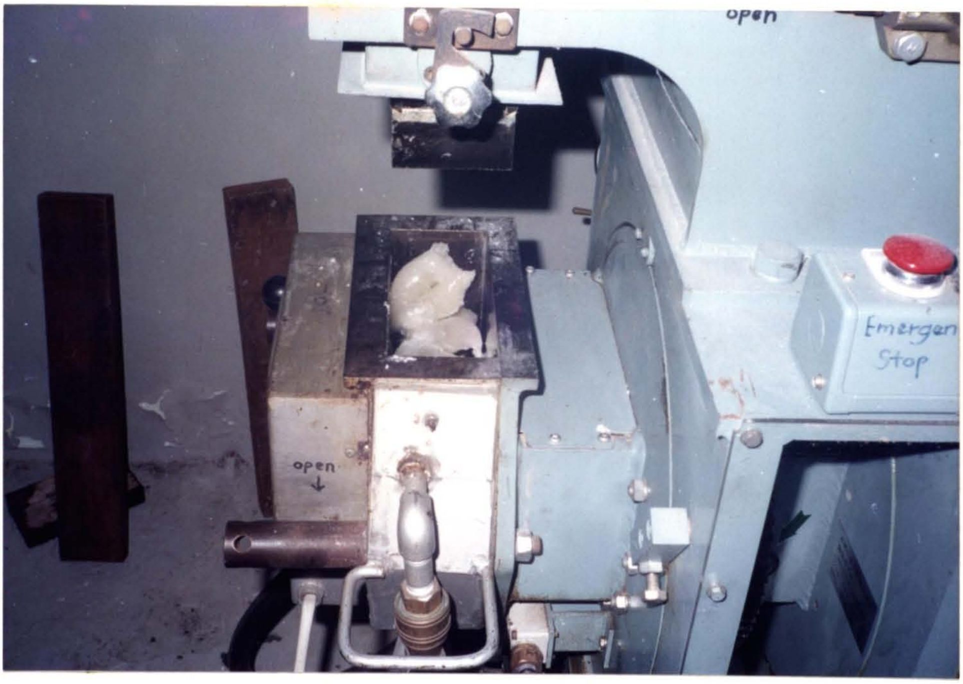


Plate 1: Mixing Process using Dispersion Mixer

Table 5: Mixing Process - Parameters of Dispersion Mixer Machine

Plastic Types	Plastic (%)	Plastic (g)	Rice Husk (%)	Rice Husk (g)	MAPP (%)	MAPP (g)	Speed/ Rear (rpm)	Speed/ Front (rpm)	Mixing Time (min)	Melting Time (min)	Temperature (^{0}C)	Weight after mixing (gram)
PP	90	900	10	100	0	0	105	145	30	35	190	858.00
	70	700	30	300	0	0	105	145	30	35	190	958.60
	50	500	50	500	0	0	105	145	30	35	190	947.40
	89	890	10	100	1	10.0	105	145	30	35	190	986.30
	69	690	30	300	1	10.1	105	145	30	35	190	966.00
	49	490	50	500	1	10.1	105	145	30	35	190	932.90
	87	870	10	100	3	30.2	105	145	30	35	190	986.40
	67	670	30	300	3	30.1	105	145	30	35	190	963.30
	47	470	50	500	3	30.2	105	145	30	35	190	939.50

Table 6: Moulding Process - Parameters of Hot Press Machine

Plastic Types	Plastic (%)	Plastic (g)	Rice Husk (%)	Rice Husk (g)	MAPP (%)	MAPP (g)	Material weight for Tensile (g)	Pressure (psi)	Material weight for Flexural (g)	Pressure (psi)	Temperature (^{0}C)	Pressing Time (min)/ Cooling Time
PP	90	900	10	100	0	0	70	1000	30	700	190	8-9/4-5
	70	700	30	300	0	0	70	1000	30	700	190	8-9/4-5
	50	500	50	500	0	0	70	1000	30	700	190	8-9/4-5
	100	1000	0	0	0	0	70	1000	30	700	190	8-9/4-5
	89	890	10	100	1	10	70	1000	30	700	190	8-9/4-5
	69	690	30	300	1	10	70	1000	30	700	190	8-9/4-5
	49	490	50	500	1	10	70	1000	30	700	190	8-9/4-5
	87	870	10	100	3	30	70	1000	30	700	190	8-9/4-5
	67	670	30	300	3	30	70	1000	30	700	190	8-9/4-5
	47	470	50	500	3	30	70	1000	30	700	190	8-9/4-5

The compounded sample was extracted out from dispersion mixer and roll with a metal cylinder into thin sheets before crushing process. Plate 2 shows the rolling process using metal cylinder.

Plate 2: Rolling into Thin Sheets.

Crusher Machine was use to crushed the thin sheets into granules. The time taken to crush the entire sample was about 5 minutes per batch. The function of this machine is to granulate into small pellets. Plate 3 shows the crushing process using Crushing Machine.

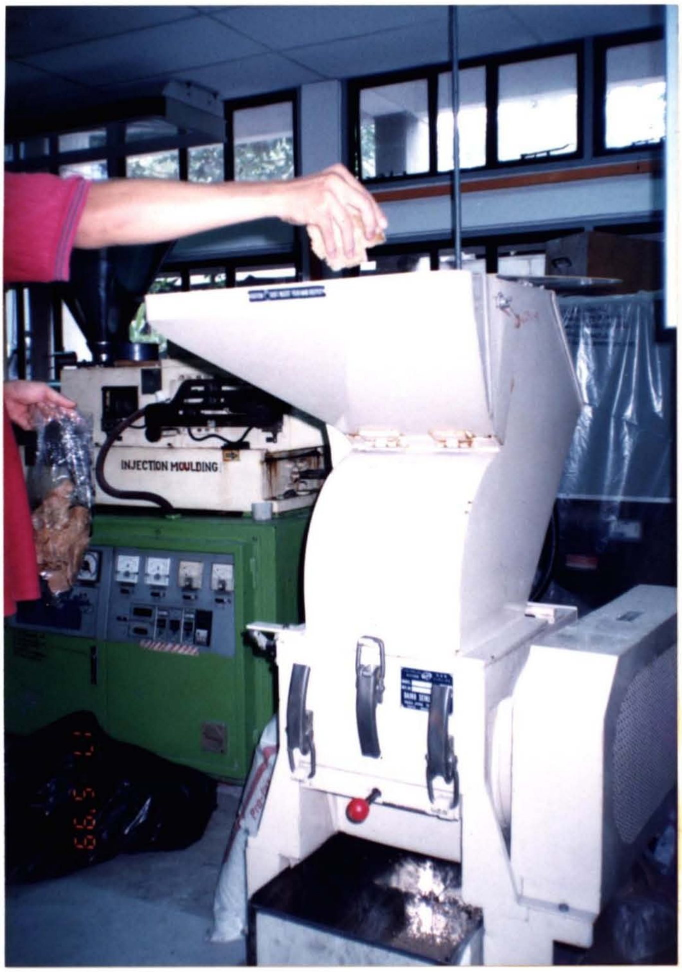


Plate 3: Crushing Process using Crushing Machine.

The small pellets were then moulded into sheets of plastic composite using a hot press. Time taken to mould was about 8-9 minutes and after the hot pressing the mould was cool down at cold press for another 4-5 minutes. Plate 4 and 5 shows the moulded sample after curing using hot press.

Plate 4: Thermoplastic Board After Curing (Tensile and Water Absorption sample)

Plate 5: Thermoplastic Board After Curing (Bending sample)

Composite Evaluation

Sample Cutting

Sample for bending was separately prepared using a mould of measuring 150 mm X 25 mm X 6 mm. Sample for water absorption and tensile was cut used small band saw where were available from ITM Furniture Laboratory, Shah Alam. Figure 2 shows the shape of sample for bending test and Figure 3 shows the shape of sample for tensile test and water absorption with the measure while Table 7 shows the experimental requirement of sample testing.

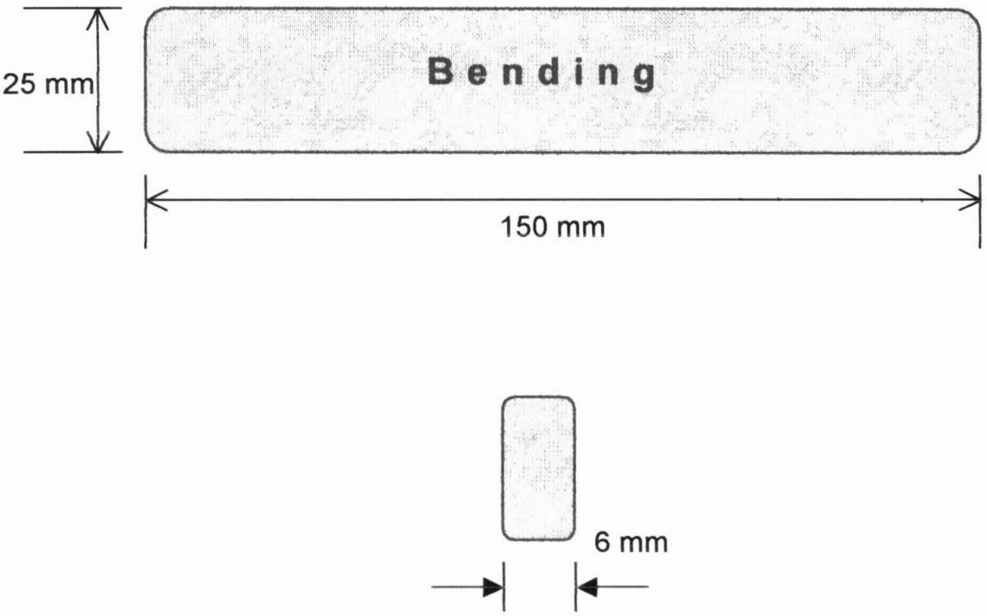


Figure 2: Shape of Sample for Bending Test

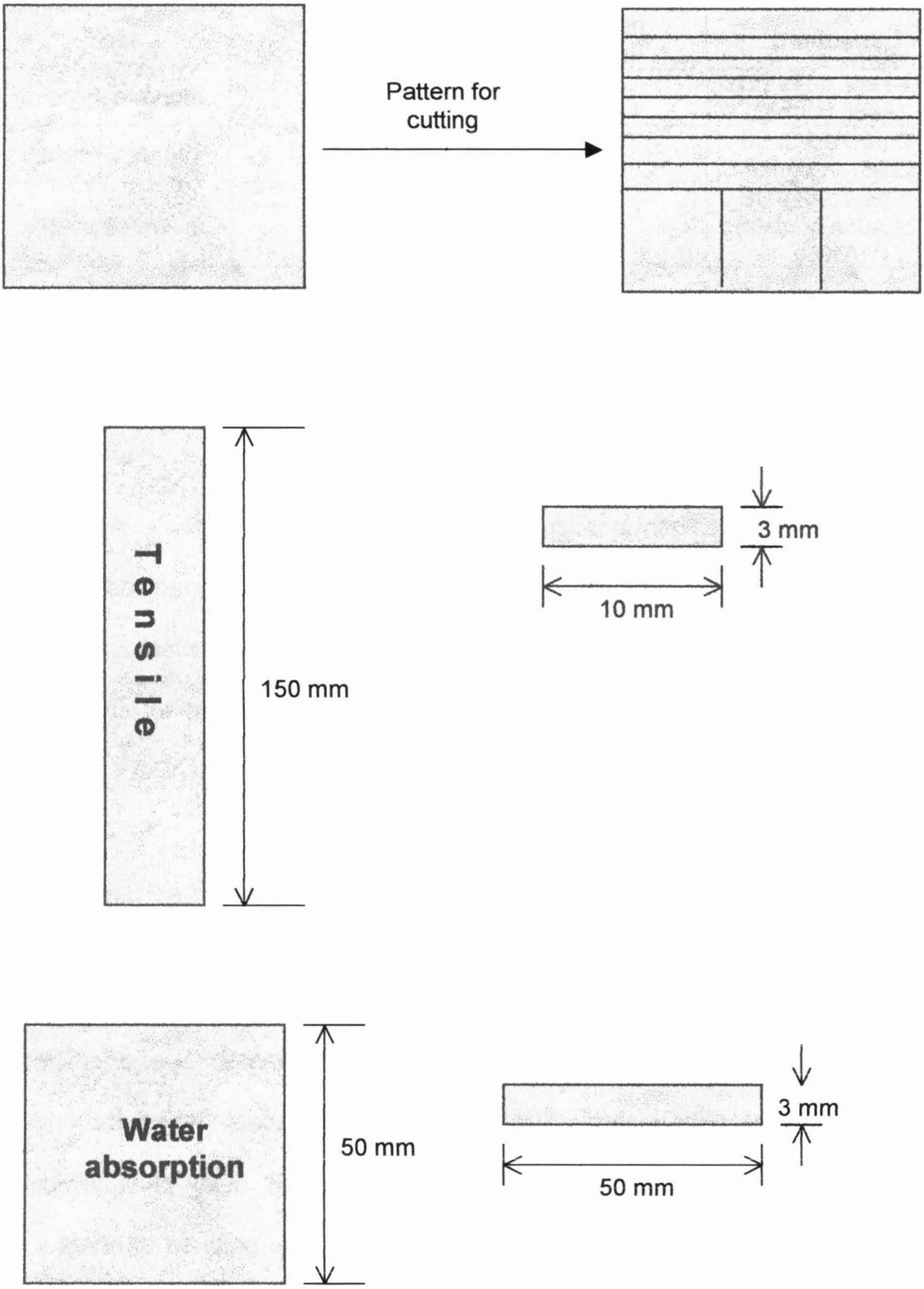


Figure 3: Shape of Sample for Tensile and Water Absorption Test

Table 7: The Experimental Design of Sample Testing.

Test	Specimen size (mm)	Specimen required	Standard
Bending strength	150 X 25	6	BS 2782: Part 3 (Method 335A)
Tensile strength	150 X 10	6	BS 2782: Part 3 (Method 321&322)
Water absorption	50 X 50	6	BS 2782: Part 4 (Method 430A to 430D)

Testing

There were three types of test in rice husk thermoplastic will be tested. There were bending strength, tensile strength and water absorption. All the specimens test will tested in condition 65% RH (relative humidity) at 27^0C. All specimens for tensile and bending test were tested at room temperature is around 27^0C.

Determination of Bending Strength

The method is used to investigate the flexural behaviour of the test specimens and determining the flexural strength. It applies to a freely supported beam, loaded at midspan until the deformation reaches some predetermined value. (BS 2782: Part 3: Method 335A: 1993 ISO 178: 1993) is a guide to bending test. This tests using Instron Testing Machine. Plate 6 shows the bending test.

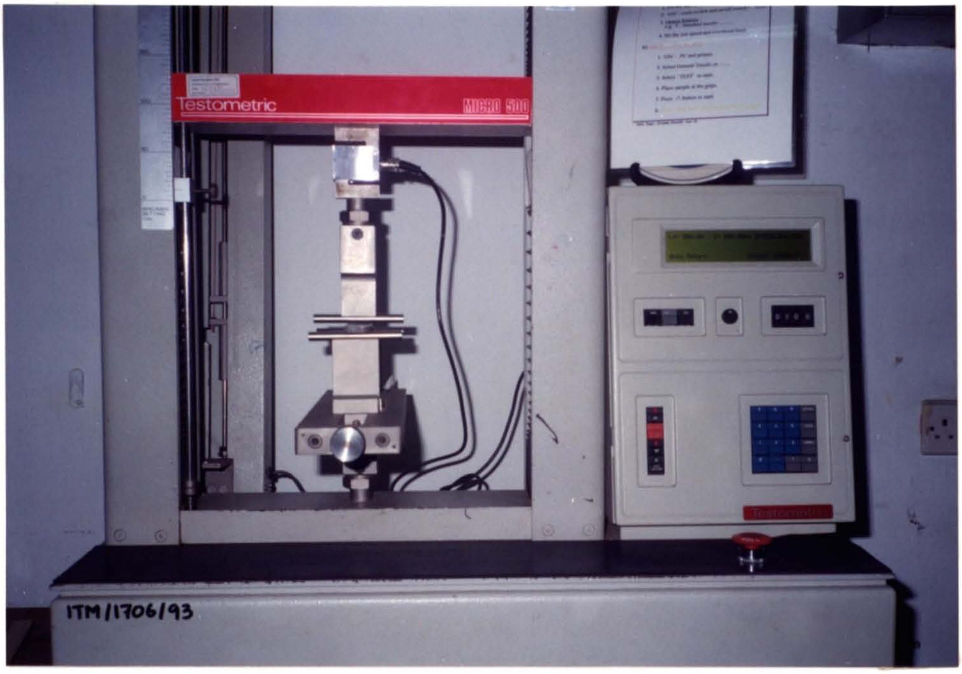


Plate 6: Bending Strength Testing

Test Specimens

The dimensions of the test specimens were obtained directly by moulding process. The estimate thickness *h*, $5 < h \leq 10$ mm, width *b*, 25 ± 1 mm, and length *l*, 150 ± 1 mm. The specimens must be free of twist and have mutually perpendicular parallel surfaces. The surfaces and edges shall be free from scratches, pits, sink mark and flash.

The specimens must be check for conformity with these requirements by visual observation against straightedges, squares and flat plates, and by measuring with micrometer caliper. Six specimens were tested in bending strength testing.

Procedure

The width *b* of the test specimens was measured to the nearest 0.1 mm and the thickness *h* to the nearest 0.11 mm in the centre of the test specimens. Both edges of each specimen were within 5.00 mm of each end of the gauge length. The mean thickness *h*, for the test of specimen is taken.

The span L was adjusted to comply with the following equation:

$L=(16 \pm 1)\ \overline{h}$ (mean) and measure the resulting span to the nearest 0.5%. The span L was used for blending test is 105 mm. The speed of testing is 10 mm/min.

The test specimens were placed symmetrically on the two supports and were applied with 1 N force at midspan. The force was automatically recorded and the corresponding deflection of the specimen during the test. The expression of the results was shown in Appendix A, table 11a to table 11j.

Determination of Tensile Strength

Tensile properties are the most important single indication strength in a material. The main principle is the test specimen is extended along its major longitudinal axis at constant speed. Testing should continue until the stress (load) or the strain (elongation) reaches some predetermined value. This method covers testing such as tensile stress, strain, and elongations at break and peak. BS 2782: Part 3: Method 321: 1994 ISO 527-1: 1993 and BS 2782: Part 3: Method 322: 1994 ISO 527-2: 1993 was a guide or procedure to tensile strength. This tests using Instron Testing Machine. Plate 7 shows the tensile test.

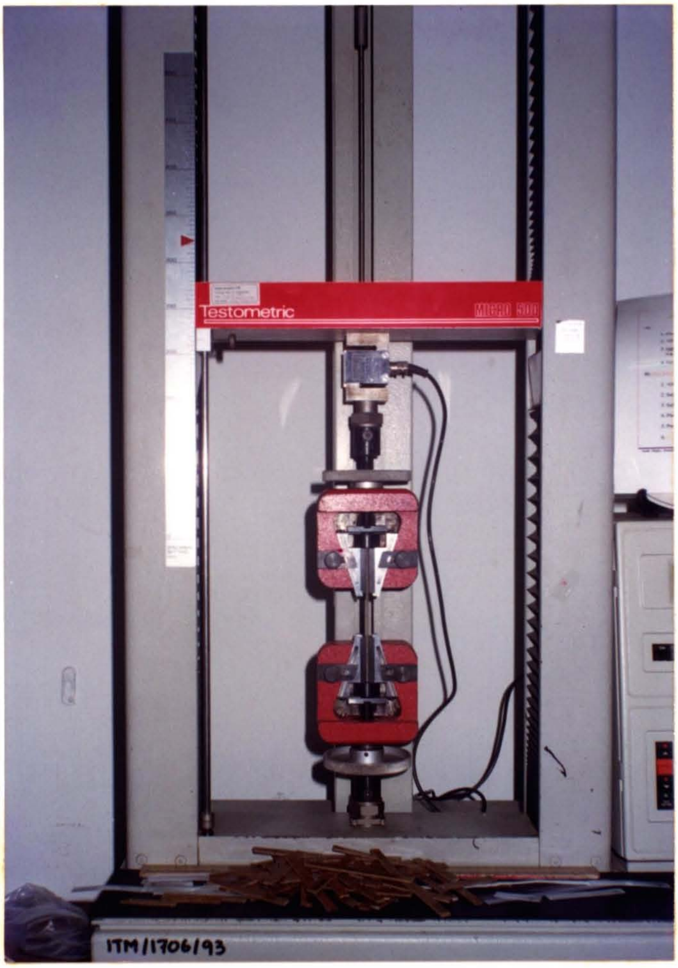


Plate 7: Tensile Strength Testing

Test specimens

The shape and dimension of test specimens for tensile strength is width b, 10.00 ± 0.05 mm width, thickness h, 3.00 ± 0.05 mm with the length of 150 ± 0.05mm. The tensile strength was tested based on strip. The specimen obtained was from board with the dimension is 150 mm X 150 mm X 3 mm where it cut to the desired shape and dimension. The gauge marks on the specimen were necessary to define the gauge length. These shall be approximately equidistant from the midpoint, and the distance between the marks was measured to an accuracy of 1%.

The specimen was free of twist and mutually perpendicular pairs of parallel surfaces. The surfaces and edges free from scratches, pits, sink marks and flash. The specimens were checked for conformity with these requirements by visual observation against straight edges, squares and flat plate, and with micrometer caliper. The number of test specimens that required for tensile strength test is six test specimens.

Procedure

Dimensions of test specimens were measured. The width *b* to the nearest 0.1 mm and the thickness *h* to the nearest 0.02 mm at the centre of each specimen and within 5mm each end of the gauge length. The test specimens were placed in the grips. The extensiometer was set and adjusted to the desired gauge length of the test specimen (50 mm of the gauge length of the test specimen). The speed of testing was 10 mm/min. The expression of the results was shown in Appendix B, table 12a to table 12j.

Determination of water absorption

Complete immersion test specimen of the plastic material in water for a specified period of time and at a specified temperature. Determination of changes in the mass of the test specimens after immersion in water and if required after elimination of the water by drying.

The water absorption may be expressed in the following ways; (1) as the mass of water absorbed, (2) as the water absorbed per unit of surface area and (3) as a percentage by mass of water absorbed with respect to the mass of the test. BS 2782: Part 4: Method 430A to 430D is a standard for water absorption. This test was used thickness dial gauge to measure the thickness after water absorption test. Plate 8 shows the water absorption test.

Plate 8: Water Absorption Testing

Test Specimens

Six specimens will be test. All specimens was cut by machining, cut surface should be smooth and shall not show any trace of charring that may be due to the method of preparation. Samples for the test have a diameter 50 ± 1 mm. The thickness of each specimen shall be same to relevant specifications. Dial gauge was used to measure the thickness of the test specimens.

Procedure

Specimens were dried for 24 ± 1 hour in the oven which controlled at 50 ± 2^0C, allowed to cool to ambient temperature in the desiccator and weight each specimen to the nearest 1mg. The volume of water used at least 8ml per square centimetre of the total surface of the test specimens, so as to avoid any extraction product becoming excessively concentrated in the water during the test.

After that place the specimens in a container containing water, controlled at 23^0C with a tolerance of ± 0.5^0C or ± 2^0C according to the relevant specification. Further more immersion for 24 ± 1 hour, take the specimens from the water and remove all surface water with a clean, dry cloth or with filter paper and re weight the specimens to the nearest 1 mg within 1 min of taking them from the water. The expression of the results was shown in Appendix C, table 13a to table 13j.

CHAPTER IV

RESULTS AND DISCUSSIONS

Properties of Rice Husk Thermoplastic Composite

Table 8 shows the mechanical and water absorption properties of rice husk thermoplastic composite produced at various plastic : rice husk ratio and maleated anhydride polypropylene (MAPP) addition.

Table 8: Mechanical and Water Absorption Properties of Rice Husk Thermoplastic Composite.

PP : RH (%)	MAPP (%)	Bending Strength		Tensile Strength			Water Absorption (%)
		MOE (N/mm^2)	MOR (N/mm^2)	TMOE (N/mm^2)	TEN (N/mm^2)	Elongation (mm)	
90 : 10	0	2088	46.39	2248	24.12	3.60	0.00
70 : 30	0	2228	34.13	2712	17.97	1.82	1.18
50 : 50	0	2686	30.07	2907	14.28	1.07	2.21
90 : 10	1	2094	46.80	2191	23.63	3.04	0.00
70 : 30	1	2627	39.69	2731	20.97	1.56	0.86
50 : 50	1	3256	35.76	3240	18.97	1.11	1.73
90 : 10	3	2109	48.11	2608	25.89	3.62	0.21
70 : 30	3	2711	40.90	2856	21.38	1.78	0.94
50 : 50	3	3124	32.70	3209	18.45	1.04	1.25
100*	-	1818	50.02	2307	35.98	10.43	0.00

Note: * Control sample – 100% PP, PP – Polypropylene, RH – Rice Husk, MAPP – Maleic Anhydride (MA)-Grafted Polypropylene. MOR – Modulus of Rapture, MOE – Modulus of Elasticity, TEN – Tensile strength, TMOE – Tensile Modulus of Elasticity

The MOE showed an increasing trend with rice husk addition with or without MAPP addition. With or without MAPP a higher amount of rice husk increased the modulus of elasticity (MOE) dramatically indicating that the thermoplastic composite are becoming stiffer. The highest MOE (3256 MPa) was shown by boards produced with a ratio of 50% rice husk and 1% MAPP while the lowest (2088 MPa) was produced by boards with 10% rice husk without MAPP. In general increasing the MAPP from 1 to 3% showed a general increasing trend in the MOE.

The MOR value of the thermoplastic composite produced with or without MAPP showed a general decreasing trend with higher amount of rice husk. The highest MOR (50.02 MPa) was shown by board produced from neat PP. With rice husk addition the highest MOR (48.11 MPa) was recorded by boards produced with 10% rice husk and 3% MAPP. The lowest MOR (30.07 MPa) was shown by boards made with 50% rice husk without MAPP. Generally a 3% MAPP addition gave better MOR value compared to boards produced with 1% or without MAPP.

For tensile strength test, a decreasing trend was also observed with rice husk addition. The highest tensile strength (TEN) value was shown by boards produced from neat PP (35.98 MPa). With rice husk and MAPP addition highest TEN was produced by boards with 10% rice husk and 3% MAPP while the lowest was from boards with 50% rice husk without MAPP.

An increasing trend in MOE was exhibited with rice husk and MAPP addition. Highest MOE (3240 MPa) was shown by boards with 50% rice husk and 1% MAPP while the lowest MOE (2191 MPa) by boards with 10% rice husk and 1% MAPP. In general higher amount of MAPP and rice husk showed an increase in the MOE value.

The elongation at break (Elong) showed a decreasing trend with rice husk addition. The highest Elong value was exhibited by the control sample with a value of 10.43%. When rice husk addition, the highest Elong value of 3.62% was shown by boards made with 10% rice husk and 3% MAPP. The lowest Elong was shown by boards with 50% rice husk and 3% MAPP. In general MAPP increased the Elong.

From the results shown in Table 8, boards made from 100% PP did not show any water absorption (WA). Water absorption also did not occur for boards produced with 90% PP without MAPP and 1% MAPP. However with addition of higher amount of rice husk a general increase in the WA properties was observed. Highest WA (2.21%) was shown by boards produced with 50% rice husk without MAPP and the lowest (0%) was exhibited by 10% without MAPP. In general the WA properties increased with higher amount of rice husk and MAPP addition.

Statistical Significance

Table 9 shows the summary of analysis of variance (ANOVA) on the properties of the rice husk thermoplastic composite. Results showed that the Ratio significantly ($p < 0.01$) affected the value of MOR, MOE, TEN, TMOE, Elong, and WA. MAPP addition also showed highly significant effect on MOR, MOE, TEN, TMOE and WA at the 1% probability level (except for Elong at 5% the probability level). The interaction effects between Ratio and MAPP significantly affected the MOR, MOE, Ten and WA at $p < 0.01$ probability level. However their effects on TMOE and Elong were not significant.

Table 9: Summary of ANOVA on The Properties of Rice Husk Thermoplastic Composite.

Source	**df**	**MOR (N/mm^2)**	**MOE (N/mm^2)**	**TEN (N/mm^2)**	**TMOE (N/mm^2)**	**Elong (mm)**	**WA (%)**
Ratio (R)	2	935.34**	3.8E6**	244.63**	2.7E6**	25.81**	12.43**
MAPP (M)	2	84.21**	6.2E5**	47.95**	3.3E5**	0.34*	0.55**
R X M	4	22.51**	1.6E5**	10.51**	1.1E5ns	0.18ns	0.54**

Note: df – degree of freedom, ns – significant at $p < 0.05$, * - significant at $p < 0.05$, ** - significant at $p < 0.01$. MOR – Modulus of Rapture, MOE – Modulus of Elasticity, TMOR – Tensile – Modulus of Elasticity, TEN – Tensile strength, WA – Water Absorption. Elong – Elongation at break

Effect of Rice Husk

Lignocellulosic/plastic composites can be used to fill a performance gap between unfilled thermoplastic and other conventional wood composites. When the rice husk ratio was increased from 10% to 50%, MOR and TEN decrease significantly. When the rice husk was increased from 10 to 50% the MOR, TEN properties decreased by about 30.27% and 29.45% respectively. Figure 4 showed the effects of rice husk on the strength. Correlation coefficients analysis (in Table 10) further revealed that MOR ($r = -0.87$ at $p < 0.01$) and TEN ($r = -0.84$ at $p < 0.01$) showed negative correlation with rice husk addition. The lignocellulosic filler increased the stiffness of the plastic but decreased the strength of the composite (Youngquist, 1995). Addition rice husk in plastic bonding system, it can disconnect that chain so the physically strengths of plastic become weak. The addition of coupling agents and compatibilizer helps improve the inherently poor bonding between the hydrophilic lignocellulosic filler and the hydrophobic polymer matrix and can help recover some of impact strength (Youngquist, 1995).

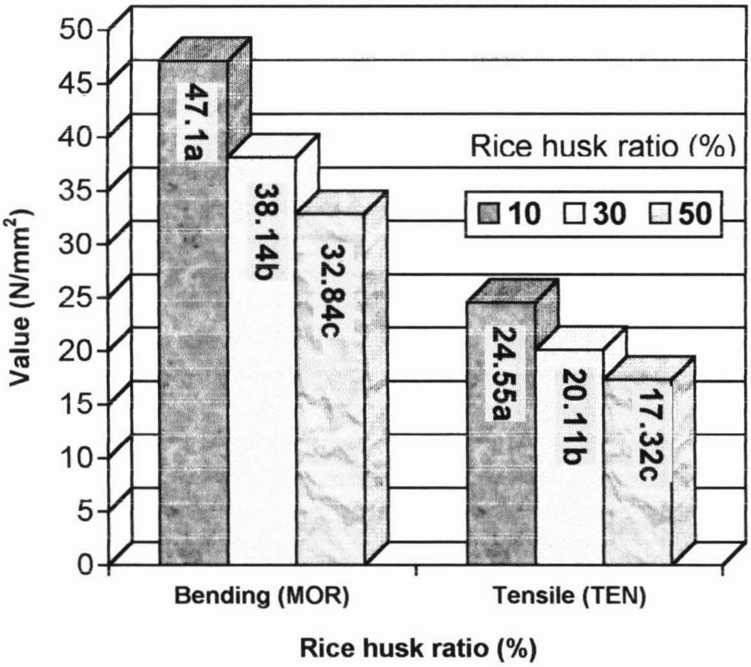


Figure 4: Effects of Rice Husk Addition on Bending and Tensile Strength

When the rice husk ratio was increased from 10% to 50%, MOE and TMOE increased significantly at $p < 0.05$ probability level. The increase in MOE and TMOE value are about 30.63% and 24.66%, respectively. The effects of rice husk on the modulus properties are shown in Figure 5. Correlation analysis (Table 10) further showed that MOE ($r = 0.87$ at $p < 0.01$) and TMOE ($r = 0.76$ at $p < 0.01$) have positive correlation with rice husk addition. The strength properties of a lignocellulosic composite can be greatly improved with an impregnated a monomer and polymerized or impregnated with a preformed polymer (Rowell, 1992). Higher strengths are likely if alternate processing techniques are developed that reduce the amount of fiber attraction while at the same time achieving good fiber dispersion.

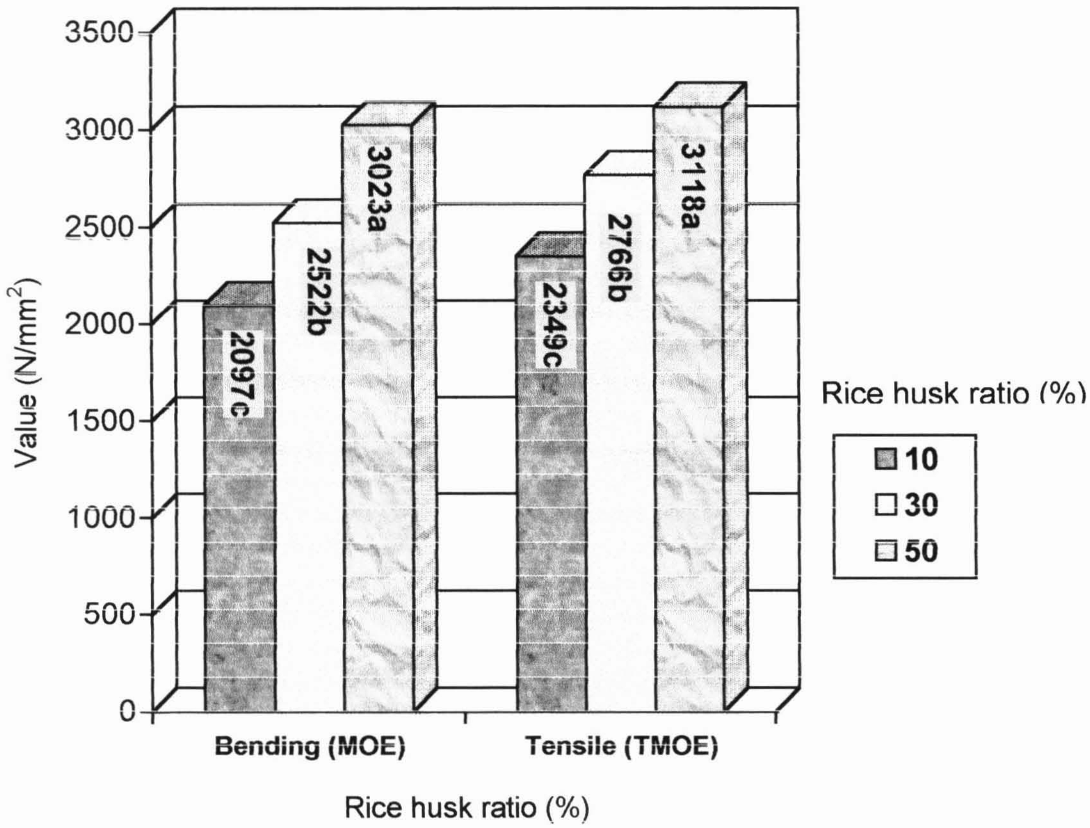


Figure 5: Effects of Rice Husk Addition on Bending and Tensile for Modulus of Elasticity

Figure 6 showed the effects of rice husk on the WA and Elong properties. Addition of rice husk into the composite showed that the elongation decreased while the WA increased significantly. When the rice husk addition was increased from 10 to 50% a decreased of about 68.44% in the Elong property was observed. When rice husk addition increased from 10% to 50% the water absorption increased by about 95.95%. Lignocellulosic material like rice husk is a hydrophilic material that way increases of rice husk addition the water absorption water absorption in lignocellulosic based composites can lead to a build up in the fibre cell wall and also in the fibre-matrix interphase region. Moisture build up in the cell could result fibre swelling and affect the dimensional stability (Sanadi et al., 1997). Good wetting of the fibre by the matrix and adequate fibre matrix bonding can decrease the rate and amount water absorption in the interphasial region of the composite. WA could be explained by the increase in surface are of the fillers, which are hygroscopic in nature. Elong is common observation in all filled polymer system and was probably due to the decreased deformability of a rigid intrephase between the filler and the matrix material. Increased in rice husk addition gave the plastic more brittle and it can make the board easy to break.

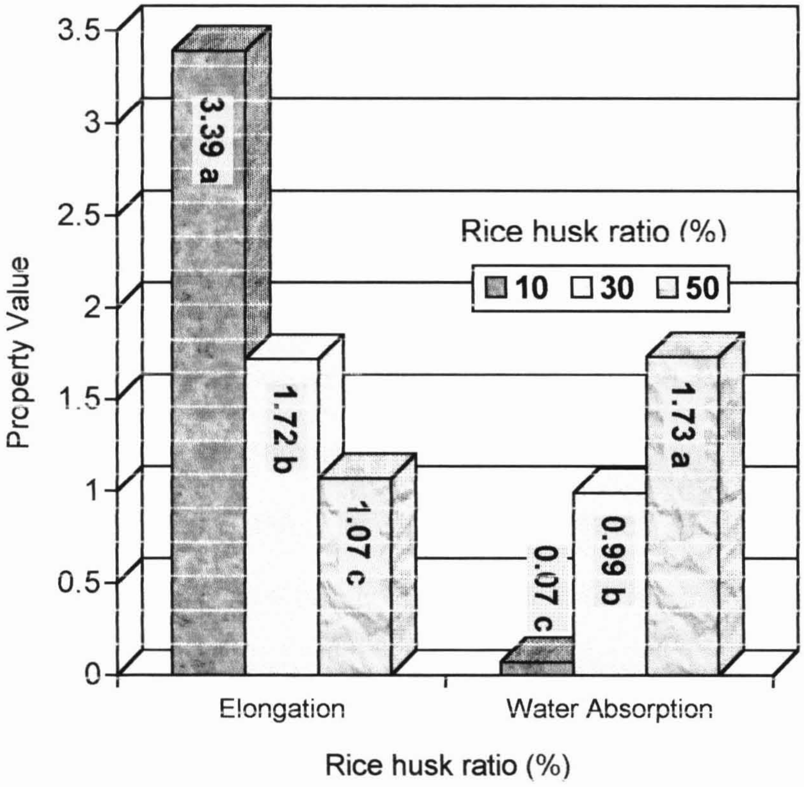


Figure 6: Effects of Rice Husk Addition on Elongation and Water Absorption

Effects of MAPP

According to Sanadi et al. (1997) a small amount of the MAPP (by weight) affects the flexural, tensile strength, and elongation of the rice husk composite. From Figure 7 the incorporation of MAPP resulted in a significant increase in MOR and TEN values (at $p < 0.05$ probability level). However there is no significant difference between the MOR properties obtained from 1 and 3% MAPP.

When the MAPP ratio was increased from 0 to 3%, MOR and TEN increase by about 9.14% and 14.24 %, respectively. The correlation analysis showed that the MOR ($r = 0.20$ at $p < 0.05$) and TEN ($r = 0.33$ at $p < 0.05$) have positive correlation with addition of MAPP. All of the filler systems will react in a similar fashion when no MAPP is used during the compounding stage (Jacobson et al., 1995). The addition of MAPP has the most amazing effect on the tensile strengths of agro-waste composites. The interaction between non-polar thermoplastic such as PP and any coupling agents such as MAPP are predominantly those chain entanglements. When polymer chains very short, there is little chain chance of entanglements between chains and they can easily slide past one another (Neilson, 1977) .The anhydride groups present in the MAPP can covalently bond to the hydroxyl groups of the fiber or lignocellulosics surface (Sanadi et al., 1997; Jacobson et al., 1995; Oksman, 1996). The improved interaction and adhesion between the fibers and the matrix leads to better matrix to fiber stress transfer.

The short fiber lengths thus limited the strengths obtained in our composites. Higher strengths are likely if alternate processing techniques are developed that reduce the amount of fiber attraction while at the same time achieving good fiber dispersion. As a result, strength properties of agro-waste composites can be improved with small additions of MAPP.

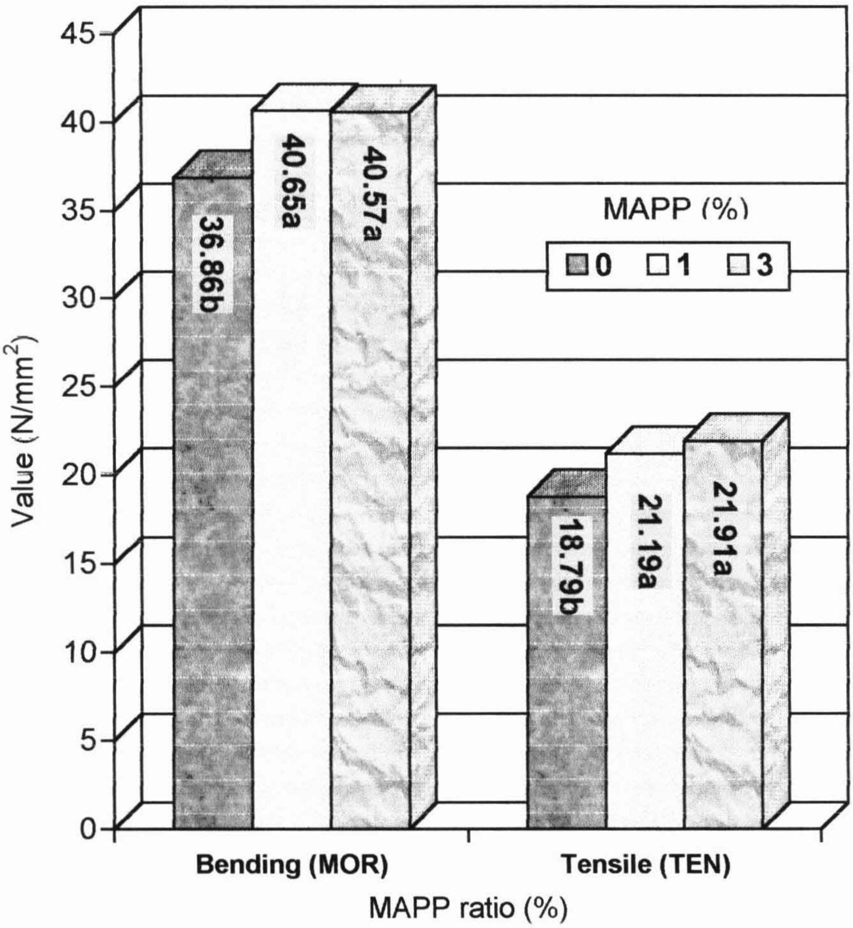


Figure 7: Effects of MAPP addition on Bending and Tensile Strength

The effects of MAPP on the modulus properties are shown in Figure 8. Increasing MAPP ratio from 0 to 3% showed that the MOE and TMOE increased significantly. The correlation analysis further revealed the MOE ($r = 0.26$ at $p < 0.05$) and TMOE ($r = 0.27$ at $p < 0.05$) have positive correlation with addition of MAPP. Increased adhesion between the lignocellulosics fibers and the matrix provides for increased stress transfer from the matrix to filler. This results in an increased stress at failure and the higher values for flexural strengths in the coupled systems verses un-coupled systems. Rice husk have flexural strengths slightly less than wood flour and talc filled composites. These systems still show an increase in flexural strengths.

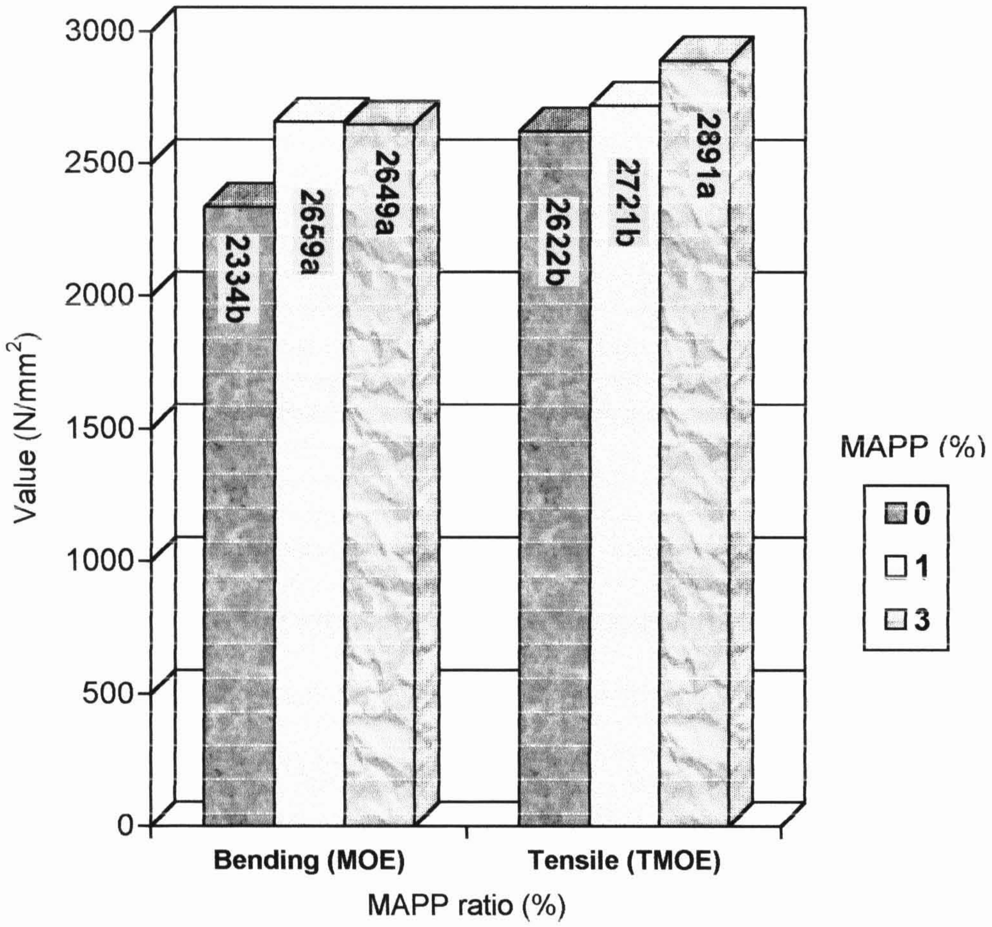


Figure 8: Effects of MAPP on Bending and Tensile Modulus of Elasticity

The effects of MAPP on the WA and Elong are shown in Figure 9. An increase in MAPP from 0% to 3%, WA increased while Elong was unaffected at p <0.05 probability level. The increment of MAPP on Elong from 0% to 3% does not showed any definite trend as revealed by the correlation coefficients of r = 0.02. However, 1% MAPP addition showed that the Elong decreased about 11.21%. For WA the correlation coefficient in Table 10 showed that it has a negative correlation with MAPP (r = -0.17 at p < 0.05) while the Elong (r = 0.02 at p < 0.05) was unaffected.

Table 10: Correlation Coefficients of the Effects of Ratio and MAPP on the Composite Properties.

Properties	**MOR**	**MOE**	**TEN**	**TMOE**	**ELONG**	**WA**
Ratio	-0.87**	0.87**	-0.84**	0.76**	-0.92**	0.90**
MAPP	0.20ns	0.26ns	0.33*	0.27ns	0.02ns	-0.17ns

Note: ns – significant at p < 0.05, * - significant at p < 0.01, ** - significant at p < 0.05. MOR – Modulus of rapture, MOE – Modulus of elasticity, TEN – Tensile strength, TMOE – Tensile Modulus of elasticity, WA – Water absorption.

Water absorption of lignocellulosic fiber composites is important characteristics that determine end use applications of these materials. Dimensional stability can be a great problem in composites made from high percentage of lignocellulosics. One noteworthy observation from the water soak experimental is that doubling the amount of polypropylene (that, is decreasing the amount of rice husk) approximately halved water absorption values. Dimensional stability (water absorption and Elong) can be greatly improved by bulking the lignocellulosic cell wall either with simple bonded chemicals or buy impregnation with water-soluble polymers

(Rowell and Youngs, 1981). As a result the polypropylene is encapsulating the lignocellulosic, thus limiting the Elong and water uptake by these fiber.

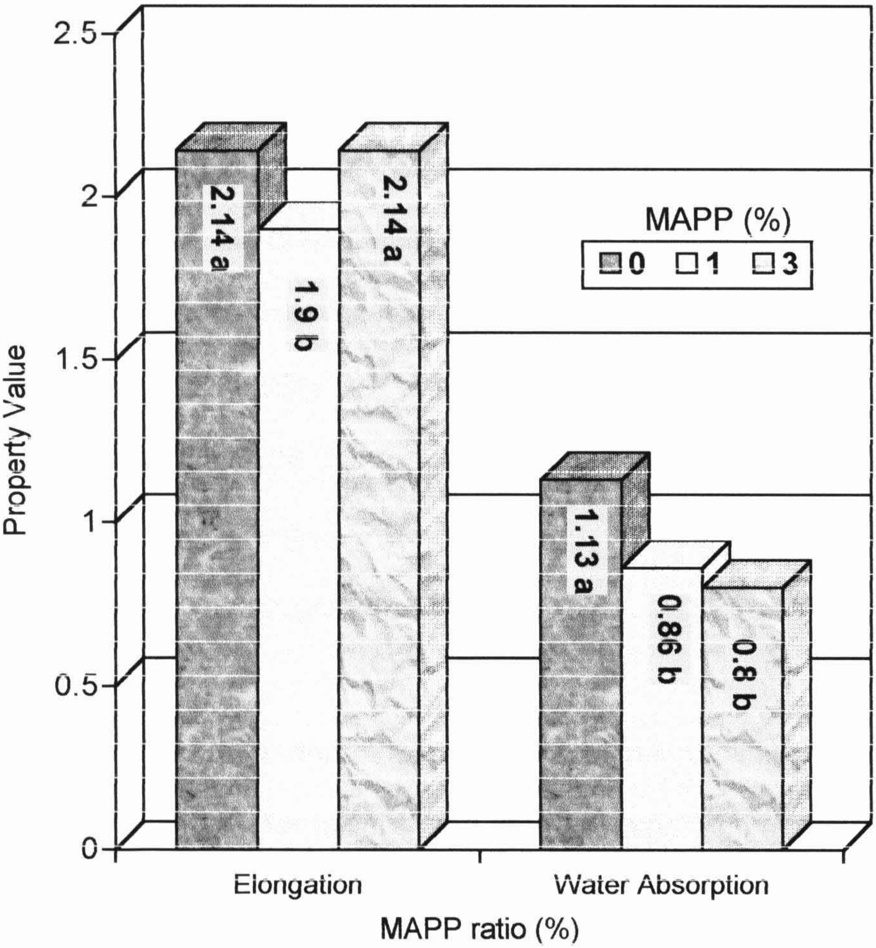


Figure 9: Effects of MAPP on Elongation and Water Absorption

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The costs of natural fibers are, in general, less than those of the plastic matrix in bio-based composites, and high fibre loading can result significant material cost savings. The main point out of the study was analysing the suitability of rice husk as a material for manufacture thermoplastic composite board and the mechanical and physical properties of rice husk. The effects of filler loading and MAPP addition on the thermoplastic board properties were analysed.

The rice husk thermoplastic composites exhibit higher values of modulus of elasticity for flexural and tensile strength compared 100% plastic material. Increasing amount of rice husk had a lower of tensile strength and un-stability of dimensional. Water absorption increases significant when increasing the amount of rice husk added while the addition of rice husk the value of elongation decrease compare to 100% plastic.

The addition of MAPP has the most effect on rice husk board properties. With the addition of a maleic anhydride grafted PP to rice husk composites, the tensile strength, flexural strength and MOE improve substantially over un-coupled systems. Increased adhesion between the lignocellulosic fibers and the matrix provides for increased stress transfer from the matrix to the filler. After analyses the effects of MAPP, the result shows that the water absorption decrease when increasing the MAPP addition. Small amount of MAPP (3% by weight) gave the lowest water absorption (0.8%). The MAPP addition gave effects on elongation. 3% MAPP by weight gave the best result compare 1% MAPP and the value of 3% MAPP is same with without MAPP. As a result, strength properties of agro-waste composites can be improved with small additions of MAPP.

Recommendations

1. The amount of filler loading should be small because rice husk have high silica content. Amount of filler loading effects the strength of plastic, thermoplastic composite from rice husk become brittle if the amount of rice husk is over the plastic ratio.

2. To make high quality thermoplastic composite, the rice husks have to be refine. This can accomplish by hammer milling or refining. Smaller sizes of rice husk can improved the mechanical and physical properties of rice husk thermoplastic composite board.

3. Maleated anhydride polypropylene (MAPP) must add when making rice husk thermoplastic composite because the MAPP increase the internal bonding. The small amount of MAPP also improved or increases the mechanical and physical properties.

4. Rice husk thermoplastic composite suitable for product did required strength and do not suitable for heavy construction and supported.

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APPENDICES

APPENDIX A: BENDING STRENGTH

Table 11a: Polypropylene Bending Strength – Standard Sample

Polypropylene: MAPP: Rice Husk (100: 0: 0)

mple No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	150.40	25.24	6.19	19.50	829.86	247.30	12.850	40.275	4.3288	1549.0	48.53	1866.58
2	150.32	25.06	6.22	19.72	841.63	259.20	18.339	42.107	6.2077	1390.6	50.03	1652.27
5	149.66	24.44	6.20	18.60	820.19	238.00	17.820	39.900	6.0127	1418.2	48.65	1729.11
6	149.84	24.98	6.20	19.76	808.39	275.30	18.183	39.608	6.5509	1335.9	49.00	1652.54
7	149.46	25.50	5.99	19.13	837.96	246.80	17.545	42.485	5.7194	1613.5	50.70	1925.51
9	149.98	25.00	6.16	18.81	804.39	257.70	17.377	42.785	5.8253	1675.5	53.19	2082.95
ean	149.94	25.04	6.16	19.25	823.74	254.05	17.019	41.193	5.7741	1497.1	50.02	1818.16
Dev	0.336	0.321	0.078	0.442	14.038	11.882	1.894	1.295	0.700	123.573	1.615	156.449

Table 11b: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (90: 0: 10)

mple No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	151.10	25.24	6.56	18.76	749.85	218.70	11.655	31.513	4.1492	1347.8	42.03	1797.43
2	150.52	24.98	6.60	18.22	734.21	238.50	13.440	34.521	4.8274	1538.5	47.02	2095.45
3	150.72	25.20	6.67	18.85	744.07	266.50	14.686	37.439	5.3309	1599.5	50.32	2149.66
4	150.62	25.32	6.47	17.85	723.42	248.30	13.352	36.896	4.7013	1634.2	51.00	2258.99
8	150.74	25.54	6.80	18.80	718.12	240.50	11.884	33.237	4.3204	1538.7	46.28	2142.68
9	150.82	25.32	6.62	19.05	753.55	221.40	10.116	31.425	3.6444	1568.3	41.70	2081.22
ean	150.75	25.27	6.62	18.59	737.20	238.98	12.533	34.172	4.4956	1537.8	46.39	2087.57
Dev	0.182	0.167	0.010	0.416	13.149	16.161	1.481	2.370	0.536	91.407	3.608	141.753

Table 11c: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (70: 0: 30)

mple No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	151.52	25.42	6.53	21.47	853.64	198.00	8.443	28.770	3.0005	1895.8	33.70	2220.84
8	151.08	24.66	6.70	21.69	868.93	220.40	7.872	30.136	2.8703	1959.4	34.68	2254.96
9	151.24	25.48	6.38	21.50	874.48	203.70	8.461	30.934	2.9377	2125.7	35.37	2430.82
5	151.78	25.34	6.75	21.90	842.57	198.50	7.470	27.079	2.7441	1805.6	32.14	2142.97
2	151.28	25.98	6.47	22.20	873.03	207.90	7.998	28.526	2.8933	1888.2	32.68	2162.81
3	151.40	24.96	6.52	21.42	869.36	212.00	10.157	31.469	3.6039	1873.7	36.20	2155.26
ean	151.38	25.31	6.56	21.697	863.67	206.75	8.400	29.486	3.0083	1924.7	34.13	2227.94
Dev	0.223	0.416	0.128	0.277	11.621	7.844	0.856	1.510	0.277	100.464	1.437	98.896

APPENDIX A: BENDING STRENGTH

Table 11a: Polypropylene Bending Strength – Standard Sample

Polypropylene: MAPP: Rice Husk (100: 0: 0)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	150.40	25.24	6.19	19.50	829.86	247.30	12.850	40.275	4.3288	1549.0	48.53	1866.58
2	150.32	25.06	6.22	19.72	841.63	259.20	18.339	42.107	6.2077	1390.6	50.03	1652.27
5	149.66	24.44	6.20	18.60	820.19	238.00	17.820	39.900	6.0127	1418.2	48.65	1729.11
6	149.84	24.98	6.20	19.76	808.39	275.30	18.183	39.608	6.5509	1335.9	49.00	1652.54
7	149.46	25.50	5.99	19.13	837.96	246.80	17.545	42.485	5.7194	1613.5	50.70	1925.51
9	149.98	25.00	6.16	18.81	804.39	257.70	17.377	42.785	5.8253	1675.5	53.19	2082.95
Mean	149.94	25.04	6.16	19.25	823.74	254.05	17.019	41.193	5.7741	1497.1	50.02	1818.16
Std Dev	0.336	0.321	0.078	0.442	14.038	11.882	1.894	1.295	0.700	123.573	1.615	156.449

Table 11b: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (90: 0: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	151.10	25.24	6.56	18.76	749.85	218.70	11.655	31.513	4.1492	1347.8	42.03	1797.43
2	150.52	24.98	6.60	18.22	734.21	238.50	13.440	34.521	4.8274	1538.5	47.02	2095.45
3	150.72	25.20	6.67	18.85	744.07	266.50	14.686	37.439	5.3309	1599.5	50.32	2149.66
4	150.62	25.32	6.47	17.85	723.42	248.30	13.352	36.896	4.7013	1634.2	51.00	2258.99
8	150.74	25.54	6.80	18.80	718.12	240.50	11.884	33.237	4.3204	1538.7	46.28	2142.68
9	150.82	25.32	6.62	19.05	753.55	221.40	10.116	31.425	3.6444	1568.3	41.70	2081.22
Mean	150.75	25.27	6.62	18.59	737.20	238.98	12.533	34.172	4.4956	1537.8	46.39	2087.57
Std Dev	0.182	0.167	0.010	0.416	13.149	16.161	1.481	2.370	0.536	91.407	3.608	141.753

Table 11c: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (70: 0: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	151.52	25.42	6.53	21.47	853.64	198.00	8.443	28.770	3.0005	1895.8	33.70	2220.84
8	151.08	24.66	6.70	21.69	868.93	220.40	7.872	30.136	2.8703	1959.4	34.68	2254.96
9	151.24	25.48	6.38	21.50	874.48	203.70	8.461	30.934	2.9377	2125.7	35.37	2430.82
5	151.78	25.34	6.75	21.90	842.57	198.50	7.470	27.079	2.7441	1805.6	32.14	2142.97
2	151.28	25.98	6.47	22.20	873.03	207.90	7.998	28.526	2.8933	1888.2	32.68	2162.81
3	151.40	24.96	6.52	21.42	869.36	212.00	10.157	31.469	3.6039	1873.7	36.20	2155.26
Mean	151.38	25.31	6.56	21.697	863.67	206.75	8.400	29.486	3.0083	1924.7	34.13	2227.94
Std Dev	0.223	0.416	0.128	0.277	11.621	7.844	0.856	1.510	0.277	100.464	1.437	98.896

Table 11d: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (50: 0: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	152.24	25.52	6.88	25.20	942.76	206.50	5.0500	26.924	1.8908	2358.1	28.56	2501.27
2	152.00	25.74	6.90	25.08	929.02	232.80	5.5497	29.920	2.0840	2398.4	32.21	2581.65
6	151.74	25.10	6.60	25.02	995.34	211.10	5.0825	30.409	1.8256	2714.0	30.55	2726.71
7	151.78	25.56	6.56	24.86	976.84	183.80	4.4757	26.318	1.5979	2586.8	26.94	2648.13
8	151.62	25.30	6.65	25.39	995.32	213.30	4.2400	30.027	1.5345	2830.4	30.17	2843.71
9	152.18	25.44	6.88	25.24	947.60	231.80	5.3000	30.318	1.9844	2665.2	32.00	2812.58
Mean	151.93	25.44	6.75	25.13	964.48	213.22	4.9497	28.986	1.8195	2592.2	30.07	2685.67
Std Dev	0.230	0.203	0.144	0.169	26.046	16.552	0.454	1.689	0.197	167.975	1.852	121.791

Table 11e: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (90: 1: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
2	150.86	25.70	6.74	20.71	792.53	277.00	11.462	37.369	4.2043	1740.0	47.15	2195.50
3	150.98	25.30	6.65	19.90	783.41	250.90	14.892	35.320	5.3894	1539.0	45.09	1964.49
4	150.76	25.24	6.73	20.31	793.08	283.50	11.408	39.058	4.1783	1722.4	49.25	2171.79
5	150.46	25.14	6.83	20.32	786.53	290.50	14.190	39.014	5.2744	1659.4	49.60	2109.77
6	150.50	25.90	6.50	19.92	786.21	263.00	14.347	37.854	5.0750	1583.7	48.15	2014.35
7	150.64	25.28	6.55	20.59	825.46	236.30	8.632	34.315	3.0770	1740.5	41.57	2108.52
Mean	150.70	25.43	6.67	20.29	794.54	266.87	12.489	37.155	4.5331	1664.2	46.80	2094.07
Std Dev	0.187	0.275	0.114	0.305	14.257	18.895	2.207	1.782	0.809	78.669	2.771	81.579

Table 11f: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (70: 1: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
2	151.48	25.34	6.78	22.85	878.00	254.10	6.8436	34.357	2.5251	2263.2	39.13	2577.68
3	151.48	25.50	6.78	22.99	877.84	262.50	6.3338	35.270	2.3370	2325.3	40.18	2648.89
5	151.50	25.44	6.73	22.51	867.82	245.90	6.8171	33.612	2.4968	2209.9	38.73	2546.50
6	151.62	25.26	6.90	22.04	834.01	252.40	4.9963	33.055	1.8761	2488.5	39.63	2983.78
8	151.34	25.58	6.84	23.25	878.04	276.20	6.7164	36.349	2.5002	2251.8	41.40	2564.58
9	151.26	26.00	6.68	22.11	841.60	231.00	6.8000	31.359	2.4721	2055.7	37.26	2442.61
Mean	151.45	25.52	6.79	22.63	862.89	253.68	6.4179	34.000	2.3679	2265.7	39.39	2627.34
Std Dev	0.116	0.238	0.071	0.446	18.225	13.914	0.659	1.596	0.228	129.489	1.274	170.577

Table 11g: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (50: 1: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
3	151.56	25.28	6.81	25.42	974.24	274.30	4.5133	36.850	1.6727	3216.2	37.82	3301.24
4	151.48	25.38	6.80	25.17	962.78	272.90	4.0381	36.625	1.4944	3122.5	38.04	3243.21
5	151.38	26.04	6.56	25.57	988.82	255.50	4.3933	35.911	1.5684	3357.3	36.32	3395.26
6	151.86	25.42	6.67	24.79	962.79	247.80	4.2773	34.511	1.5526	3101.4	35.84	3221.26
7	151.38	24.82	6.85	25.23	980.24	258.50	3.9240	34.959	1.4628	3121.8	35.66	3184.73
8	151.46	25.10	6.68	25.00	984.45	215.90	3.4537	30.360	1.2556	3139.4	30.84	3188.99
Mean	151.52	25.34	6.73	25.20	975.55	254.15	4.1000	34.869	1.5011	3176.4	35.76	3255.78
Std Dev	0.164	0.372	0.101	0.257	10.041	19.501	0.351	2.182	0.128	88.684	2.381	73.461

Table 11h: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (90: 3: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	150.46	25.98	6.56	19.62	765.13	245.70	9.470	34.613	3.3809	1676.9	45.24	2191.65
2	150.98	25.48	6.60	19.00	748.33	262.40	11.496	37.235	4.1291	1589.7	49.76	2124.33
3	150.54	24.84	6.65	19.14	769.69	274.90	11.371	39.415	4.1152	1670.3	51.21	2170.09
4	150.80	25.00	6.60	19.39	779.28	258.00	11.073	36.101	3.9773	1613.1	46.33	2069.99
8	151.00	25.48	6.50	19.34	773.33	252.60	13.792	36.956	4.8788	1538.5	47.79	1989.45
9	151.00	25.48	6.65	19.66	768.40	265.80	13.567	37.153	4.9098	1621.7	48.35	2110.49
Mean	150.80	25.38	6.59	19.36	767.36	259.90	11.795	36.912	4.2319	1618.4	48.11	2109.33
Std Dev	0.222	0.371	0.052	0.237	9.586	9.351	1.490	1.436	0.531	47.192	1.996	66.602

Table 11i: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (70: 3: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	151.54	25.38	6.77	23.18	890.24	283.50	6.9482	38.385	2.5600	2435.6	43.12	2735.89
2	151.18	26.06	6.73	23.21	875.37	272.80	6.7400	36.402	2.4686	2370.1	41.58	2707.54
3	151.48	25.24	6.82	22.30	855.22	269.40	6.2629	36.143	2.3245	2350.7	42.26	2748.65
4	151.50	25.60	6.76	23.18	884.13	282.10	6.3300	37.980	2.3288	2472.4	42.96	2796.42
5	151.12	24.72	6.76	22.52	891.77	243.70	5.9950	33.978	2.2055	2343.5	38.10	2627.92
7	151.20	25.00	6.80	21.60	840.34	230.70	5.9331	31.432	2.1956	2228.0	37.40	2651.31
Mean	151.34	25.33	6.77	22.67	872.85	263.70	6.3682	35.72	2.3472	2366.7	40.90	2711.29
Std Dev	0.173	0.428	0.029	0.594	18.981	19.727	0.369	2.390	0.132	77.420	2.292	57.461

Table 11j: Thermoplastic Composite Bending Strength

Polypropylene: MAPP: Rice Husk (50: 3: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Deflection @ Peak (mm)	Stress @ Peak (N/mm^2)	Strain @ Peak (%)	Young Modulus (N/mm^2)	Cal. Value (MOR)	Cal. Value (MOE)
1	152.00	25.44	6.75	24.70	946.31	207.90	3.1469	28.249	1.1560	3116.0	29.85	3292.79
2	151.64	25.60	6.84	25.39	955.96	249.40	3.7413	32.475	1.3927	3013.4	33.97	3152.22
3	151.58	25.54	6.61	24.49	957.03	223.00	3.7900	31.475	1.3634	2856.8	32.89	2985.07
4	151.66	25.00	6.58	24.78	993.26	227.60	3.8080	33.118	1.3636	3082.4	33.34	3103.32
7	151.92	25.28	6.76	25.39	977.97	243.80	3.5963	33.239	1.3231	3227.4	33.99	3300.10
8	151.60	26.02	6.85	26.50	980.73	244.40	3.8011	31.528	1.4170	2873.9	32.15	2930.37
Mean	151.73	25.48	6.73	25.21	968.54	232.68	3.6473	31.680	1.3360	3028.3	32.70	3124.31
Std Dev	0.164	0.311	0.104	0.670	16.500	14.572	0.235	1.682	0.052	131.487	1.422	139.914

APPENDIX B: TENSILE STRENGTH

Table 12a: Polypropylene Tensile Strength – Standard Sample

Polypropylene: MAPP: Rice Husk (100: 0: 0)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
3	149.92	10.00	2.25	2.84	841.93	651.50	8.345	28.956	2144.5	9.91	34.39	2547.12
5	149.24	10.06	2.09	2.67	850.91	659.50	9.333	31.367	1930.2	10.97	36.86	2268.40
6	149.98	10.00	2.23	2.90	867.08	662.50	9.366	29.709	1949.3	10.80	34.26	2248.12
7	149.02	9.98	2.05	2.53	829.83	634.20	9.606	30.999	1876.8	11.58	37.36	2261.66
8	148.68	10.00	2.01	2.53	846.59	629.80	8.427	31.333	1858.4	9.95	37.01	2195.17
9	149.48	10.02	2.33	2.95	845.31	709.90	7.905	30.407	1963.4	9.35	35.97	2322.70
Mean	149.39	10.01	2.16	2.74	846.94	657.90	8.830	30.462	1953.8	10.43	35.98	2307.19
Std Dev	0.466	0.025	0.116	0.170	11.120	26.204	0.632	0.885	93.154	0.753	1.238	113.596

Table 12b: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (90: 0: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A3	149.72	10.78	2.43	3.41	869.46	549.10	3.1600	20.962	1973.7	3.63	24.11	2270.03
A6	149.86	10.96	2.29	3.38	898.64	579.90	3.2030	23.105	2179.6	3.56	25.71	2425.45
B2	149.82	10.86	2.40	3.47	888.63	563.90	3.0138	21.635	2142.4	3.39	24.35	2410.92
B6	149.82	10.46	2.39	3.24	865.06	502.50	3.7639	20.100	1811.8	4.35	23.24	2094.42
C4	149.72	10.46	2.39	3.31	884.34	557.70	3.2093	22.309	2114.9	3.63	25.23	2391.50
D2	149.70	10.46	2.14	2.96	883.33	437.00	2.2999	19.523	1672.3	2.60	22.10	1893.17
Mean	149.77	10.66	2.34	3.30	881.58	531.68	3.1083	21.272	1982.5	3.60	24.12	2247.58
Std Dev	0.062	0.210	0.099	0.167	11.337	48.579	0.4309	1.231	185.915	0.512	1.202	195.191

Table 12c: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (70: 0: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A1	151.14	10.48	2.55	3.79	938.34	457.90	1.7252	17.134	2526.9	1.84	18.26	2692.96
B1	151.06	10.48	2.55	3.78	936.36	443.60	1.9484	16.599	2400.5	2.08	17.73	2563.66
B2	151.18	10.38	2.58	3.86	953.40	423.40	1.6254	15.810	2484.4	1.70	16.58	2605.83
D2	151.10	10.46	2.57	3.81	937.98	477.00	1.4499	17.744	2390.2	1.55	18.92	2548.23
D5	151.14	10.46	2.58	3.76	921.84	471.10	1.7960	17.457	2769.3	1.95	18.94	3034.09
D7	151.28	10.38	2.52	3.62	914.81	416.10	1.6256	15.907	2614.0	1.78	17.39	2857.44
Mean	151.15	10.44	2.56	3.77	933.79	448.18	1.6951	16.775	2530.88	1.82	17.97	2712.03
Std Dev	0.069	0.043	0.021	0.074	12.467	22.784	0.155	0.736	130.843	0.171	0.840	166.797

Table 12d: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (50: 0: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
B2	151.98	10.68	2.43	3.95	1001.46	383.40	1.2450	14.773	2807.7	1.24	14.75	2803.61
C1	152.00	10.68	2.31	3.85	1026.68	369.40	1.2593	14.973	3023.0	1.23	14.58	2944.45
C4	151.98	10.64	2.42	4.01	1024.71	385.50	1.2423	14.972	3177.9	1.21	14.61	3101.27
C6	152.02	10.74	2.45	4.10	1024.97	373.70	1.0217	14.202	3316.6	1.00	13.86	3235.79
D1	151.98	10.64	2.39	4.25	1099.67	373.90	0.9555	14.703	3380.7	0.87	13.37	3074.28
D9	151.78	10.64	2.43	4.12	1049.87	393.30	0.9398	15.212	2396.3	0.90	14.49	2282.48
Mean	151.96	10.67	2.41	4.05	1037.89	379.87	1.1106	14.805	3017.0	1.07	14.28	2906.98
Std Dev	1.080	0.036	0.046	0.128	30.968	8.245	0.141	0.315	335.916	0.159	0.496	309.824

Table 12e: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (90: 1: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A2	150.00	10.98	2.48	3.57	874.02	511.30	2.7193	18.777	1962.5	3.11	21.48	2245.26
A3	150.04	10.80	2.45	3.54	891.67	532.40	2.7397	20.121	1921.9	3.07	22.57	2155.38
B3	150.08	10.76	2.40	3.40	877.27	486.10	2.5192	18.824	1937.2	2.87	21.46	2208.22
B5	150.14	10.86	2.41	3.39	862.69	614.70	2.5979	23.486	2379.0	3.01	27.22	2757.64
C2	149.98	10.98	2.31	3.41	896.41	511.70	2.5367	20.174	1966.6	2.83	22.51	2193.86
D6	150.24	10.58	2.27	3.22	892.40	569.00	2.9840	23.692	1415.1	3.34	26.55	1585.73
Mean	150.08	10.83	2.39	3.42	882.41	537.53	2.6828	20.846	1930.38	3.04	23.63	2191.03
Std Dev	0.089	0.138	0.075	0.114	12.022	42.763	0.158	2.017	279.653	0.169	2.351	339.600

Table 12f: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (70: 1: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A2	151.22	10.84	2.48	3.82	939.67	522.80	1.3597	19.447	2774.6	1.45	20.70	2952.75
B2	151.14	10.86	2.50	3.84	935.80	529.70	1.9186	19.510	2355.6	2.05	20.85	2517.21
C5	151.06	10.40	2.43	3.60	943.00	499.80	1.2599	19.777	2056.0	1.34	20.97	2180.27
D2	151.00	10.64	2.48	3.76	943.66	506.60	1.3178	19.199	2561.8	1.40	20.35	2714.74
D3	151.20	10.64	2.45	3.76	953.96	545.90	1.4798	20.941	2781.0	1.55	21.95	2915.23
D5	151.10	10.42	2.43	3.67	959.24	509.60	1.5087	20.126	2980.2	1.57	20.98	3106.83
Mean	151.12	10.63	2.46	3.74	945.89	519.07	1.4741	19.833	2584.87	1.56	20.97	2731.17
Std Dev	0.077	0.180	0.027	0.083	8.136	15.617	0.217	0.573	306.472	0.235	0.491	309.204

Table 12g: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (50: 1: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A4	151.84	10.78	2.47	4.05	1001.74	497.00	1.1286	18.666	3277.2	1.13	18.63	3271.52
B4	151.56	10.66	2.51	4.21	1038.17	538.30	1.2394	20.118	3216.0	1.19	19.38	3097.77
C3	151.84	10.30	2.35	3.82	1039.37	477.40	1.0928	19.723	3660.7	1.05	18.98	3522.02
C7	151.78	10.12	2.46	3.97	1050.66	495.60	0.9498	19.907	3526.9	0.90	18.95	3356.86
D1	151.80	10.62	2.39	3.96	1027.78	502.30	1.2870	19.790	3309.2	1.25	19.26	3219.75
D7	151.82	10.22	2.50	4.05	1044.08	496.90	1.2033	19.448	3101.7	1.15	18.63	2970.74
Mean	151.77	10.45	2.45	4.01	1033.63	501.25	1.1502	19.609	3348.62	1.11	18.97	3239.78
Std Dev	0.098	0.247	0.058	0.118	15.83	18.31	0.111	0.467	189.03	0.112	0.283	176.694

Table 12h: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (90: 3: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A1	150.16	10.82	2.36	3.35	873.68	538.60	2.5844	21.092	2177.3	2.96	21.14	2492.11
B7	150.32	11.12	2.18	3.12	856.20	516.80	2.7846	21.319	2136.0	3.25	24.90	2494.74
C1	150.22	10.32	2.35	3.14	861.89	554.00	3.1380	22.843	2382.3	3.64	26.50	2764.03
C5	150.32	10.40	2.33	3.11	853.80	558.30	3.6542	23.040	2118.4	4.28	26.99	2481.15
D1	150.30	10.12	2.30	3.11	888.98	535.00	2.9962	22.985	2359.0	3.37	25.86	2653.60
D3	150.26	10.40	2.38	3.10	833.50	556.20	3.5033	22.471	2303.5	4.20	26.96	2763.63
Mean	150.26	10.53	2.317	3.16	861.34	543.15	3.1101	22.292	2246.08	3.62	25.89	2608.21
Std Dev	0.058	0.336	0.066	0.088	17.198	14.71	0.376	0.792	106.266	0.485	1.061	124.495

Table 12i: THERMOPLASTIC COMPOSITE TENSILE STRENGTH

Polypropylene: MAPP: Rice Husk (70: 3: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A3	151.38	10.54	2.49	3.77	948.93	537.60	1.7524	20.484	2587.1	1.85	21.59	2726.34
B1	151.22	10.74	2.63	3.90	913.05	560.70	1.7155	19.850	2829.5	1.88	21.74	3098.95
B5	151.26	10.74	2.52	3.81	930.67	551.10	1.8812	20.362	2502.6	2.02	21.88	2689.03
C1	151.38	10.60	2.39	3.68	959.57	514.90	1.5317	20.324	2857.0	1.60	21.18	2977.38
C4	151.34	10.70	2.31	3.56	951.70	485.50	1.6839	19.642	2683.1	1.77	20.64	2817.27
D5	151.26	10.84	2.44	3.82	954.82	536.60	1.4859	20.288	2694.7	1.56	21.25	2822.22
Mean	151.31	10.69	2.46	3.76	943.12	531.07	1.6751	20.158	2692.33	1.78	21.38	2855.53
Std Dev	0.063	0.098	0.101	0.110	16.196	24.801	0.133	0.304	124.562	0.161	0.414	141.973

Table 12j: Thermoplastic Composite Tensile Strength

Polypropylene: MAPP: Rice Husk (50: 3: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Weight (g)	Density (kg/m^3)	Load @ Peak (mm)	Elongation @ Peak (mm)	Stress @ Peak (N/mm^2)	Youngs Modulus (N/mm^2)	Cal. Value Elong.	Cal. Value (MOR)	Cal. Value (MOE)
A3	151.70	10.78	2.43	4.34	1092.14	527.10	1.1327	20.122	3509.6	1.04	18.42	3213.50
C2	151.62	10.80	2.50	4.38	1069.93	541.20	1.1362	20.044	3383.7	1.06	18.73	3162.55
C3	151.68	10.78	2.48	4.38	1080.13	503.70	1.0831	18.841	3031.6	1.00	17.44	2806.70
D1	151.72	10.44	2.55	4.19	1037.36	507.10	0.9672	19.048	3511.1	0.93	18.36	3384.64
D4	151.68	10.20	2.45	4.08	1076.38	500.80	1.1583	20.040	3647.3	1.08	18.62	3388.49
D7	151.82	10.64	2.35	3.91	1030.00	492.20	1.1368	19.685	3396.1	1.10	19.11	3297.18
Mean	151.70	10.61	2.46	4.21	1064.32	512.017	1.1024	19.630	3413.23	1.04	18.45	3208.84
Std Dev	0.060	0.221	0.062	0.174	22.750	16.788	0.065	0.508	191.686	0.056	0.511	197.847

APPENDIX C: WATER ABSORPTION

Table 13a: Polypropylene Water Absorption – Standard Sample

Polypropylene: MAPP: Rice Husk (100: 0: 0)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
1	50.10	51.38	2.47	5.14	5.14	0	808.41	0
3	50.82	50.28	2.00	4.54	4.54	0	888.37	0
5	50.06	50.68	1.98	4.44	4.44	0	883.87	0
6	50.78	50.00	2.03	4.54	4.54	0	880.84	0
7	50.38	50.04	2.03	4.40	4.40	0	859.77	0
9	50.84	50.00	2.12	4.78	4.78	0	886.99	0
Mean	50.50	50.40	2.11	4.64	4.64	0.00	868.04	0.00
Std Dev	0.333	0.500	0.169	0.254	0.254	0.000	28.317	0.000

Table 13b: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (90: 0: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A1	51.38	50.00	2.56	5.92	5.92	0	900.16	0
A2	51.18	50.00	2.55	5.58	5.58	0	855.11	0
B2	49.88	5016	2.38	5.39	5.39	0	905.17	0
C1	49.92	49.98	2.53	5.72	5.72	0	906.16	0
D1	50.10	50.00	2.19	4.84	4.84	0	882.25	0
D2	50.10	50.86	2.13	4.84	4.84	0	891.77	0
Mean	50.43	50.17	2.39	5.38	5.38	0.00	890.10	0.00
Std Dev	0.612	0.316	0.174	0.414	0.414	0.000	17.677	0.000

Table 13c: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (70: 0: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A1	50.20	49.94	2.51	5.87	5.95	1.36	932.85	1.46
B1	50.28	49.88	2.73	6.49	6.55	0.92	947.90	0.98
B2	49.88	50.00	2.62	6.14	6.20	0.98	939.66	1.04
C1	50.28	50.08	2.38	5.54	5.62	1.44	924.43	1.56
C2	49.94	50.10	2.59	6.19	6.25	0.97	955.22	1.01
D2	49.92	50.00	2.68	6.20	6.26	0.97	926.86	1.04
Mean	50.08	50.00	2.59	6.07	6.14	1.11	937.82	1.18
Std Dev	0.173	0.076	0.115	0.298	0.290	0.211	11.044	0.235

Table 13d: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (50: 0: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A1	50.00	50.00	2.35	5.99	6.16	2.84	1019.57	2.78
B1	50.00	49.92	2.66	6.92	7.05	1.88	1042.27	1.80
C1	50.26	50.12	2.30	5.99	6.14	2.50	1033.87	2.42
C3	50.28	50.12	2.77	7.10	7.23	1.83	1017.12	1.80
D1	50.02	50.00	2.77	7.20	7.33	1.81	1039.30	1.74
D2	50.00	50.32	2.39	6.16	6.33	2.76	10.24.41	2.69
Mean	50.09	50.08	2.54	6.56	6.71	2.27	1029.42	2.21
Std Dev	0.125	0.129	0.198	0.523	0.507	0.443	9.626	0.441

Table 13e: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (90: 1: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
B1	50.30	50.00	2.35	5.08	5.08	0.00	859.52	0.00
C1	50.20	50.20	2.21	5.01	5.01	0.00	899.58	0.00
C2	50.10	50.36	2.42	5.41	5.41	0.00	886.05	0.00
D1	50.10	49.98	2.55	5.72	5.72	0.00	895.82	0.00
D2	50.10	50.40	2.45	5.36	5.36	0.00	866.42	0.00
D3	48.44	50.20	2.36	5.00	5.00	0.00	871.26	0.00
Mean	49.87	50.19	2.39	5.26	5.26	0.00	879.78	0.00
Std Dev	0.645	0.160	0.104	0.260	0.260	0.000	15.001	0.000

Table 13f: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (70: 1: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A2	50.12	50.20	2.63	6.19	6.23	0.65	935.45	0.69
B2	50.26	50.00	2.55	6.00	6.05	0.83	936.31	0.89
B3	49.56	50.34	2.46	5.73	5.78	0.87	933.63	0.93
C1	50.18	50.02	2.49	5.90	5.96	1.02	944.01	1.08
C2	50.10	50.14	2.54	6.08	6.12	0.66	952.90	0.69
D2	49.98	50.10	2.59	6.07	6.12	0.82	935.95	0.88
Mean	50.03	50.13	2.54	6.00	6.04	0.81	939.71	0.86
Std Dev	0.228	0.115	0.057	0.147	0.143	0.127	6.749	0.136

Table 13g: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (50: 1: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A2	50.00	49.82	2.60	6.58	6.68	1.52	1015.97	1.50
B2	49.82	50.00	2.59	6.70	6.82	1.79	1038.49	1.72
C1	50.00	50.08	2.32	5.88	6.00	2.04	1021.17	2.00
C2	50.00	49.98	2.61	6.57	6.68	1.67	1007.30	1.66
D1	50.40	49.90	2.41	6.22	6.34	1.93	1026.22	1.88
D2	50.30	50.00	2.53	6.58	6.69	1.67	1034.11	1.62
Mean	50.09	49.96	2.51	6.42	6.52	1.77	1023.88	1.73
Std Dev	0.199	0.083	0.109	0.284	0.274	0.173	10.555	0.167

Table 13h: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (90: 3: 10)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A1	50.26	50.12	2.23	5.00	5.01	0.20	980.09	0.20
A2	50.00	50.02	2.36	5.31	5.32	0.19	899.64	0.21
B1	50.10	50.02	2.28	4.99	5.00	0.20	873.34	0.23
B2	50.20	50.00	2.36	5.20	5.21	0.19	877.84	0.22
C1	50.26	49.98	2.40	5.38	5.39	0.19	892.39	0.21
D1	50.18	50.00	2.43	5.43	5.44	0.18	890.62	0.21
Mean	50.17	50.02	2.34	5.22	2.23	0.19	902.32	0.21
Std Dev	0.092	0.045	0.068	0.173	0.173	0.006	35.893	0.009

Table 13i: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (70: 3: 30)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A2	50.00	49.98	2.58	6.08	6.13	0.82	943.01	0.87
B1	50.10	49.98	2.46	5.80	5.86	1.03	941.58	1.10
B2	50.00	50.00	2.61	6.11	6.16	0.82	936.40	0.87
C2	50.00	50.00	2.52	5.84	5.89	0.86	926.98	0.92
D1	50.20	49.98	2.29	5.47	5.52	0.91	952.03	0.96
D3	50.00	49.98	2.53	5.98	6.03	0.84	945.83	0.88
Mean	50.05	49.99	2.50	5.88	5.93	0.88	940.97	0.94
Std Dev	0.076	0.009	0.104	0.216	0.215	0.076	7.822	0.079

Table 13j: Thermoplastic Composite Water Absorption

Polypropylene: MAPP: Rice Husk (50: 3: 50)

Sample No	Length (mm)	Width (mm)	Thick. (mm)	Initial Weight (g)	Final Weight (g)	Water Absorption (%)	Density (kg/m^3)	Cal. Value (WA)
A2	50.00	50.40	2.85	7.33	7.41	1.09	1020.61	1.07
B1	50.10	50.00	2.44	6.21	6.32	1.77	1016.00	1.74
B2	50.00	50.00	2.69	6.90	7.00	1.45	1026.02	1.41
B3	50.20	50.30	2.87	7.48	7.56	1.07	1032.16	1.04
C1	50.00	49.82	2.83	7.26	7.35	1.24	1029.86	1.20
D1	50.24	49.52	2.91	7.39	7.47	1.08	1020.75	1.06
Mean	50.09	50.01	2.77	7.10	7.19	1.28	1024.23	1.25
Std Dev	0.099	0.292	0.161	0.436	0.425	0.255	5.638	0.254

APPENDIX D: UNIVARIATE ANALYSIS OF VARIANCE

Between-Subject Factors

		N
RATIO	50.00	18
	70.00	18
	90.00	18
MAPP	0.00	18
	1.00	18
	3.00	18

Tests of Between-Subjects Effects

Dependent Variable: MOE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9608262.20[a]	8	1201032.78	79.596	.000
Intercept	350410613	1	350410613	23222.678	.000
RATIO	7733251.66	2	3866625.83	256.252	.000
MAPP	1233172.16	2	616586.081	40.863	.000
RATIO * MAPP	641838.387	4	160459.597	10.634	.000
Error	679012.009	45	15089.156		
Total	360697887	54			
Corrected Total	10287274.2	53			

a. R Squared = .934 (Adjusted R Squared = .922)

Post Hoc Tests

RATIO

Homogenous Subsets

MOE

Duncan[a, b]

RATIO	N	Subset		
		1	2	3
90.00	18	2096.9917		
70.00	18		2522.1906	
50.00	18			3022.9228
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 15089.156.

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

MAPP

MOE

Duncan[a, b]

MAPP	N	Subset	
		1	2
.00	18	2333.7300	
3.00	18		2649.3111
1.00	18		2659.0639
Sig.		1.000	.813

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 15089.156.

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

Between-Subject Factors

		N
RATIO	50.00	18
	70.00	18
	90.00	18
MAPP	0.00	18
	1.00	18
	3.00	18

Tests of Between-Subjects Effects

Dependent Variable: TMOE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6436329.02[a]	8	804541.127	12.601	.000
Intercept	406764376	1	406764376	6370.780	.000
RATIO	5343210.76	2	2671605.38	41.843	.000
MAPP	665062.098	2	332531.049	5.208	.009
RATIO * MAPP	428056.162	4	107014.040	1.676	.172
Error	2873179.76	45	63848.439		
Total	416073885	54			
Corrected Total	9309508.77	53			

a. R Squared = .691 (Adjusted R Squared = .637)

Post Hoc Tests

RATIO

Homogenous Subsets

TMOE

Duncan[a, b]

RATIO	N	Subset		
		1	2	3
90.00	18	2348.9356		
70.00	18		2766.2461	
50.00	18			3118.5333
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 63848.439

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

MAPP

TMOE

Duncan[a, b]

MAPP	N	Subset	
		1	2
.00	18	2622.1989	
3.00	18	2720.6544	
1.00	18		2890.8617
Sig.		.249	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 63848.439

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

Between-Subject Factors

		N
RATIO	50.00	18
	70.00	18
	90.00	18
MAPP	0.00	18
	1.00	18
	3.00	18

Tests of Between-Subjects Effects

Dependent Variable: MOR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2129.133[a]	8	266.142	44.600	.000
Intercept	83662.042	1	83662.042	14010.010	.000
RATIO	1870.674	2	935.337	156.743	.000
MAPP	168.427	2	84.214	14.112	.000
RATIO * MAPP	90.032	4	22.058	3.772	.010
Error	268.530	45	5.967		
Total	86059.705	54			
Corrected Total	2397.663	53			

a. R Squared = .888 (Adjusted R Squared = .868)

Post Hoc Tests

RATIO

Homogenous Subsets

MOR

Duncan[a, b]

RATIO	N	Subset		
		1	2	3
50.00	18	32.8411		
70.00	18		38.1400	
90.00	18			47.1022
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 5.967

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

MAPP

MOR

Duncan[a, b]

MAPP	N	Subset	
		1	2
.00	18	36.8639	
3.00	18		40.5717
1.00	18		40.6478
Sig.		1.000	.926

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 5.967

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

Between-Subject Factors

		N
RATIO	50.00	18
	70.00	18
	90.00	18
MAPP	0.00	18
	1.00	18
	3.00	18

Tests of Between-Subjects Effects

Dependent Variable: TMOR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	627.191[a]	8	78.399	59.999	.000
Intercept	22979.344	1	22979.344	17586.118	.000
RATIO	489.265	2	244.663	187.218	.000
MAPP	95.898	2	47.949	36.695	.000
RATIO * MAPP	42.028	4	10.507	8.041	.000
Error	58.800	45	1.307		
Total	23665.336	54			
Corrected Total	685.991	53			

a. R Squared = .914 (Adjusted R Squared = .899)

Post Hoc Tests

RATIO

Homogenous Subsets

TMOR

Duncan[a, b]

RATIO	N	Subset		
		1	2	3
50.00	18	17.2317		
70.00	18		20.1056	
90.00	18			24.5489
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 1.307

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

MAPP

TMOR

Duncan[a, b]

MAPP	N	Subset	
		1	2
.00	18	18.7900	
3.00	18		21.1900
1.00	18		21.9061
Sig.		1.000	.067

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 1.307

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

Between-Subject Factors

		N
RATIO	50.00	18
	70.00	18
	90.00	18
MAPP	0.00	18
	1.00	18
	3.00	18

Tests of Between-Subjects Effects

Dependent Variable: ELONG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	53.035[a]	8	6.629	73.644	.000
Intercept	229.649	1	229.649	2551.110	.000
RATIO	51.624	2	25.812	286.740	.000
MAPP	.682	2	.341	3.787	.000
RATIO * MAPP	.729	4	.182	2.025	.107
Error	4.051	45	9.002E-02		
Total	286.735	54			
Corrected Total	57.086	53			

a. R Squared = .929 (Adjusted R Squared = .916)

Post Hoc Tests

RATIO

Homogenous Subsets

ELONG

Duncan[a, b]

RATIO	N	Subset		
		1	2	3
50.00	18	1.0739		
70.00	18		1.7189	
90.00	18			3.3939
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 9.002E-02

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

MAPP

ELONG

Duncan[a, b]

MAPP	N	Subset	
		1	2
1.00	18	1.9033	
.00	18		2.1394
3.00	18		2.1439
Sig.		1.000	.965

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 9.002E-02

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

Between-Subject Factors

		N
RATIO	50.00	18
	70.00	18
	90.00	18
MAPP	0.00	18
	1.00	18
	3.00	18

Tests of Between-Subjects Effects

Dependent Variable: WA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	28.106[a]	8	3.513	71.560	.000
Intercept	46.835	1	46.835	953.961	.000
RATIO	24.855	2	12.427	253.126	.000
MAPP	1.108	2	.554	11.285	.000
RATIO * MAPP	2.143	4	.536	10.915	.000
Error	2.209	45	4.910E-02		
Total	77.150	54			
Corrected Total	30.315	53			

a. R Squared = .927 (Adjusted R Squared = .914)

Post Hoc Tests

RATIO

Homogenous Subsets

WA

Duncan[a, b]

RATIO	N	Subset		
		1	2	3
90.00	18	7.111E-02		
70.00	18		.9933	
50.00	18			1.7294
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 4.910E-02

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

MAPP

WA

Duncan[a, b]

MAPP	N	Subset	
		1	2
3.00	18	.8000	
1.00	18	.8633	
.00	18		1.1306
Sig.		.396	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square (Error) = 4.910E-02

a. Uses Harmonic Mean Sample Size = 18.000
b. Alpha = .05

APPENDIX E: CORRELATIONS

		RATIO	MAPP	MOR	MOE	ELONG	TMOR	TMOE	WA
RATIO	Person Correlation	1.000	.000	-.874**	.866**	-.921**	-.838**	.757**	.904**
	Sig. (2-tailed)	.	1.000	.000	.000	.000	.000	.000	.000
	N	54	54	54	54	54	54	54	54
MAPP	Person Correlation	.000	1.000	.197	.256	.022	.329*	.267	-.165
	Sig. (2-tailed)	1.000	.	.153	.062	.872	.015	.051	.234
	N	54	54	54	54	54	54	54	54
MOR	Person Correlation	-.874**	.197	1.000	-.587**	.853**	.879**	-.552**	-.844**
	Sig. (2-tailed)	.000	.153	.	.000	.000	.000	.000	.000
	N	54	54	54	54	54	54	54	54
MOE	Person Correlation	.866**	.256	-.587**	1.000	-.797**	-.555**	.740**	.682**
	Sig. (2-tailed)	.000	.062	.000	.	.000	.000	.000	.000
	N	54	54	54	54	54	54	54	54
ELONG	Person Correlation	-.921**	.022	.853**	-.797**	1.000	.873**	-.672**	-.832**
	Sig. (2-tailed)	.000	.872	.000	.000	.	.000	.000	.000
	N	54	54	54	54	54	54	54	54
TMOR	Person Correlation	-.838**	.329*	.879**	-.555**	.837**	1.000	-.482**	-.850**
	Sig. (2-tailed)	.000	.015	.000	.000	.000	.	.000	.000
	N	54	54	54	54	54	54	54	54
TMOE	Person Correlation	.757**	.267	-.552**	.740**	-.672**	-.482**	1.000	.605**
	Sig. (2-tailed)	.000	.051	.000	.000	.000	.000	.	.000
	N	54	54	54	54	54	54	54	54
WA	Person Correlation	.904**	-.165	-.844**	.682**	-.832**	-.850**	.605**	1.000
	Sig. (2-tailed)	.000	.234	.000	.000	.000	.000	.000	.
	N	54	54	54	54	54	54	54	54

PUBLICATION OF THE THESIS UNDERTAKING

This is to certify that I have no objection to publish the thesis entitled Rice Husk Filled Thermoplastic Composite by the major supervisor in a joint form approved by the Faculty.

....

(ARIFF MOHAMED)

Date: 05 OCT 1999

Ketua
Perpustakaan
Universiti Teknologi MARA
40450 Shah Alam, Selangor.

Kebenaran Membuat Salinanfoto Tesis

Saya Ariff bin Mohamed dengan ini mengaku bahawa Tesis berjudul Rice Filled Thermoplastic Composite adalah karangan saya. Saya membenarkan Tesis ini digunakan oleh pelajar-pelajar Universiti ini dan sesiapa yang mempunyai minat akademik untuk tujuan pembelajaran, pengajaran dan penyelidikan. Saya juga bersetuju memberi kebenaran kepada Universiti Teknologi MARA untuk membuat salinanfoto Tesis ini untuk tujuan yang sama.

Saya dengan ini menjamin bahawa Tesis ini adalah karya asal dan saya adalah pemilik hakciptanya. Saya juga memperakui bahawa saya belum pernah membuat sebarang penyerahan hak atau memberi sebarang lesen mengenainya kepada sesiapa atau pertubuhan dan ianya belum pernah diterbitkan.

Bertarikh pada : 05 OCT 1999

Ditandatangani oleh : ....

Nama : ARIFF MOHAMED