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Research on Paddy Residual Reinforced as a Composite Board

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Abstract

This research is specifically designed to study the physical and mechanical properties of rice straw and epoxy resin for the purpose of producing environmentally friendly composite materials. Rice straw is selected because rice straw is the main residue of rice cultivation produced during the harvesting process which will be disposed of by open burning method after harvesting. As a result, to avoid environmental pollution, rice straw was chosen to be an environmentally friendly composite material. Rice straw is a raw material that is readily available because of its annual production and low cost. The production of environmentally friendly composite materials is carried out by conducting tensile tests, flexural tests, impact tests, water absorption and density. The production of composites materials using the cold pressing. The results of these research, the highest tensile test results were 0.705kN / mm² at 90% epoxy sample and the lowest was 0.610kN / mm² at 60% epoxy. The highest flexural test result was 0.338kN / mm² in the 60% epoxy sample and the lowest was 0.145kN / mm² in the 90% epoxy sample. The highest impact test was 4 joules on a sample of 60% epoxy. The highest water absorption test was 13% in the 60% epoxy sample and the lowest was 0% in the 90% epoxy sample. The highest density test is 1.5g / ml in a 90% epoxy sample. Based on the results of this research, the best sample is sample 2 which is (80% epoxy and 20% rice straw) due to its balanced mechanical and physical properties. It can be concluded that the presence of compositematerials from rice straw and epoxy can reduce environmental pollution and enhance the mechanical and physical properties of previously available composite materials.

Key-word: - Paddy Residual, Composite Board, Rice Straw

1. Introduction

Government of Malaysia under the National Agriculture Policy has introduced the granary area for the systematic paddy plantation in Malaysia. Granary area refers to major irrigation schemes up to 4000 hectares of paddy plantation. There are eight Granary Areas in Malaysia, namely Muda Agriculture Development Authority (MADA), Kemubu Agriculture Development Authority (KADA), Kerian-Sungai Manik Integrated Agriculture Development Area, Barat Laut Selangor Integrated Agriculture Development Area, Seberang Perak Integrated Agriculture Development Area, Penang Integrated Agriculture Development Area, North Terengganu Integrated Agriculture Development Area (KETARA) and Integrated Agriculture Development Kemasin Semerak. Fig.1.1.1 shows the Paddy Production in Granary area in 2011 (Department of Statistic, 2011). Half of the total paddy production is from MADA area.

Paddy seedlings are planted twice a year in Malaysia, in main season and off season. The main season paddy plantation in Northern region is defined as paddy which has a commencement month of planting between August to February of the following year. However, there is no significant difference regarding the tillage energy, fertilizing consumption and harvesting energy between the main season and off season (Bockari-Gevoa, S.M., et al, 2005). Fig.1.1.2 shows the paddy harvesting calendar in Peninsular Malaysia.

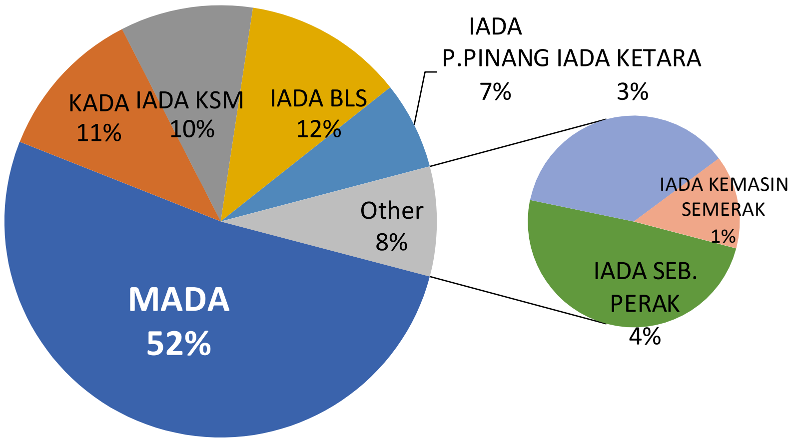


Fig.1.1.1: Paddy Production in Granary Area in 2011 (Department of Statistic, 2011)

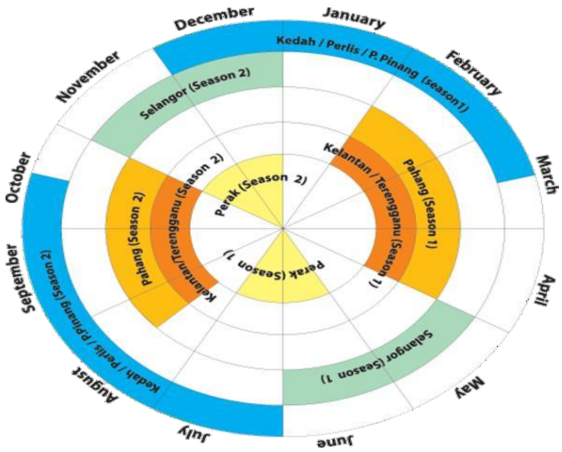


Fig.1.1.2: Paddy Harvesting Calendar in Peninsular Malaysia (BERNAS, 2013)

1.1 Problem Statement

1.1.1 Forest Damage

Wood is one of the main materials in building construction and furniture manufacturing. Wood usage continues to rise from year to year as the population grows in the world. However, the availability of natural wood is very limited. The high rate of forest damage followed by increasing public demand for wood makes wood materials in rare conditions so that the price of natural wood rises sharply. Thus, an alternative wood substitute is needed to overcome this problem. An alternative wood substitute is a particleboard made of agricultural wastes. One of the potential organic wastes that can be used as raw material for particleboard manufacturing is rice straw (Odozi TO et al, 1986).

1.1.2 Paddy residue production in Malaysia

Rice straw and rice husks are the main residues from paddy cultivation, generated during the harvesting and milling process. Malaysia is one of the leading producers of paddy. It has gained 0.48 Million tonne of rice husk with 3,176,593.2 tonnes production of rice straw in a year due to the emerging technological development in agro-industry (UNDP, 2002). Malaysia's agriculture department is targeting to improve the productivity of the paddy sector from the current yield from 3 to 5 tonnes per hectare to around 8 tonnes per hectare in 2012 and 9 to 10 tonnes per hectare by 2020 (NCER, 2007). Fig.1.2.2.1 shows the time line of paddy residue production from, 1980 to 2011 (Department of Statistic, 2011). If the target is achieved with 10 tonnes per hectare, the output of paddy will be increased to 6,575,474.8 tonnes per year.

According to national news agency, 200,000 ha idle land in Malaysia will be used for paddy plantation (BERNAMA, 2013). This will increase to about 30% of paddy production. Parallel to these, the paddy residue production will increase up to 7 million in 2020. These need the good waste management practice to handle with this residue.

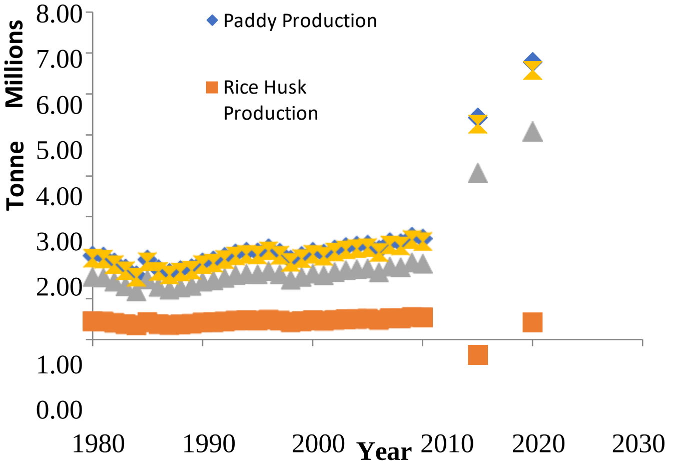


Fig.1.2.2.1: Paddy Residue Production, 1980-2011 (Department of Statistic, 2011).

1.1.3 Open Burning

This study focuses on a source of agricultural fire, which is open burning of rice straw in paddy fields. Following harvesting of rice, there are various practices to clear the land for next cultivation. The common practice is burning, which is the most convenient, cheapest, and fastest way to eliminate rice straw, especially in irrigated paddy field. Burning of rice straw in the field releases pollutants to the atmosphere and contributes to enhance global problems such as climate change. During burning, carbon is released into the air in various forms (J. S. Levine et al, 1996).

1.2 Objective of the Study

i. To evaluate the incorporation of paddy straw in epoxy resin for the production of reinforced composites.
ii. To determine the mechanical properties and physical properties of paddy straw in order to reinforced composite fabrication.

1.3 Scope of Study

i. Recycle of paddy straw waste in reinforced composite fabrication with an average size of 0.106-13.20mm.
ii. Apply of epoxy resin as a matrix material for composite.
iii. Produce paddy waste reinforced composite mix with epoxy resin by weight ratio varied from 0wt% - 100wt% with the presence of epoxy and hardener.
iv. To determine mechanical properties of paddy waste reinforced composite such as tensile, flexural and impact.
v. To identify physical properties of water absorption and density.

1.3.1 Quantity of Epoxy Resin (600g)

Sample	Epoxy (g) + Hardener(g)	Rice Straw
1	67.5%(405g) + 22.5%(135g)	10%(60g)
2	60%(360g) + 20%(120g)	20%(120g)
3	45%(315g) + 15%(150g)	40%(180g)

Table 1.4.1.1 The Ratio of Epoxy Resin and Rice Straw

2. LITERATURE REVIEW

2.1 Composite

Composite is a combination of fiber reinforcement and matrix resin. It is a material formed by combining two ingredients in different phases which cause the new material to have different characteristics of the parent material (Newell J, 2009). The composite consists of two parts, which are matrix as a tie or composite protector and fillers as composite fillers. Natural fibers produce significant advantages such as low density, persistency and proper mechanical properties and re-disposed and re-renewable abilities. In addition, it can be recycled and environmentally friendly (Samrat Mukhopadhyay, et al, 2008). Natural fibers can be disposed and recycled without contaminating nature. The natural fibers are a composite alternative for different composite polymers because of superiority compared to the fiber's synthesis. Natural fibers present important advantages such as low density, appropriate stiffness and mechanical properties, high disposability and renewability which are recyclable and biodegradable. Nature fibers are readily available and known for low-cost, light, biodegradability, lower energy inputs in production per units, easy to process, less abrasive to environment and risk- free.

2.2 Material (Reinforcement)

Among the materials used are residue of paddy straw waste in reinforced composite fabrication. Besides that, apply of epoxy resin as a matrix material for composite. Produce paddy waste reinforced composite mix with epoxy resin by weight ratio varied from 0wt% - 100wt% with the presence of epoxy and hardener.

2.2.1 Rice Straw

Rice straw is the only organic material available in significant quantities to most rice farmers. About 40 percent of the nitrogen (N), 30 to 35 percent of the phosphorus (P), 80 to 85 percent of the potassium (K), and 40 to 50 percent of the Sulphur (S) taken up by rice remains in vegetative plant parts at crop maturity. Previous research has shown that rice straw contains 32-47% cellulose, 19-27% hemicellulose, and 5-24% lignin. Cellulose is a fiber that has the potential to be filler in the manufacture of composite materials (Karimi K et al, 2006).

2.3 Resin (Matrix)

Epoxy resins are relatively low molecular weight monomers with low shrinkage during cure. They can be partially cured and stored in that state. The cured epoxy resins have high chemical and corrosion resistance, good mechanical thermal properties. However, they are more expensive compared to polyester resin. The second of the essential ingredients of an advanced composite system is the curing agent or hardener. These compounds are very important because they control the reaction rate and determine the performance characteristics of the finished part. Since these compounds act as catalysts for the reaction, they must contain active sites on their molecules. Some of the most commonly used curing agent in the advanced composite industry is the aromatic amines like 4.4 methylene-di-aniline (MDA) and 4.4-sulfonylianiline (DDS) (Gassan J et al, 1999).

2.4 Current and Previous Project Related

2.4.1 Rice Straw Particleboard

Several studies relating to the rice straw were done before this, this study was conducted to the rice straw has been utilized to form particleboard by using an epoxy resin matrix. The rice straw particle (20 mesh) was mixed with epoxy resin with the various compositions, pressed with 5 ton of load to produce the rice straw particleboard samples. Mechanical and physical properties of rice straw particleboard were measured. The results showed that the modulus of rupture (MOR) of rice straw particleboard is in the range of 2.07 to 3.31 kgf/mm2, the bending modulus of elasticity (MOE) is found to be 408 to 1490 kgf/mm2, and the density (ρ) is in the range of 0.360 to 0.480 g/cm3. The MOR, MOE, and ρ have the exponential function of the resin composition with the equations of MOR=2.0668+6.5604e-0. 3327.x (kgf/mm2), MOE=344.55+3159.5e-0.203.x (kgf/mm2), and ρ=0.4414-0.3338e-0. 2183.x (g/cm2), where x is the epoxy resin composition (%). This finding will help manufactory to produce rice straw particleboard for desired values of MOR, MOE, and density (Ismail et al, 2018).

2.4.2 Sugarcane Bagasse Board

This study is about the production of composite boards that can prevent heat transfer processes from happening between different dimensions. Sugar cane extraction and kenaf fiber will be used as the main ingredient for this composite production. Natural fibers have many advantages over non-natural fibers. Polyethylene acts as a bond for these two substances. Different composition values for different boards will be applied and generated.

There are four different compositions performed in this study. The first composition is 100% polyethylene. The second composition is 80% polyethylene, 10% kenaf fiber and 10% sugar cane. The second composition consists of 60% polyethylene, 10% kenaf fiber and 30% cane residue. The fourth composition is composed of 60% polyethylene, 10% sugar cane and 30% kenaf fiber.
The created boards will be tested using Rockwell for strength testing, Instron for tension and flexibility testing while KD2 Pro will be used to find thermal conduction rates. The impact test pendulum machine is used to test the strength of the impact. After performing all of these mechanical tests on each board of different composition, the board with 60% polyethylene composition, 30% cane residue and 10% kenaf fiber is the board with the best mechanical properties (M. I. Iskandar et al, 2012).

2.4.3 Rice Husk Particleboard

This study was conducted to develop particleboard formed from rice husk particles by hot pressing with a PVA (Polyvinyl alcohol) binder. A preform was prepared using mixed rice husk particles, PVA powder, and purified water. The rice husk particle and the PVA binder contents were fixed at 80:20. The rice husk particleboard was fabricated using the hot-pressing method. The flexural strength and modulus of resulting particleboard were investigated. Results showed that mainly, the rice husk particleboard satisfied the reference flexural strength (flexural strength is 13 MPa or more) of base type 13 particleboard according to JIS A 5908. However, it exceeded the reference density even for flexural modulus higher than 2.5 GPa (Takao Ota, et al, 2015).

3. Methodology

This research starts with rice straw collection as the main material, crushing rice straw, size reduction, mixing with epoxy and hardener and molding. The composites board than being test by tensile test, flexural test, impact test and density test. The flow of this research as shown on flowchart below.

3.1 Preparation of Raw Material

The paddy straw were collected from residues from paddy cultivation, generated during the harvesting and milling process around the Alor Setar, Kedah,Malaysia. After the collectionin figure 3.1.1, the paddy straw has been crushing by crusher machine to smaller size screened by a sieve with an average of 0.106mm.

Figure 3.1.1 Paddy Straw Collected

Figure 3.1.2 Crushing Paddy Straw

3.2 Preparation of Composites

The composites composed of the fibres and Epoxy solvent were mixed. The mixing process took placed by a hand drill mixer for 10 minutes (Bosch CSB 550 RE, Germany). A steel mould was designed to produce the composite with the length of 300 mm, a width of 200mm and thickness 10 mm which are capable of fabricating specimen according to the standard size. The internal part of the mould was wiped using mould release wax (Meguiar's M08, USA). Upon completion of the mixing process, the mixtures of Epoxy and fibres were put into the mould separately and the mixture was pressed under pressure.

Figure 3.3.1 Paddy Straw and Epoxy

Figure 3.3.2 Weight the Quantity of Resin and Reinforcement

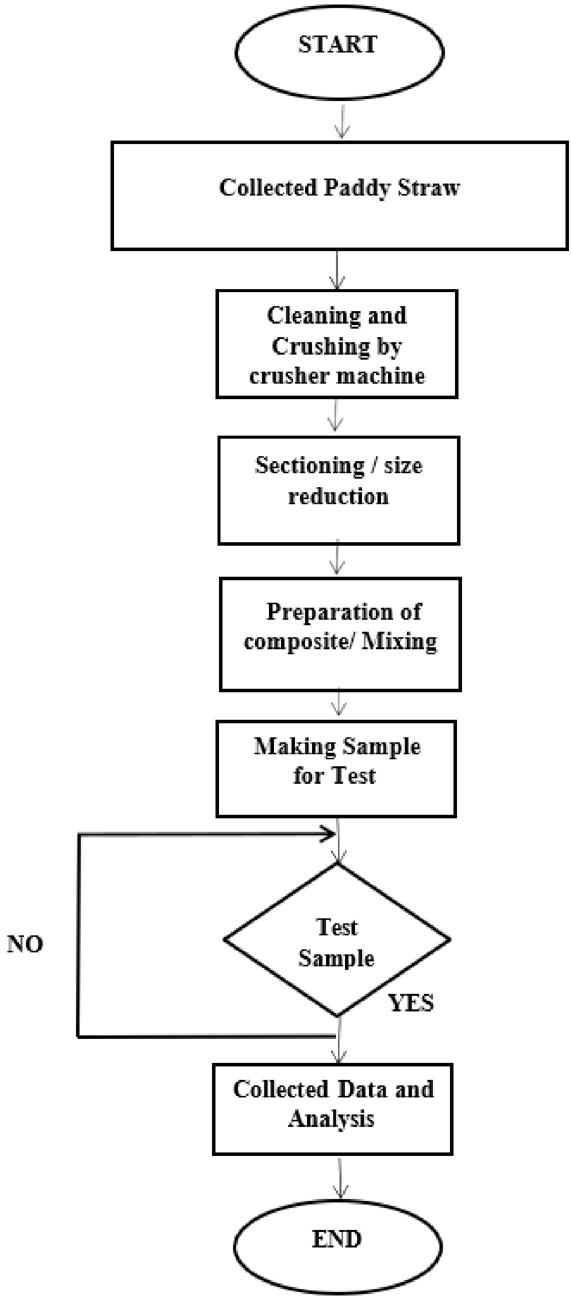
Figure 3.3.3 Mixing Process

Figure 3.3.4 The Mould Was Wiped using Mould

Figure 3.3.5 Moulding Process

Figure 3.3.6 Sample Test

3.3 Flow chart of the research.



3.4 Mechanical properties of Paddy Residuals Reinforced Composites (PRRC)

Mechanical Testing of Composite Samples. To obtained the mechanical property of rice straw fibres-reinforced Epoxy composites, samples were prepared for the tensile, impact and flexural test.

3.4.1 Tensile Test

The tensile test determines the behavior of material under uni-axial loads i.e. tensile modulus. The test was conducted using a universal tensile machine (UE34100 Computer Control Electronic Universal Testing Machine 100kN, China) at a fixed crosshead speed of 1 mm/min in room temperature 25℃.

The specimens were analyzed with dimensions according to ASTM D638. For fibresunder a random-discontinuous orientation, the recommended dimensions of specimens under a sheet, plate and moulded plastics are approximately 165mm x 19 mm x 5mm with 115 mm distance between grips, 76 mm radius of a fillet and 50 mm gauge length.

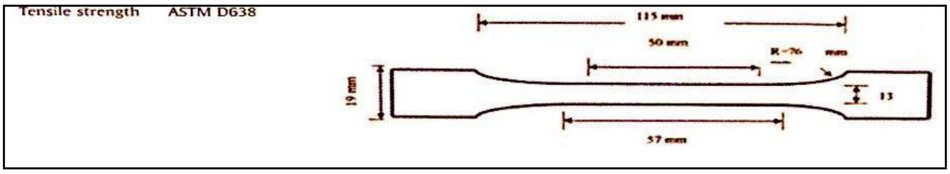


Figure 3.4.1.1 Tensile Strength ASTM D638

3.4.2 Izod Impact Test (Notched)

The notched Izod impact test measure the resistance to impact from a swinging pendulum until the specimen is broken and used to determine the material specific impact properties for general toughness. The test was conducted on Izod Impact Tester (LS-22006-50J, Malaysia) with 8.607 kg hammer mass, 3.4 m/s hammer speed and 120° hammer angle in room temperature. The standard specimen for ASTM is 64 mm x 12.7 mm x 3.2 mm with 45° V notch and 2.5 mm deep at its centre according to ASTM D256.

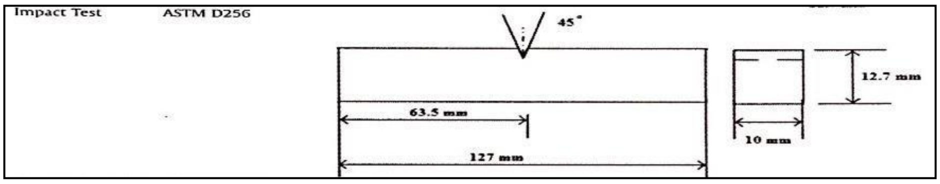


Figure 3.4.2.1 Impact Test ASTM D256

3.4.3 Flexural Test

To obtain the flexural property of paddy residuals reinforced Epoxy composite, samples were prepared to flexural test. The flexural test determines how to the force required to bend a beam under three-point loading conditions. Flexural modulus is used as an indication of a material's stiffness when flexed. The test was conducted using a universal tensile machine (UE34100-100kN, China) at a fixed crosshead speed of 1 mm/min in room temperature 25°C through compressive mode. All the specimens are tested through three samples one by one and the load at crushing was noted. The flexural modulus was taken for each samples and average values were measured. The specimens were analyzed with dimensions according to ASTM D790. The most commonly used specimen size for ASTM is 3.2 mm x 12.7 mm x 125 mm.

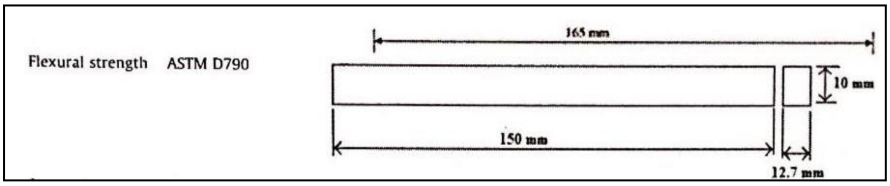


Figure 3.6.3.1 Flexural Strength ASTM D790

3.4.4 Water Absorption Test

The water absorption test determines the water absorption in percent by weight for rice straw fibres reinforced composite (PRRC). The samples were dried in the oven at a temperature of 105°C to 115°C. After that, the dry condition samples were placed on that tray and cool at room temperature. Weight the cool PRRC with digital balance (W1-Dry weight) (Kern PCB, Germany). The test was carried out at room temperature by immersing the dry PRRC in clean water for 24 hours or until equilibrium according to ASTM D570. The PRRC was removed and wiped out with cloth from water and weight immediately (W2- Wet weight). The difference shown the weights is the water absorbed by the PRRC. The difference between the dry and wet PRRCs percentage was calculated.

Eq 1: Percent water absorption (%) = (W2 − W1) x 100.

3.4.5 Density Test

The density test measures the mass per unit volume for paddy straw residuals reinforced composite (PRRC) were determined by the digital balance (Kern PCB, Germany). The density of a composite is determined using its weight in the air (Wa) and in water (Ww) where the densities of air (negligible) and water (ρw) are equal to 0.9975 g/cm^3. The volume in air and the weight in water. Then the calculationof composite density, ρc is:

Eq 2: Composite density, ρc (g/cm^3) = (Wa)/ [(Wa−Ww)/ ρw]

3.5 Process of Grain Size Identification

Figure 3.5.1 Weigh of Rice Straw 50 g

Figure 3.5.3 Weigh the Quantity of Rice Straw Remaining on each Sieve.

Figure 3.5.4 Measured the rice straw remaining on each sieve after weight.

3.5.5 Calculation of Grain Size Identification

The adoption of the ISO metric sieves means that the old AFS grain fineness number can no longer be calculated. Instead, the average grain size, expressed as milimetres (mm) is now used. This determined as follows:

1. Weight 50 g sample of rice straw.
2. Place the sample into the top sieve of a nest of ISO.
3. Remove the sieve and, beginning with the top sieve, weigh the quantity of rice straw remaining on each sieve.
4. Collect the weight of rice straw remaining on each sieve.

50 gram Rice Straw

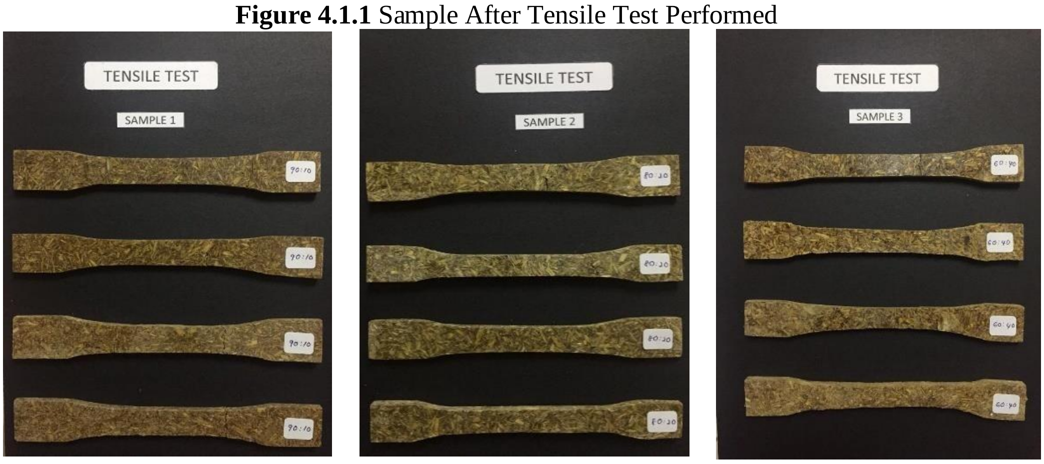
ISO Sieve(mm)	Weigh (g)	Percentage(%)
13.20	4.4	8.8
9.50	4.5	9
5.60	4.8	9.6
3.35	5.8	11.6
1.18	32.1	64.2
0.850	12.9	25.8
0.500	10.9	21.8
0.365	5.7	11.4
0.106	7.2	14.4

Table 3.5.5.1 Table Results of Grain Size Identification of Rice Straw

4. RESULTS AND ANALYSIS

4.1 Results of Tensile test

Figure 4.1.1 Sample After Tensile Test Performed

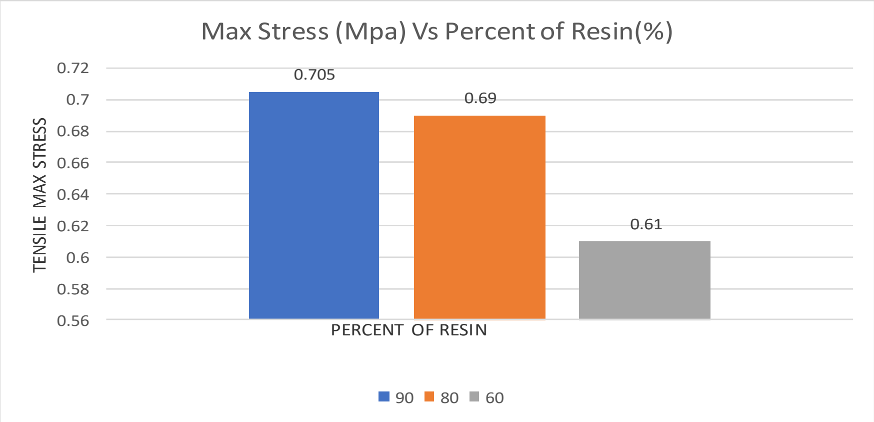


Percentage of Epoxy Resin	Data Results of Tensile Test		
	Area (mm^2)	Maximum Load (kN)	Maximum Stress (kN/mm^2)
S1-90%	100	70.5	0.705
S2-80%	100	69	0.690
S3-60%	100	61	0.610

Table 4.1.1 Tensile Test Data Results

Table 4.1.1 shows the results of tensile test for rice straw composite board. The tensile test results show that sample 1 is the highest maximum load composite 70.5kN, follows by sample 2 with maximum load of 69kN. The lowest maximum load is sample 3 61kN.

Observations of graph 4.1.1 show the maximum stress that occurs on specimen 1 with higher percentage of epoxy resin. The tensile strength of each specimen varies depend on percentage of epoxy resin. The test results show that the tensile strength of the composite material affects the straw fiber.



Graph 4.1.1 Maximum Pressure Against Resin Percentage for Tensile Test

4.2 Results of Flexural Test

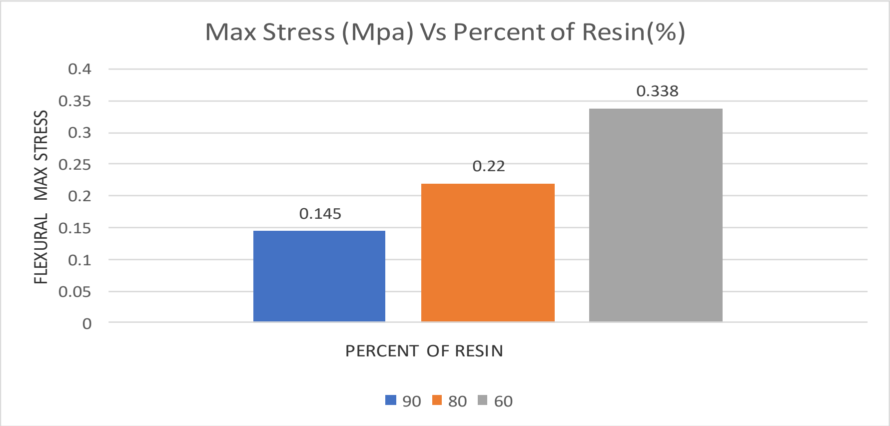
Figure 4.2.1 Sample After Flexural Test Performed

Percentage of Epoxy Resin	Results of Flexural Test		
	Width (mm)	Thickness (mm)	Maximum Pressure (kN/mm²)
S1-90%	10.00	10.00	0.145
S2-80%	10.00	10.00	0.220
S3-60%	10.00	10.00	0.338

Table 4.2.1 Flexural Test Data Results

Based on the above information data, the table describe the maximum amount of composite material pressure from each specimen. The maximum pressure received through rice straw fiber composite material with epoxy resin is 0.338 kN /mm^2. The lowest compressive stress on the flexural test specimen is 0.145 kN /$mm2$ which is 60% of the epoxy resin used. All specimens were categorized according to a predetermined percentage of epoxy resins.

This shows that the rice fiber composite material is a good flexural strength. The flexural test is found in graph 2 below which states the tensile strength of the material through flexural test for rice straw fiber composite. Observations of graph 4.2.1 show the maximum stress that occurs on specimen that have low the percentage of epoxy resin. The compressive strength of each specimen occurs because the rice straw fiber material is reinforced with epoxy resin. The flexural test results show that the tensile strength of the composite material affects the fiber material of the rice straw.



Graph 4.2.1 Maximum Pressure Against Resin Percentage for Flexural Test

4.3 Results of Impact Test

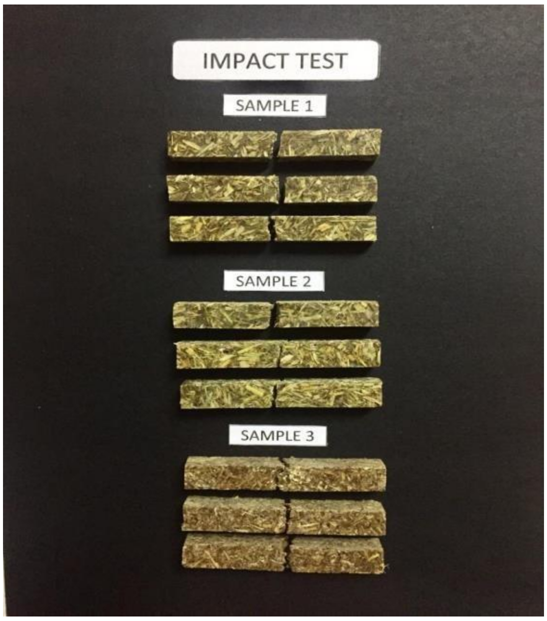
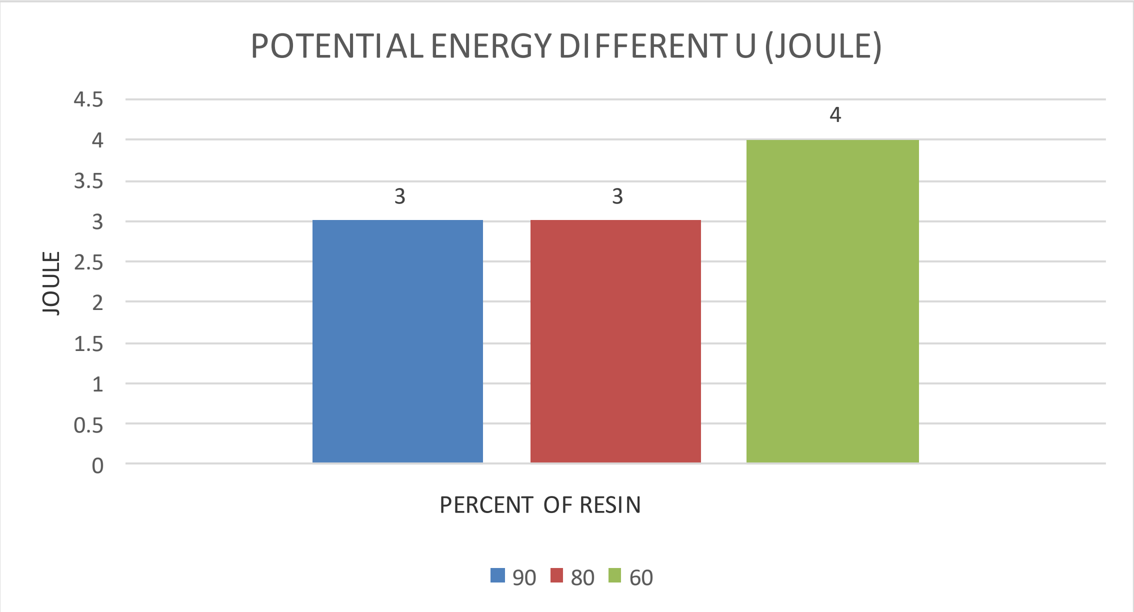


Figure 4.3.1 Sample After Impact Test Performed

Percentage of Epoxy Resin	Energy Absorb (Joule)			
	Sample	Angle	Izod (J)	Average Izod (J)
90 %	S1	111	3.00	3.00
	S2	111	3.00	
	S3	111	3.00	
80%	S1	112	3.00	3.00
	S2	112	3.00	
	S3	112	3.00	
60%	S1	110	4.00	4.00
	S2	110	4.00	
	S3	110	4.00	

Table 4.3.1 Energy Absorb for Impact Test Results

Based on the data and information above, shows the energy absorbed for the impact test (Izod) on all samples used. The Izod test used is to determine the amount of energy absorbed by the material during fracture. The results of the study found that the maximum average energy absorb is 4.00J which is in the sample 60% of resin. This shows that the sample has a lot of energy absorbed by the material compared to other samples. While the average minimum Izod is 3.00J in the 90% and 80% samples. The amount of energy absorbed can determine the toughness of the material depending on the ductile- brittle transition. It is widely used in industry because it is easy to carry out and results can be obtained.



Graph 4.3.3 Potential Energy for Izod test

4.4 Results of Density Test

Figure 4.4.1 Density Test

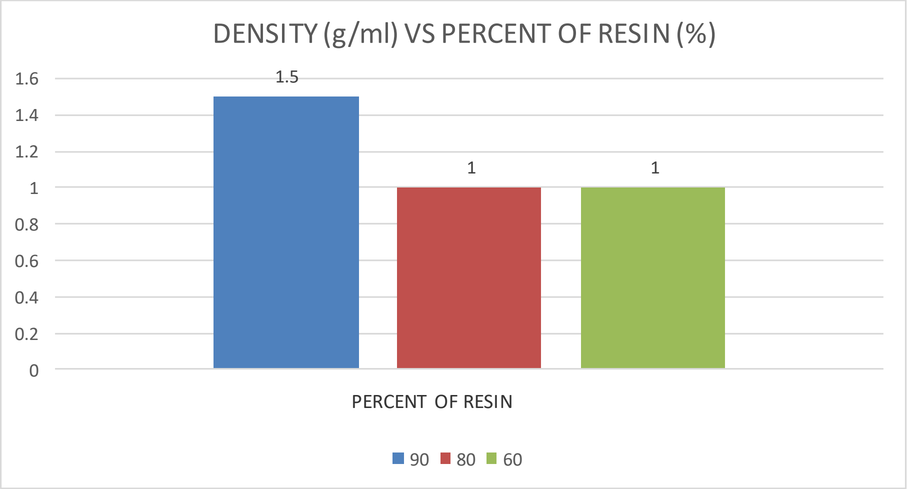
No	Fiber	Weight (g)	V1 (ml)	V2	V=V2-V1	Density
1.	90: 0	3.0	100	102	2	1.50
2.	80: 20	4.0	100	104	4	1.00
3.	60: 40	3.0	100	103	3	1.00

Table 4.4.1 Density Test Results

Based on the data and information above, show the immersion volume of the specimen and the total density of each specimen according to the set ratio. This data also states the specimen weight, total volume before and after, and total density according to the sample.

The formula for density is as follows:

$$\text{Density} = \frac{weight}{Volume}$$



Graph 4.4.1 Density Vs Percent of Resin

4.5 Results of Water Absorption Test

Initial Weight (g)	Ratio	Time (1 hours)	Time (2 hours)	Time (3 hours)	Time (4 hours)	Percentage (%)
16	90: 10	16 g	16g	16g	16g	0
17	80: 20	17g	18g	18g	18g	6
15	60: 40	15g	16g	17g	17g	13

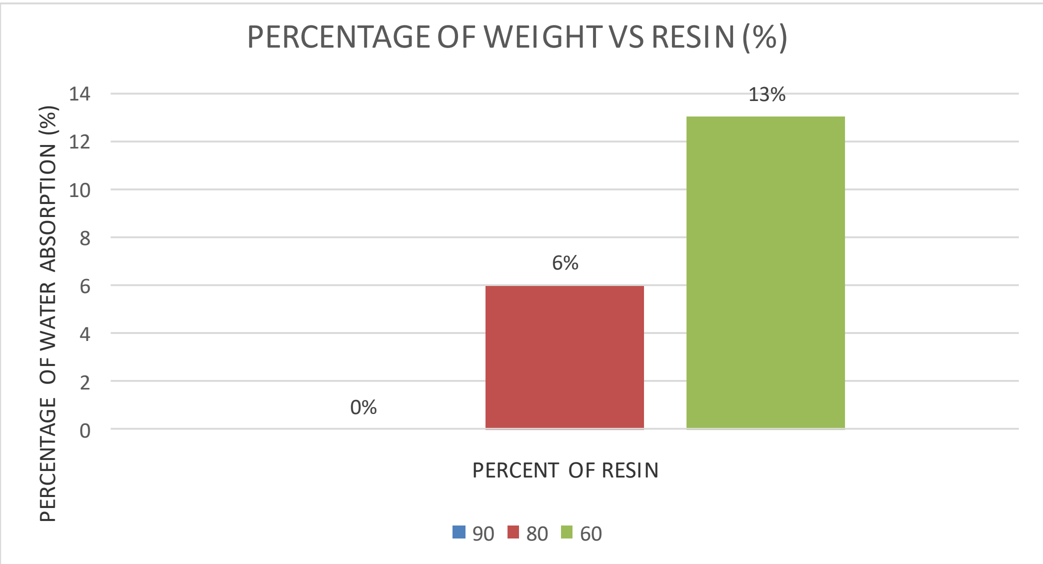
Table 4.5.1 Water Absorption Test Results

Based on the data and information above, shows the percentage of water immersion in one day for all samples performed. The percentage value of water immersion different according to different sample ratio. The highest percentage of water seepage is 13% which is absorbed at a ratio of 60 percent. At a ratio of 90%, no water absorption occurs on the sample because the ratio uses 90 percent epoxy resin which is a very strong material and is not absorbed by water.

The percentage of water absorption can be obtained by using the formula as below:

Percentage:

$$= \frac{(W2 - W1)}{W1} \times 100$$



5. CONCLUSION

Based on the results of this research, paddy residual reinforced composite can be use as particle board, where, the best sample is sample no 2 which is (80% epoxy and 20% rice straw) due to its balanced mechanical and physical properties. composite board that contains a higher percentage of epoxy will make the composite board hard and high strength, while the low percentage of resin will make composite board soft and low strength. The presence of composite materials from rice straw and epoxy can reduce environmental pollution and enhance the mechanical and physical properties of previously available composite materials.

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