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Recycled polystyrene with UF addition as the binder for PCM-impregnated particleboard: effect of adhesive percentage

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A proposal submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Forest Resources Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY

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DECLARATION

I declare that this thesis entitled “Properties of Phase Change Material Impregnated Sawdust” is the results of my own research except as cited in the references.

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RECYCLED POLYSTYRENE WITH UF ADDITION AS THE BINDER FOR PCM-IMPREGNATED PARTICLEBOARD: EFFECT OF ADHESIVE PERCENTAGE

ABSTRACT

In the research, sawdust mixed with polystyrene that has been diluted with urea formaldehyde (UF) and impregnated with palmitic acid (PCM) is a solution to reduce the release of formaldehyde that can cause pollution of the indoor environment for human health, and the effect will cause various symptoms such as headache, nose and throat irritation, and fatigue (Kanazawa et al., 2010). Additionally, palmitic acid (PA) is a phase change material (PCM) to prevent external light from penetrating into the particle board. By creating a wood composite mixed with a percentage of polystyrene AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%) and mixed with UF and PCM (Palmitic Acid), researchers can analyse the wood dust resistance. to polystyrene and urea formaldehyde and also the quality of sawdust impregnated with Palmitic Acid (PA) as PCM and evaluate the physical and mechanical properties of wood composites formed from rubber wood mixed with polystyrene and urea formaldehyde (UF) and impregnated with Palmitic Acid (PA). The assessment involves rubber-wood sawdust tests (TGA, XRD, and FTIR tests) and wood composites (bending and water absorption tests). For example, the result found in this thesis is the XRD test, which is a sample of AMR 1 (10%) in wood that has gone through the impregnation process. The degree of crystallinity is 40.8%, which is usually caused by.

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RECYCLED POLYSTYRENE WITH UF ADDITION AS THE BINDER FOR PCM-IMPREGNATED PARTICLEBOARD: EFFECT OF ADHESIVE PERCENTAGE

ABSTRACT

Dalam penyelidikan habuk papan yang dicampurkan dengan Polisterin yang telah dicairkan dengan Urea Formaldehyde (UF) dan diresapi dengan Palmatic Acid (PCM), ini adalah satu penyelesaian untuk mengurangkan pelepasan Formaldehyde yang boleh menyebabkan pencemaran pencemaran persekitaran dalaman bagi kesihatan manusia, dan kesannya akan mengalami pelbagai gejala seperti sakit kepala, kerengsaan hidung dan tekak dan keletihan (Kanazawa et al., 2010). Selain itu, Palmitic Acid (PA) adalah sebagai Phase Change Material (PCM) untuk menebat cahaya luar untuk tembus kedalam papana zarah. Dengan mencipta komposit kayu bercampur dengan kadar peratusan polisterin AMR 1 (10%), AMR 2 (15%), dan AMR 3 (20%) dan dicampurkan dengan UF dan PCM (Palmitic Acid), penyelidik boleh menganalisis ketahanan habuk kayu terhadap polisterin dan urea formaldehyde dan juga kualiti habuk papan yang diresapi dengan Asid Palmitic (PA) sebagai PCM dan menilai sifat fizikal dan mekanikal komposit kayu yang terbentuk daripada kayu getah yang dicampurkan dengan polisterin dan urea formaldehyde (UF) dan diresapi dengan Asid Palmitic (PA). Penilaian adalah melibatkan ujian habuk papan kayu getah iaitu TGA, XRD, FTIR, dan ujian komposit kayu iaitu ujian lenturan dan serapan air. Sebagai contoh, keputusan yang terdapat dalam tesis ini adalah ujian XRD iaitu sampel AMR 1 (10%) dalam kayu yang telah melalui proses impregnasi , darjah kehabluran adalah 40.8% yang disebabkan oleh lazimnya .

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CHAPTER 1

1 Introduction

1.1 Background of study

When paired with Phase Change Materials (PCM), recycled polystyrene (PS) with the addition of Urea-Formaldehyde (UF) as a binder provides a great option for manufacturing composite materials with better thermal qualities. PS, a widely recycled plastic polymer, has good thermal insulation qualities and is therefore suited for a wide range of thermal applications. In contrast, PCM is a material that can absorb and release huge quantities of thermal energy during its phase change. The inclusion of UF as a binder improves the mechanical strength and stability of the composites, as well as the adhesion between the PS and PCM particles. This combination results in a composite material with a number of advantages. First, because of the inherent qualities of PS, it provides great thermal insulation. When paired with Phase Change Materials (PCM), recycled polystyrene (PS) with the addition of Urea-Formaldehyde (UF) as a binder provides a great option for manufacturing composite materials with better thermal qualities. PS, a popular recycled plastic Second, the addition of PCM allows for effective thermal energy storage by capturing and releasing heat during the phase change. Third, the UF binder boosts the composite's mechanical strength, assuring longevity and robustness.

Finally, UF enhances PS and PCM particle compatibility, resulting in a uniform distribution and a stable composite structure. Thorough testing and consideration of safety

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considerations should be done to assess the performance and suitability features of composite material for a given application.

The use of UF (Urea-Formaldehyde) as a binder for PCM (Phase Change Material) to recycled polystyrene can be utilised to make composite materials with better thermal qualities. Recycled Polystyrene (PS) and Phase Change Materials (PCM) are discussed in detail. Polystyrene is a popular polymeric polymer that may be recycled and transformed into a variety of products. It is useful for thermal applications because to its strong thermal insulation qualities. At a given temperature, PCM is a material that may absorb or release a considerable quantity of heat energy during its phase change (solid to liquid or vice versa). It is frequently utilised in applications like as building insulation, energy storage systems, and temperature regulation to store and release thermal energy.

Adding UF as a Binder: Urea-Formaldehyde (UF) is a thermoset resin that is frequently used as a binder in composite materials. It may increase the mechanical strength and stability of composites, as well as the adhesion of PS and PCM particles. You may build numerous composite materials with benefits by mixing recycled polystyrene with UF as a binder for PCM. Thermal insulation, energy storage, mechanical strength, and compatibility are a few examples. However, it is critical to evaluate your application's unique demands and conduct extensive testing to optimise the composition and identify the performance characteristics of the composite material. Also, whether working with UF or any other chemical, be certain that all appropriate safety precautions are taken.

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1.2 Problem statement

The biggest issue with particleboard is that it is susceptible to moisture damage. Particleboard is created by compressing wood particles with glue, resulting in a board with poorer structural integrity than solid wood. Particleboard may expand, deform, and even disintegrate when exposed to dampness, affecting its strength and longevity.

Furthermore, particleboard has a poorer screw-holding ability than solid wood, making it less appropriate for applications requiring strong connections. It is also more prone to edge chipping and damage. Particleboard also has low impact and abrasion resistance, making it unsuitable for high-traffic areas or applications that need regular handling.

Moreover, particleboard contains formaldehyde, a volatile organic compound (VOC) that can be released over time and offer possible health problems, especially in poorly ventilated environments or when exposed for an extended period of time.

However, technological developments have resulted in the creation of moisture-resistant and low-formaldehyde emission particleboards, which address some of these difficulties to some extent.

1.3 Expected output

In this research project, particleboard can be prepared with UF that has impregnated polystyrene as a binding material. PCM has also been treated with polystyrene to absorb heat. The primary materials for preparing the qualities and structure of this wood will be capric acid and acetone. As a result, this combination is projected to increase the physical and mechanical qualities, as well as the density of particleboard manufactured from recycled polystyrene (PS), which may be properly assessed.

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1.4 Objective

1- To study the properties of wood composite of different adhesive percentage made using PS/UF mixture as a binder with PCM addition.

2- To study the thermal performance of wood composite made using PS/UF mixture as a binder with PCM addition.

1.5 Scope of study

The scope of the research on recycled polystyrene with urea-formaldehyde (UF) addition as a binder for Phase Change Materials (PCMs) encompasses many essential areas. The study's goal is to examine and optimise the composition, characteristics, and performance of the PCM material created utilising this binder system. Within the scope of the study, the following topics will be addressed

Furthermore, he was able to test the impact of different ratios on the thermal and mechanical characteristics of the composite by employing several composite formulations by adjusting the amount of recycled polystyrene, UF binder, and phase change material according to the predefined phase. Furthermore, by employing proper manufacturing technologies and procedures to manufacture composite materials of consistent quality and homogeneous component distribution. This can include compression molding, extrusion, or other appropriate procedures.

Then, conduct experiments to determine the thermal characteristics and performance of composite materials. This may include testing the composite's thermal conductivity, thermal stability, latent heat storage capacity, and thermal cycling resistance. Additionally, analyze the mechanical qualities of composites, such as tensile strength, flexural strength, and impact resistance. This will entail performing routine mechanical tests to determine the overall structural integrity and durability of the composite. Finally,

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analyze the experimental results to optimise the composite formulation and production parameters. This might include statistical analysis, modeling, and simulation approaches to better understand the link between the composition and performance of composite materials

The scope of the research on recycled polystyrene with urea-formaldehyde (UF) addition as a binder for Phase Change Materials (PCMs) encompasses many essential areas. The study's goal is to examine and optimise the composition, characteristics, and performance of the PCM material created utilising this binder system. Within the scope of the study, the following topics will be addressed:

Binder Optimisation: The study will determine the best ratio or proportion of UF resin to use in the recycled polystyrene matrix. To obtain the necessary mechanical strength, stability, and thermal characteristics of the PCM material, several compositions will be developed and assessed.

1.6 Significant of study

As a result of this study, the usage of recycled polystyrene with the addition of UF as a PCM binder has been recommended. It is important in a number of essential areas, including sustainability and environmental impact, which it addresses by using recycled polystyrene, diverting garbage from landfills, and reducing reliance on virgin materials. This study follows the principles of the circular economy and contributes to the reduction of plastic waste.

The inclusion of PCM into composite materials then enables effective thermal energy storage and management. By better understanding the performance characteristics of composites, this research has the potential to enhance the development of energy-efficient building insulation, thermal control systems, and energy storage applications. This can assist cut energy use and increase overall sustainability in a range of industries. Another

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critical consideration is possible cost-effectiveness. The utilisation of recycled polystyrene, which is typically less expensive than virgin material, allows for the manufacture of cost-effective composite materials. This low cost may contribute to greater adoption and use of composites in industries seeking effective heat management solutions.

Furthermore, the combination of recycled polystyrene with UF binder improves the composite's mechanical strength and stability. As a result, the material is more robust and has greater thermal insulation capabilities. The study's findings may have practical consequences for industries such as construction, transportation, and others where effective heat transfer regulation is critical

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CHAPTER 2

2 LITERATURE REVIEW

2.1 RUBBER WOOD (HEVEA BRASILIENSIS)

2.1.1 TAXONOMY, MORPHOLOGY AND ECOLOGY OF RUBBERWOOD

Hevea brasiliensis, often referred to as rubberwood, is a substantial evergreen tree with the potential to reach a height of 40 metres. It has a straight trunk that may measure up to 50 cm in diameter and branches out at the upper part to form a thick canopy. Hevea brasiliensis, often referred to as rubberwood, is indigenous to Bolivia, Brazil, Colombia, Peru, and Venezuela (Yi Peng Teoh, 2011). The classification of Hevea brasiliensis is as follows:

- Domain : Eukaryota
- Kingdom :Plantae
- Class :Dicotyledonae
- Family :Euphorbiarceae
- Genus :Hevea
- Speacies :Hevea brasiliensis

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2.2 Plastic problem

Plastic is a polymer designed for many uses and it is cheap. However, plastic has a dangerous effect on the environment. This plastic is also a non-biodegradable resource (Moshood et al., 2022), so researchers have found a way to reduce environmental pollution by using plastic and wood to make a variety of high performance composite products (Chaharmahali et al., 2008).

2.3 Polystyrene

Polystyrene is used for packaging goods or food. Polystyrene is also a non-biodegradable product because it is also part of plastic and it takes time to dispose of it. So, recycling polystyrene is an alternative that is used (Ricky et al,2010). Many researchers investigate the effectiveness of using polystyrene as a binder to produce value-added wood composites. This particle board was successfully produced and developed from polystyrene waste and dates and tested that the flexural and tensile strengths have achieved acceptable values plus good fiber-matrix interface adhesion (Foti et al., 2022).

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2.4 Urea Formaldehyde

Urea formaldehyde resin is polycondensation urea and formaldehyde products either in neutral or acid or alkaline or acid/alkaline medium. Urea formaldehyde, mostly used as adhesive component material, protective finish and mold. In addition, it has a low price for obtaining it, the absence of color in the cured polymer, good technological characteristics, low cure temperature, resistance to abrasion and microorganisms, hardness, easy application is exceptional urea quality formaldehyde and good thermal properties. For the resin structure

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there are also some that lead to some undesirable mechanical properties that can limit its use. Although it has advantages, as mentioned above it is accredited to urea formaldehyde, it is too brittle and hard to be used simply as a coating material. Urea formaldehyde resin also has poor properties against formaldehyde release and resistance (Osemeahon & Dimas, 2014).

Since urea formaldehyde resin is soluble in water, it requires full use to meet the different needs of industrial coating in terms of reduction due to VOC in environment and aspect of emulsion paint drafting. This can result if it exists problems of poor water resistance, brittleness, and formaldehyde emissions associated with urea formaldehyde resin can be handled (Osemeahon & Dimas, 2014). Formaldehyde can cause various symptoms, diseases, and can have adverse health effects. For long-term exposure to high levels formaldehyde has been linked to cancer. by reducing formaldehyde and adding polystyrene to further strengthen the particle board.

2.5 PCM

The Development Sector is reliant on a continuous supply of energy in order to function. The building business consumes a substantial amount of energy. Hence, it is essential to develop novel materials in order to enhance the thermal efficiency of buildings. Consequently, the use of phase change material (PCM) into structures has gained popularity in recent decades. Hence, building energy use is around 33% of total energy usage. The results indicate that policy adjustment in energy consumption is influenced by four primary factors: resource availability, energy demand, technology choice, and energy consumption (Chong et al, 2015). The link between energy usage and economic growth is inherently interconnected. The collaboration between the two parties has successfully accomplished the objective of the building sector, where energy consumption is a pivotal concern. The development sector's energy usage

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additionally exacerbates the adverse environmental impacts. Hence, several initiatives have been implemented by multiple stakeholders to mitigate this issue. Efforts are also underway to create more appropriate technology. The continuous study and development conducted by researchers have also made significant contributions to the endeavours aimed at resolving this issue.

Based on the article, energy sources may be classified into two distinct categories: renewable and non-renewable energy (Anne Marie Helmenstine. April 23, 2018). As per the findings of a scholarly publication, Phase Changing Materials (PCM) function by effectively storing and releasing energy at the suitable temperature. The usage of concrete and PCM building materials in construction sectors has proven effective in lowering global energy consumption. Utilising PCM in research or manufacturing processes will result in a reduction of energy consumption (Saman Rashidi, 2020). Phase Change Materials (PCM) enhance the thermal sensitivity of a structure by efficiently transforming heat mass. According to Georgios Deli Georgiou (2014), natural gas has been adopted as a substitute for traditional energy sources and is increasingly being used in lieu of coal in several power plants to mitigate carbon emissions resulting from electricity production. Wood, a renewable energy source, is being progressively used as an alternative to coal due to its cost-effectiveness and ease of acquisition. Wood pellets are a sustainable energy source that has the capacity to reduce overall CO2 emissions.

Energy conservation, the use of renewable energy sources, and the preservation of the environment are widely embraced. A less recognised option for developing novel energy storage technologies to mitigate the greenhouse impact is Phase Change Materials (PCM). When the material is subjected to heat, its temperature remains constant, but the heat induces a transition to a phase with greater energy. They operate at a consistent temperature. The phase change material (PCM) stores about 100 times more heat as latent heat of fusion compared to

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the heat seen by our senses. The main types of phase change materials (PCMs) that undergo melting throughout a broad temperature range consist of eutectic organic and inorganic compounds, paraffin wax, hydrated salts, and fatty acids. The wood / CA-SA composite will be evaluated for its hygroscopic and mechanical properties, as well as its thermal energy storage (TES) capabilities. The composite, which includes phase change material (PCM), will be analysed using SEM, FT-IR, and XRD techniques to assess its morphological and physicochemical characteristics. The thermal energy storage (TES) properties, chemical/thermal cycle reliability, and thermal degradation stability of the product composite will be determined using TG/DTA and DSC investigations (Ali Temir, 2010). PCM, or Phase Change Material, has significant promise for achieving energy and cost efficiencies in building construction.

According to the report, PCM technology has the capability to provide both heating and cooling for a structure via at least three distinct methods. The PCM in constructing walls is the first. The third phase change material (PCM) is used in heat and cold storage units that are situated inside the building itself, rather than in external structures like heat/ice storage tanks. The second PCM is used in building components other than walls, such as floors and ceilings. The increasing environmental concerns and escalating cost of fossil fuels have led to research into thermal energy storage for the use of space heating and cooling in buildings. Extreme temperatures necessitate the use of heating and cooling systems. By storing and then releasing thermal energy for heating or cooling purposes, a portion of the high energy needs during peak hours may be shifted to off-peak hours. Consequently, it is feasible to achieve effective energy management and financial profit. The building envelope plays a crucial role in managing building energy by adjusting the heating/cooling loads between the interior and external environments to meet the building's thermal requirements.

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The combination of these two substances will significantly enhance the surface resilience and consistency, resulting in energy savings and improved adherence to the sawdust. Furthermore, it enhances mechanical characteristics by facilitating the formation of fibre connections that contribute to improved stress distribution. These particleboards have the ability to distribute weight efficiently, hence enhancing their overall load-bearing capability. The qualities of wood, such as dimensional instability and susceptibility to fungal and insect decay, impose limitations on its usage as a material. Utilising wood resources will result in an atypical state. The non-decomposable characteristics of this wood may be enhanced by chemical treatment, namely by including capric acid. This treatment effectively reduces energy consumption in the production of particleboard. The use of sensitive, latent, and thermochemical energy storage in thermal energy storage (TES) for buildings is achieved through various methods such as passive systems in the building envelope, inactive states of phase changing materials (PCM), absorption systems, and seasonal storage. These measures aim to achieve sustainable heating and cooling in buildings through the use of TES (Alvarode Graciaa and Luisa F.Cabezab, 2015). Phase Change Materials (PCM) have the ability to absorb and release thermal energy via the mechanism of latent heat transfer during phase change. PCM may be classified as either inorganic, organic, or eutectic material. It has the ability to enhance energy efficiency in buildings while simultaneously reducing reliance on fossil fuels (Meysan Nazari, 2020).

PCM, or Phase Change Material, is a compact set of experiments that examines the absorption of chemicals present in materials. It demonstrates the process of phase change into a commonly used construction material, resulting in the formation of a superior material. Carboxylic acids and polyol alcohols provide technical properties that make them suitable as phase transition materials for studying circumstances and alterations. The absorption process is conducted on specimens composed of typical Finnish construction materials, and it may be

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accomplished by using carboxylic acids as an alternative substance to obtain a proportional increase in capacity. After absorption takes place in the manufacturing process, it is essential to implement measures to prevent mistakes or leaks. PCM has the ability to absorb or release a significant amount of heat during the interchange of physical and mechanical characteristics, such as during phase transition. In order to store thermal energy and prevent energy loss in buildings, a phase change material (PCM) is included into the cemented composite. Cement-based composites including phase change material (PCM) bodies have the potential to autonomously regulate interior temperature and enhance thermal comfort in buildings. Furthermore, this PCM may be used in any given scenario to create a more flawless end result. Most PCMs are known to melt at the required fusion temperature. However, for this material to be used as a latent heat storage material, it must have certain desirable kinetic, thermodynamic and chemical properties (Tyagi & Buddhi, 2007).

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CHAPTER 3

3 MATERIAL AND METHOD

3.1 Material preparation

For the experiment, the raw materials used are urea formaldehyde (UF), Palmitic acid as a phase change material (PCM), and polystyrene and sawdust will be obtained from the laboratory and workshop at Universiti Malaysia Kelantan, Jeli. Some polystyrene material was purchased and prepared. PCM and UF will be the main components of this project. To make particles with a narrower size range, polystyrene will be melted before the particle board production process. The wood chips will then be sieved to remove dust before particles are obtained in a smaller size range. The impregnation of rubber sawdust will be determined during the PCM process. The PCM composite will be characterized by FTIR, TGA, DSC, and XRD analysis.

3.2 PCM impregnation process

Palmatic acid is the essence of PCM will be dissolved in acetone and will be mixed with wood dust. Then dry in the oven with 50°C for overnight.

3.3 Particleboard making

Crushed rubber wood and sawdust are first conditioned to remove the moisture content by baking them in an oven at 105°C for 2 hours. The conditioned material is carefully combined with different ratios of each UF adhesive dissolved in the appropriate solvent. After that, it is combined with PCM, which is capric acid. After that, it is placed manually in a mound of size 30 cm x 30 cm 1 cm with a percentage of 10%, 15% and, 20% for each particle board to be

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produced. The mat was first pressed at 500 kg/cm2 for 2 minutes before being hot pressed at 180 °C for 10 minutes.

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3.4 Characterization

The investigation of rubber wood impregnation characteristics with Phase Change Material (PCM). The leakage test, TGA/DSC, FT-IR, and XRD will be used to characterise the impregnation in this investigation. By following the process, the morphology and physio-chemical properties will be characterised.

I. Thermogravimetric analysis (TGA) & Differential scanning calorimetric (DSC) (TGA/DSC)

TGAs are crucial laboratory tools for identifying material characteristics. Thermogravimetric analysis (TGA) is a method used to determine the characteristics of materials used in environmental, food, pharmaceutical, and petrochemical applications. TGA/DSC weighing technology provides position-independent weighing, an automated internal calibration weight with a wide measurement range, the best minimum weight performance, and the highest weighing accuracy and precision. TGA and DSC measurements will be taken using the (SDT Q600-TA Instruments) at a heating rate of 10°C/min from room temperature to 700°C.

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II. Fourier-transform infrared (FT-IR) machine

FTIR spectra may be used to identify the composition of solids, liquids, and gases. The most common uses include recognising unknown materials and confirming industrial materials (incoming or departing). The information content is usually highly specific, allowing for subtle separation between comparable pieces. The FT-IR equipment (IRAffnity-1S) will scan from 400 to 4000 cm (-1) in powder form for this investigation.

III. X-ray diffraction (XRD)

The use of X-ray diffraction (XRD) to characterise crystalline materials is a potent non-destructive method. The crystalline index is measured in wood samples to assess the structure, phase, crystal orientation, and other structural factors such as average grain size, crystallinity, stretch, and crystal defects. The investigation will be performed using an XRD equipment (Rigaku model, Japan) with Cu K at 35 kV and 30 mA, with diffraction angles ranging from 5 to 70 (2), at a scan rate of 0.04 /min.

3.5 The moisture content of particleboard

The moisture content was determined using the Japanese Standard (JIS A 5908, 2003). A particleboard sample of 10mm x 10mm thickness was cut to provide an initial weight of at least 20 g. The sample was initially weighed, then dried overnight in a 102 °C oven before being weighed again after chilling in a desiccator. The practise was repeated until the final weight remained steady. The test was run three times, with the results derived using the equation.

$$\text{Moisture content, \%} = \frac{m_H - m_0}{m_0} \times 100$$

Where mH is the test piece's original mass in grams and m0 is the test piece's mass after drying in grams.

3.5.1 Density of particleboard

With the sample dimension modified, the density of particleboards was determined using the Japanese Standard (JIS A 5908, 2003). Particleboards were cut to 10 mm thickness. Thetest

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items were conditioned in a conditioning chamber overnight at 25°C and 50% humidity. The dimensions of the sample were measured again using a caliper and weighed with an analytical balance. The density was calculated using the equation.

$$\mathrm{Density\ (kg.m^{-3}),\ \rho = \frac{m}{b_1\ \times\ b_2\ \times t}}$$

Where m represents the test piece's mass, b1 represents its width, b2 represents its length, and t represents its thickness.

3.5.2 Thickness swelling and water absorbtion of particleboard

The Swelling thickness of particleboard after immersion in water was measured using the Japanese Standard (JIS A 5908, 2003). The particle board test pieces were conditioned at 25 °C and 50% relative humidity for 24 hours but the particle board was first cut to a size of 30 mm × 30 mm. thickness, length, and width of the sample are all weighed, measured and then soaked in water. After one day (24 hours), the test pieces are removed, the excess water is collected, and the dimensions after water immersion are measured. Weighing the test piece determines the amount of water absorbed. Swelling thickness and water absorption capacity are calculated using the equation below.

$$Swelling\ or\ Water\ absorbtion, \% = \frac{m_i - m_0}{m_0} \times 100$$

Where m0 represents the measurement before immersion and mi represents the measurement after immersion.

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3.5.3 Bending strength of particleboard

Bending strength of particleboards was determined using the Japanese Standard method (JIS A 5908, 2003). Particleboard that has been cut to 200 mm x 50 mm and placed in a room with a relative humidity of 50% and air conditioning at 25 degrees Celsius. Instron Tensile Machine Model 5582 tested the seized components. For the testing, the loading rate was set at 10 mm/min. The results were represented in modulus of elasticity and bending strength using the equation.

$$E_m = \frac{l_1^3\ (F_2 - F_1)}{4\ bt^3\ (a_2 - a_1)}$$

Where modulus of elasticity = Em (in N/mm^2)

l_1 is the distance between the centers of the supports, in millimeters

b is the width of the test piece, in millimeters

t is the thickness of the test piece, in millimetres

F2 - F1 is the load increment on the straight line segment of the load-deflection curve, expressed in N. F1 should be around 10% and F2 should be around 40% of the maximum load. The increment of deflection at the mid-length of the test piece (equivalent to F2 - F1) and bending strength are denoted by a2 - a1.

$$Bending\ strength, f_m(Nmm^{-2}) = \frac{3\ F_{max}\ l_1}{2\ b\ t^2}$$

Where, F_{max} is the maximum load, in newtons l_1, b, and t are in millimeters.

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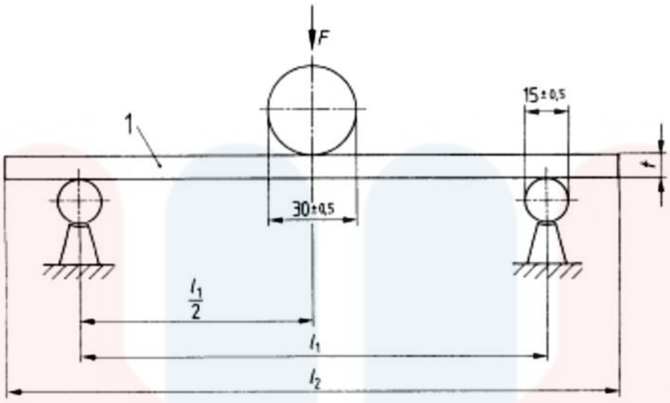

1 = test piece
F = load
t = thickness
l_1 = 20t
l_2 = l_1 + 50mm

Figure 1 : Arrangement of the bending apparatus (JIS A 5908, 2003).

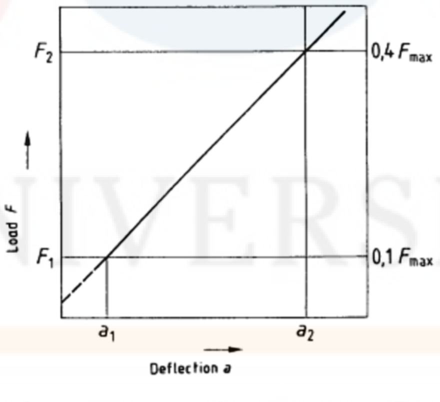

Figure 2 : Load-deflection curve within the range of elastic deformation Bending strength of particleboard (JIS A 5908, 2003).

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CHAPTER 4

4 RESULT AND DISCUSSION

4.1 Thermogravimetric Analysis (TGA)

The purpose of this study is to evaluate the particle board manufacturing technique using a mixture of polystyrene with Urea Formaldehyde and PCM. Thermogravimetric analysis is used to monitor the chemical properties or physical changes of the sample with time during which it is subjected to the temperature program (Saatdatkhah, 2019).

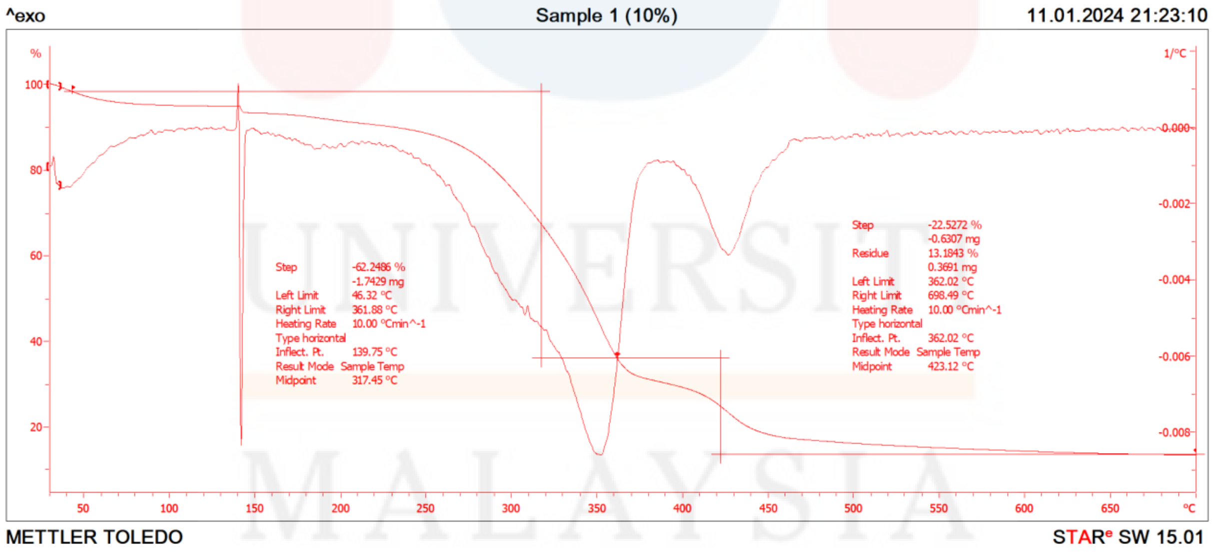

Figure 3 : TGA analysis of rubberwood sawdust of Polystyrene for AMR 1 (10%).

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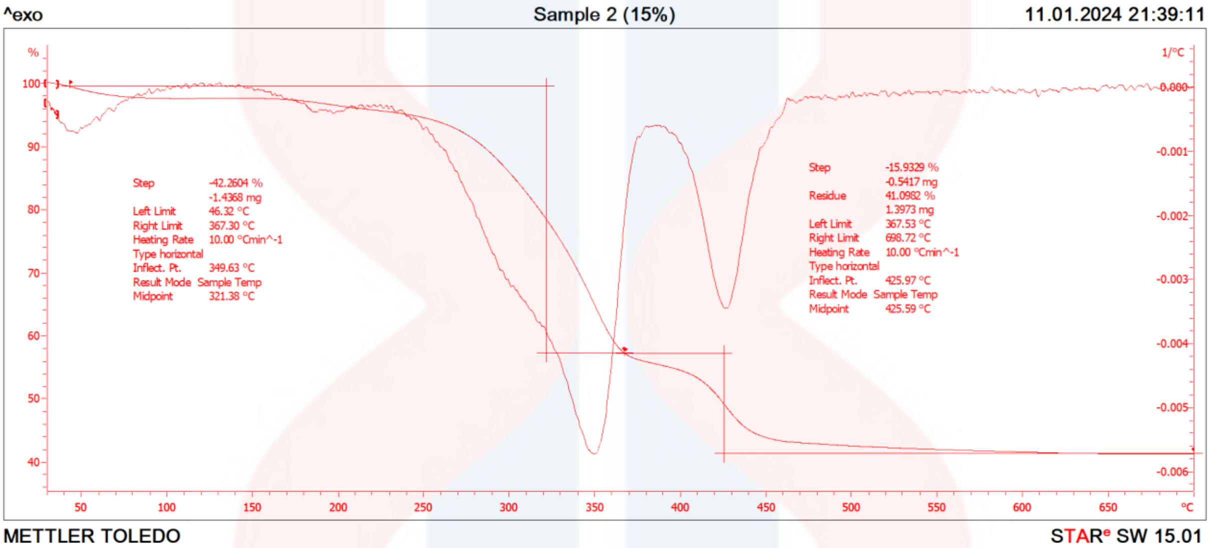

Figure 4 : TGA Analysis of rubberwood sawdust of Polystyrene for AMR 2 (15%).

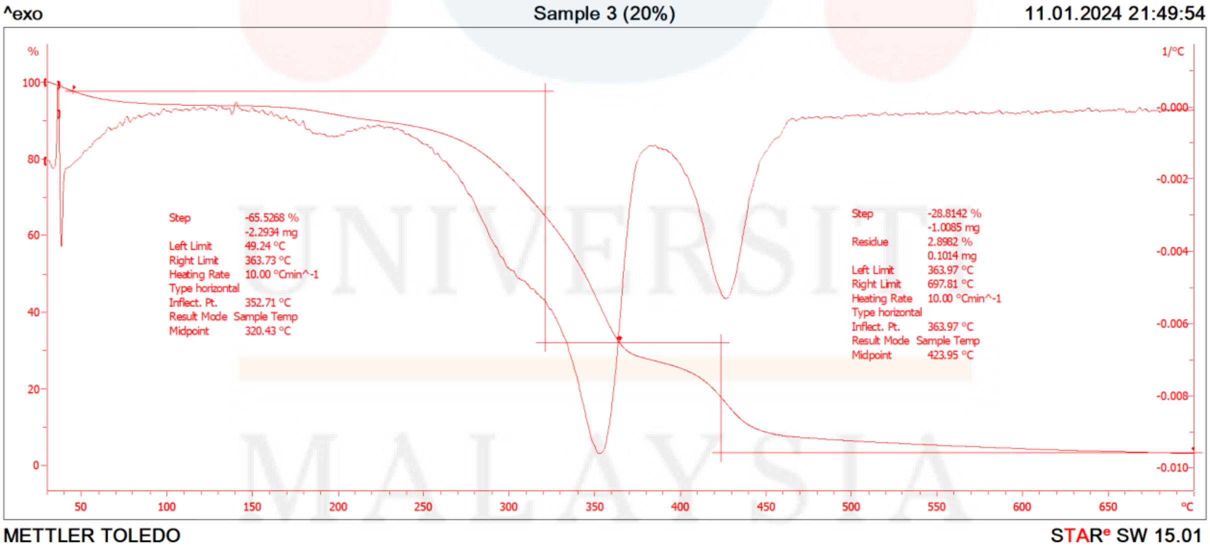

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Figure 5 : TGA Analysis of rubberwood sawdust of Polystyrene for AMR 3 (20%).

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The results of the TGA analysis that has been performed on sawdust rubber for sample AMR 1 (10%) are shown in Figure 3 below. According to table 1, the TGA study was carried out using a sample mass of approximately 0.0025 mg and at a temperature range of 30 to 700 ºC. As a function of sample temperature, the plot depicts the derivative as well as the mass percentage, i.e. the rate of mass loss. At a temperature of 50 ºC, the sample begins to experience a weight loss event, which reflects the loss of water from the sample. According to the measurement of significant weight loss, the total water mass lost is 9.3429%. At an initial temperature of 280 ºC, the sample begins to deteriorate due to thermal activity. There are various stages related to the degradation process occurring in the sample, but the overall percentage of weight loss that can be attributed to the thermal degradation of sawdust AMR 1(10%) reaches 13.1843%.

Next, the results of the TGA study conducted on sawdust rubber for AMR 2 (15%) are shown in Figure 4. According to table 1, TGA analysis was carried out with an input sample mass of about 0.0034 mg, using a temperature range of 30 to 700 ºC. The mass percentage is displayed on the plot, and the graph shows the rate of mass loss as a function of sample temperature. Also displayed is the derivation of the mass loss rate. Estimates at 20 ºC mark the beginning of the weight loss event for AMR 2 (15%), which reflects the loss of water from the sample. According to the exact measurement of weight loss, the total water mass lost is 25.1653 %. At the beginning of the temperature of 270 ºC, AMR 2 (15%) started to deteriorate due to thermal activity. The remaining sawdust residue was 41.0982% after the sample was heated under certain conditions. This weight loss is caused by a series of phases related to the degradation process such as thermal decomposition that occurs.

Figure 5 shows the results of the TGA study conducted on the AMR 3 (20%) sample. This sample experienced a weight loss event starting at 30 ºC which is the temperature at which the sample experienced water loss. According to the exact measurement of weight loss, the

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total water mass lost is 25.916%. At an initial temperature of 280 ºC, the sample begins to deteriorate due to evaporation or desorption. The most common cause of weight loss is the removal of volatile components, such as water or solvents from these samples. at a temperature of 350, the AMR 3 (20%) experienced a significant weight loss where the temperature experienced a loss of cellulose

4.2 Fourier-transform infrared (FT-IR)

This research delves into the examination of certain physical and mechanical characteristics of particle board produced from recycled wood chips and cornflour. The corn starch employed underwent treatment with triethanolamine solution at concentrations of AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%). The microstructure and elemental composition of the particle board specimens were analyzed using Fourier transform infrared spectroscopy (FTIR).

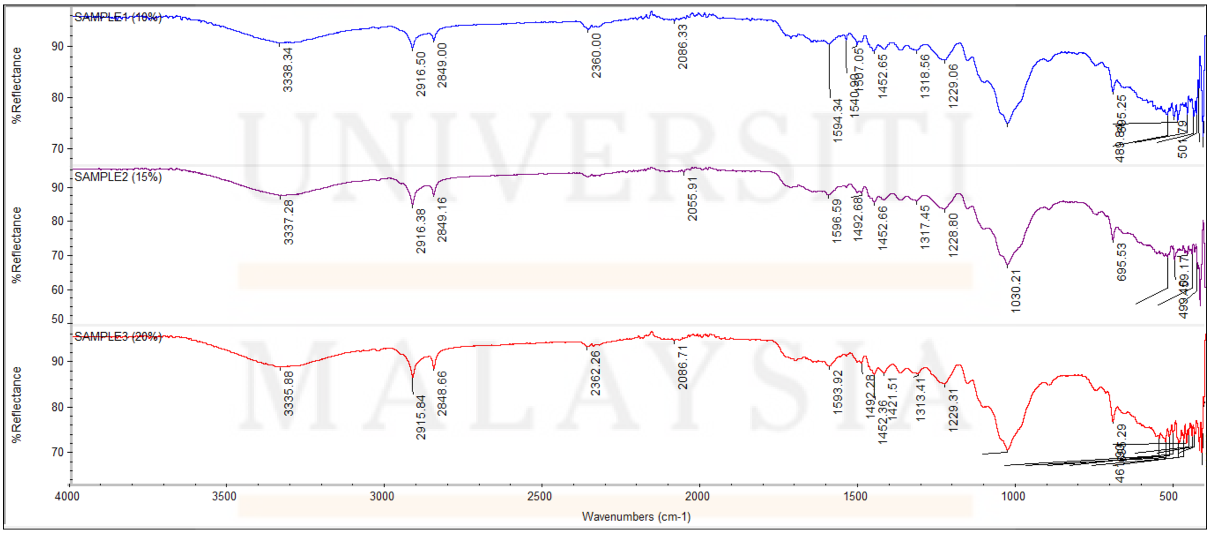

Figure 6 : FTIR peaks of comparison rubber wood with UF impregnated by PCM between AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

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Functional Group	Peak	Bond
Inorganic Phosphates	1229.06	P=O
	3338.34	N-H (1°-amines)
Aliphatic hydrocarbons	2916.50	CH3, CH2 & CH 2 or 3 bands
	1452.65	C=H
Sulfoxide	1030.21	S=O

Table 1: FT-IR peaks the main functional group of rubberwood sawdust with UF impregnated by PCM.

The provided text describes the analysis using Fourier transform infrared spectroscopy (FTIR) on three samples of rubber sawdust mixed with different percentages of AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%). In figure 6, the FTIR spectrometer displays a peak corresponding to this sample. The peaks indicate the presence of different functional groups in rubber sawdust when combined with different percentages of each sample. The functional groups identified in each of the AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%) samples are listed in Table 2. This table refers to the graphs and peaks that can be found in figures 6. The FT-IR peak associated with the main functional group of rubber sawdust is indicative of specific chemical components. In this research, the presence of inorganic phosphate is highlighted, and the chemical substance within this group is identified as phosphoric acid. The

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peak corresponding to phosphoric acid is observed at 1229.06 cm^{-1}. This information establishes that the main functional group in rubber sawdust contains phosphoric acid and its presence can be controlled and analyzed through the identified FT-IR peak.

These two compounds show a relationship with each other. In the aliphatic hydrocarbon category, there are three specific compounds namely Amines and Alkanes. Amines show peaks at 3338.34 cm^{-1}, with N-H stretch bonds (1°-amine), while Alkanes exhibit peaks at 2916.50 cm^{-1}, with CH_3, CH_2 and CH (2 or 3 bands) stretch bonds, and at 1452.65 cm^{-1}, indicating C-H stretching bonds. These characteristics define Amines and Alkanes as examples of aliphatic hydrocarbons, each exhibiting different characteristics in their respective molecular structures. Subsequently, within the range of peak position 1030–1070, there is an inclusion of a sulfoxide component. Similar to the data shown in figure 6 of the AMR 2 sample, there is a distinct peak seen at a frequency of 1030.21. The stretch bond in table 2 is a sulphur (S=O) bond. Sulfoxide serves several purposes, including textile processing and polymer manufacturing.

4.3 X-ray diffraction (XRD)

X-ray powder diffraction, often known as XRD, is a widely used analytical technique for quickly detecting phases in crystalline materials and determining the dimensions of their unit cells. After the material under inquiry was made uniform, it was subjected to rough grinding, and then the overall average composition was determined.

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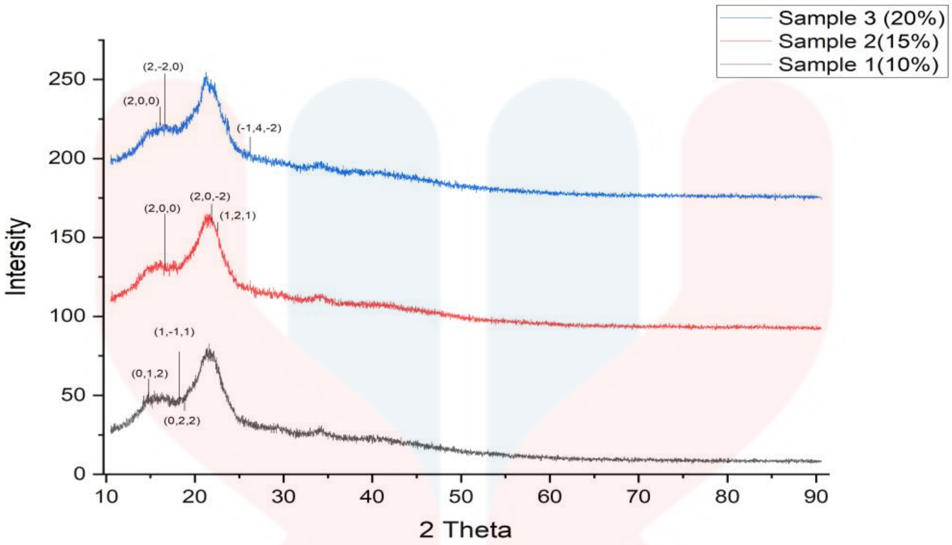

Figure 7: XRD analysis for sample AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

Sample	Crystallinity %	Amorphous %
10 %	40.8	59.2
15 %	39.2	60.8
20 %	39.5	60.5

Table 2: Percentage crystallinity and amorphous for sample AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

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Diffraction investigations were carried out to study the amorphous structure and crystallinity of the treated rubber wood dust. Based on figure 7 and table 3, the degree of crystallinity for the AMR 1 (10%) that underwent the impregnation procedure with rubber wood powder was 40.8%. A liquid solution must be cooled below its melting point to initiate the crystallization process. The latter can lead to the creation of individual crystals. Stretching of the material can also cause crystallization in polystyrene. The crystallization observed in the AMR 1 (10%) sample may be attributed to molecular alignment in the stretching direction. Applying tensile stress increases the alignment of polymer chains, thereby aiding the creation of crystalline regions. The application of mechanical treatment to this wood composite material increased crystallinity, as shown by an increase in the average size of the crystals and a decrease in the ability of the crystal domains to be replaced by deuterium. Similar patterns seen in both crystal size and deuteration measurements provide evidence that the stretching process causes the sample to undergo crystallization by aligning the molecules, leading to a more ordered structure with larger crystal areas that are less susceptible to deuterium exchange. Furthermore, the specimens used for this examination include polystyrene (C8H8), urea formaldehyde (CH4N2O), and phase change material (C16H32O2).

The polystyrene mixture on particle board consists of 59.2% amorphous structure. These numbers are important to consider when analyzing various physical and chemical properties in the solid state. The current increased interest in amorphous materials is mostly driven by the need to increase the bioavailability of materials that have limited solubility in water. After examining the data, it is evident from table 3 that the sample with a AMR 1 (10%) polystyrene mixture exhibits the greatest degree of crystallinity among the other samples, measuring 40.8%. This phenomenon is hypothesized to be the result of insufficient drying of rubber wood powder and the impurities found in the powder. The addition of more additive content results in a higher citric acid concentration, leading to more significant cellulose swelling (Navard et al. 2006). Increased swelling of cellulose can cause some degree of damage to the crystalline regions of cellulose, leading to a decrease in the crystallinity of cellulose. This may explain why the

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structural integrity of the board was affected when the percentage was added to the sample from 10% to 15%.

Figure 7 shows AMR 2 (15%), including polystyrene (C8H8), urea formaldehyde (CH4N2O), and phase change material (C16H32O2), contained in particle board. This test allows the collection of every constituent that comprises this sample, and each of those constituents contributes to the total crystallinity measurement of the sample. The crystallinity of sample 2, which has a concentration of AMR 2 (15%), was measured to be 39.2%. Therefore, the quantity of crystalline material in the sample greatly affects its physical characteristics, namely yield strength, density, and ductility. The amorphous composite in AMR 2 (15%) polystyrene, has increased to 60.8% due to increased amorphous crystallization, as shown in table 3. The wood composite material has the benefits of extended durability and less maintenance but at a greater expense. Furthermore, while wood remains a popular choice for decking, it lacks resistance to harm. Although composites can provide enhanced durability, choosing them may require making concessions to obtain the ideal natural appearance and color.

Diffraction analyses were conducted to examine the amorphous structure and crystallinity of sawdust particles including a blend of polystyrene and rubber wood. The AMR 3 (20%) wood that has undergone the impregnation procedure, has a crystallinity degree of 39.5%. This information is shown in table 3 and figure 7. Typically, liquids, powder mixes, or liquid solutions of powder mixtures must be cooled below their melting point to undergo crystallisation. Nevertheless, in this particular scenario, it is unnecessary to lower the temperature of the powder below its melting point. The latter may lead to the creation of individual crystals. Stretching of the material may also induce crystallisation in wood composites. The crystallisation process in the AMR 3 (20%) sample is influenced by thealignment of the molecules in the stretching direction. It may be inferred from this approach

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that the increase in the crystallinity of the wood composite material may be attributed to the treatment and heating of the wood using different methods. Specifically, this rise in crystallinity may be ascribed to this technique. The reduction in the ability to incorporate deuterium into the crystal area and the observed augmentation in the average size of the crystals are highly correlated. A rise in the mean crystal size was quantified. Furthermore, the proportion of amorphous configuration in the AMR 3 (20%) polystyrene blend on particle board amounts to 60.5%, and this value has significance in the assessment of diverse physical characteristics. The pursuit of enhancing the bioavailability of water-insoluble substances has significantly fueled the rising fascination in amorphous materials. Amorphous structures have the potential to enhance solubility and bioavailability in comparison to crystalline structures. Additionally, X-ray diffraction (XRD) data has the ability to provide valuable information on the degree of crystallinity. Samples that possess a higher degree of nanocrystalline nature and bigger crystalline domains exhibit diffraction peaks that are more pronounced and well-defined. A feeble and wide peak suggests a less organised structure with smaller and less distinct crystalline areas. Hence, distinct protuberances and crests in the XRD pattern may function as markers of crystallinity, with more pronounced crests indicating larger crystal dimensions and higher crystal concentration. To summarise, the study on amorphous forms was motivated by the need to enhance the solubility of medications and nutrients. XRD, on the other hand, offered a means to evaluate the degree of crystallinity by analysing diffraction peaks. The original text discusses the use of XRD peak characteristics to assess the crystallinity and crystal size, as well as the underlying motivation for doing research on amorphous materials. The following restatement maintains the essence of the original text while using different terminology (Marimuthu et al., 2013)

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4.4 Bending test for particleboard (AMR 10%, AMR 15%, and AMR 20%)

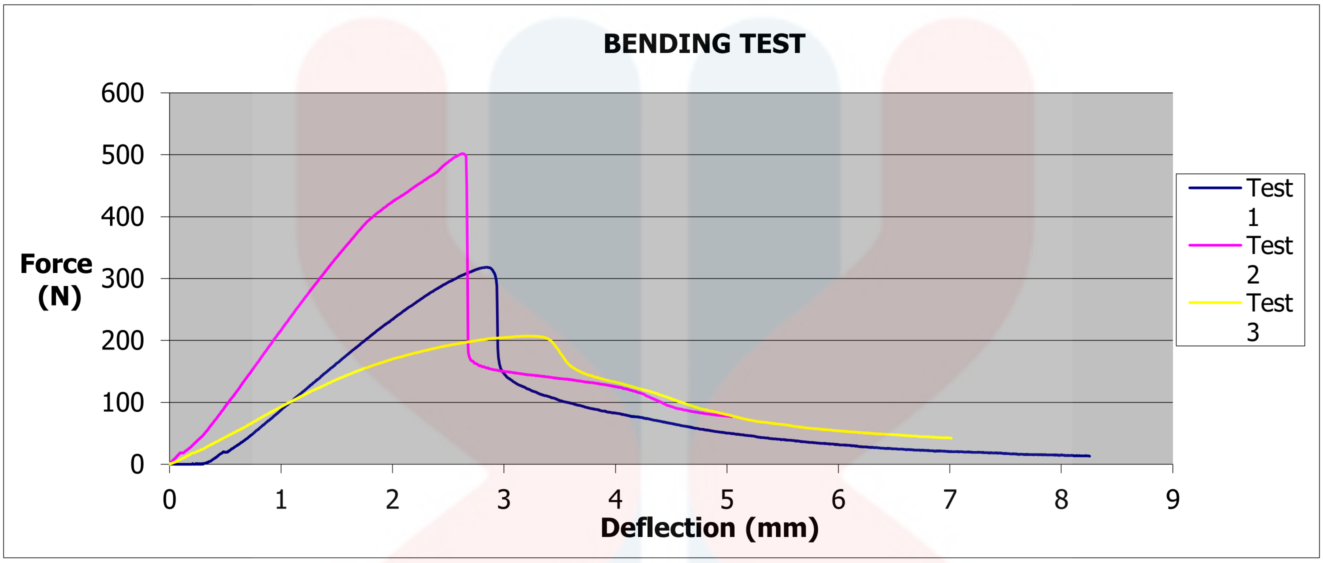

Figure 8 : Bending test data and graph for AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

Test no of particleboard (%)	Modolus of Elastic (MoE)	Modolus of Rupture (MoR)
10 %	287.992	6.270
15 %	366.406	8.236
20 %	129.175	3.170

Table 1: The average of the data for AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

The document shows mechanical testing data for three particleboard composite samples with varying composition percentages of AMR 10%, AMR 15%, and AMR 20%. Bending tests were performed to evaluate the force, modulus, and strength properties of the particleboards.

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The IS3087 standard states that the moisture content in particle board should be between AMR 1 (10%) and AMR 3 (20%). Moisture levels outside of this recommended range can harm particle board dimensions, both in terms of size and linear thickness (Harshavardhan & Muruganandam, 2017). If the moisture content falls below AMR 1 (10%) or rises above AMR 3 (20%), it can cause the board to shrink or expand in the linear direction and become thinner or thicker in the vertical dimension. This is because the moisture content affects the swelling and shrinking behaviour of the wood particles and the adhesive matrix that makes up the particle board. Excess moisture leads to swelling, while too little moisture results in shrinkage. Therefore, maintaining moisture in the range of 5–15% as per IS3087 standards helps to ensure that the manufactured particleboard product maintains its intended linear dimensions and thickness. If there is a lower concentration of moisture, the board will bend in an uneven way, but if there is a higher concentration of moisture, the strength of the board will suffer. The values for the boards produced from rubber wood dust are shown in Table 4, and they have a total polystyrene content of AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%). Particle board with polystyrene was mixed with urea formaldehyde and impregnated with PCM (palmitic acid) leveled together.

Particleboard is a kind of composite wood that is created by compressing and adhering tiny wood particles, chips, shavings, or sawdust with an adhesive binder. The mechanical characteristics of particleboard are influenced by several aspects, such as the origin of the wood, the size and shape of the particles, the technique of processing, and the formulation of the adhesive. The presented data indicates that they are particleboards undergoing experimentation, with varying levels of a crucial component in their composition. The three essential bending test findings that are provided are the force at which the material breaks, the bending modulus, and the bending strength.

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In figure 8 and table 4, the AMR 1 (10%) particleboard shows a flexural modulus of 287.992 N/mm2 - the lowest of the three samples. This shows that the 10% particle board is the most flexible and least stiff in bending. The strength is 6.270 N/mm2, again the lowest of the three samples. This makes the composite structure weaker and unable to withstand high bending forces.

The AMR 2 (15%) particleboard showed improved properties, with the highest force at a break of 500.2 N as well as the highest bending modulus of 366.406 N/mm2. This signifies creating a stronger, stiffer composite structure compared to the 10% board. The strength was also higher at 8.236 N/mm2.

However, the AMR 3 (20%) particleboard exhibited a drastic reduction in mechanical performance. The force at break dropped to 204.7 N. The modulus decreased to 129.175 N/mm2, making this the most flexible/least stiff sample. The strength fell to just 3.170 N/mm2.

These results demonstrate that an optimal balance of properties is achieved at the AMR 2 (15%) composition level. Increasing this concentration leads to a deterioration of the bending force, stiffness, and strength. This suggests that too much of the critical binder or constituent leads to embrittlement and loss of mechanical integrity. There appears to be an ideal formulation range to create a tougher, reinforced composite structure, beyond which excess amounts disrupt bonding and produce defects that worsen the bending performance.

Further analysis at narrower composition increments could determine the precise optimal concentration. Testing other mechanical properties like tensile, compression, hardness, and impact behavior would provide additional insights into the effect of composition on the overall mechanical profile of the particleboards. Characterization of the microstructure could identify defects introduced at higher concentrations that degrade the bending properties.

Overall, the data presented show that varying the composition of these experimental particleboards produced significant differences in bending behavior. The AMR 2 (15%) composition results in a maximum increase in force resistance, stiffness and strength during bending loads. This shows the importance of material formulation for the mechanical performance of wood-based composites. With more testing and research, the best composition range can be narrowed down to get the best bending properties for use in buildings, furniture and other areas that require a rigid and durable particle board material. And this study passed the JIS standard because the MoR did not exceed 16.80 and the MoE did not exceed 1721

4.5 Water absorption

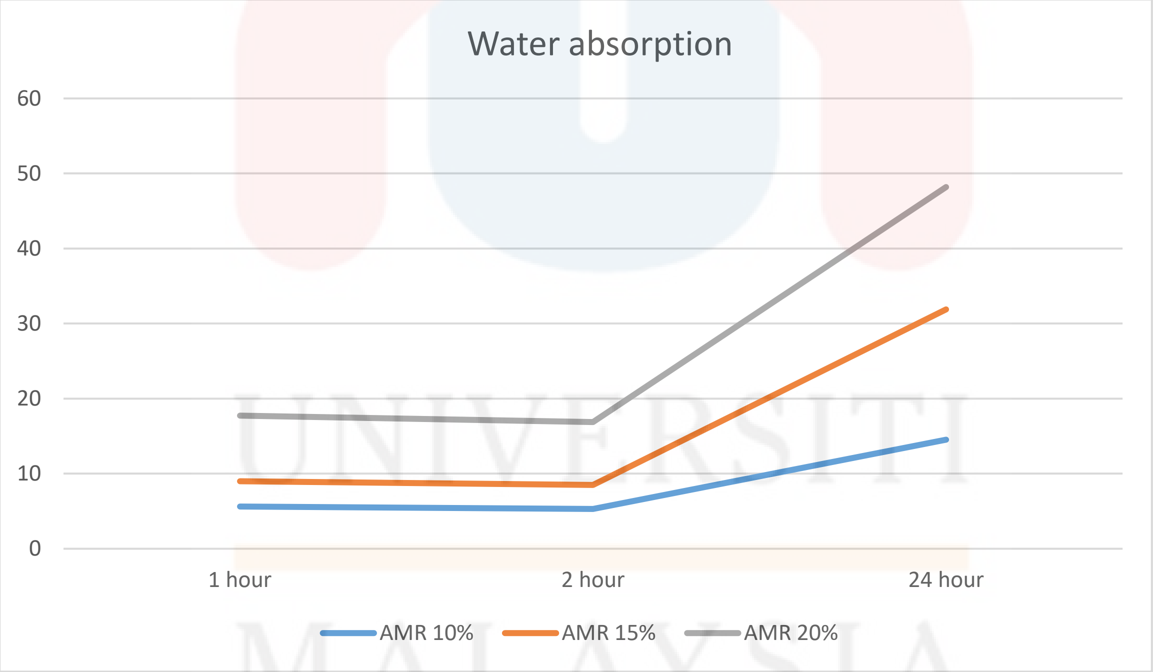

Figure 9 : Water absorption for sample particleboard AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

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Sample Hour	AMR 10%	AMR 15%	AMR 20%
1 hour	5.63	3.37	8.73
2 hour	5.3	3.20	8.38
24 hour	14.53	17.36	16.30

Table 2: The data of the initial weight until 24 hours for AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

The document shows water absorption data for three different samples measured over 24 hour. Based on the sample labels indicating AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%), it appears these are three composite samples with varying concentrations of a hygroscopic component. The initial dry weights of the three samples are provided, ranging from 26.34 g to 28.45 g. The samples were then subjected to water absorption testing by measuring their wet weights after 1 hour, 2 hours, and 24 hours of exposure to water or a humid environment. The water absorption increases over time for all three samples, as expected for diffusion-controlled water uptake into the composite materials. The largest increase occurs within the first 1-2 hours, followed by a slower continued increase up to 24 hours.

The amount of water absorption correlates with the labeled concentration of the sample. The AMR 1 (10%) sample absorbed the least amount of water overall, with a weight gain of

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7.78 g after 24 hours. The AMR 2 (15%) sample absorbed less at 7.17 g, while the 20% sample showed the highest water uptake at 9.76 g. The rate of water absorption also appears to depend on composition. While the 10% and 15% samples showed similar weight gain after 1 h (~1.6 g), the 20% sample had a greater increase of 2.3 g in the first hour. This shows that the permeability and hygroscopic properties of the composites increase with higher concentrations of water-absorbing components. According to weight, the percentage of sample weight increase after 24 hours is 27.5% for AMR 1 (10%) body weight sample, AMR 2 (15%) sample is 25.1% body weight, and AMR 3 (20%) is 37.1% body weight. The AMR 3 (20%) sample again shows the most drastic water uptake as a percentage, probably due to the highest concentration of hygroscopic substances.

This water absorption behavior indicates that the samples are composite materials containing a hygroscopic component that absorbs moisture from the environment and causes the overall weight gain. The kinetics of this absorption process depend on both the concentration and accessibility of that hygroscopic component within the composites. Some possibilities for the identity of the core hygroscopic material include hydrogels, silica gels, starches, celluloses, or other polymers with hydroxyl, amine, or other hydrophilic functional groups. The surrounding composite matrix likely consists of a hydrophobic polymer that provides mechanical integrity but allows gradual permeation of water over time to the internal hydrophilic regions.

Further analysis could help confirm the composition, such as infrared spectroscopy to identify chemical functional groups. The kinetics of the absorption process could be modeled using Fick's laws of diffusion to quantify the solute diffusion coefficients within the polymer matrices. The water uptake capacity and rates are important considerations for applications such as sensors, drug delivery devices, personal care products, and hygiene materials.

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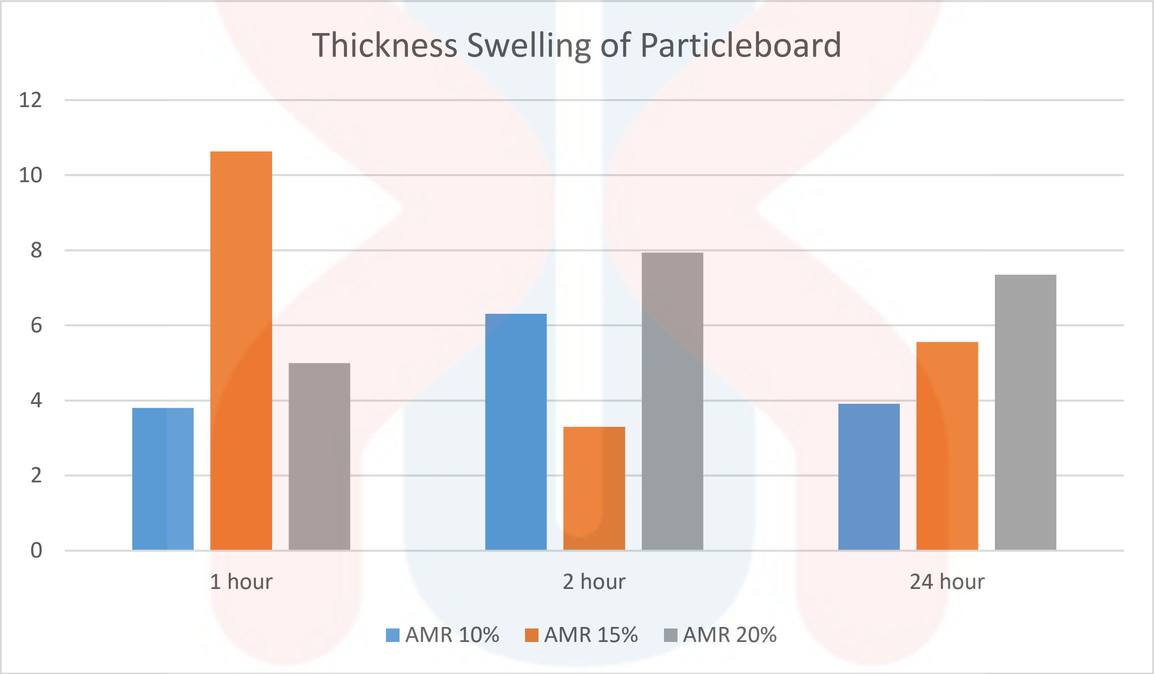
Understanding the relationships between composition, structure, and water absorption behavior will assist in designing these composite materials for optimized performance.

4.6 Thickness Swelling



Sample Hour	AMR 10%	AMR 15%	AMR 20%
1 hour	3.80	10.63	5.0
2 hour	6.31	3.30	7.94
24 hour	3.91	5.56	7.35

Figure 10: Percentage of Thickness swelling for sample AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%).

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Table 3 : Percentage of thickness swelling for AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%)

Determination of thickness swelling test (TS) 1 hour, 2 hours, and 24 hours was performed according to ASTM D-1037. There are 3 samples which are AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%) for the thickness swelling test. Water absorption is done by soaking rubber wood dust specimens mixed with polystyrene with urea formaldehyde and impregnated with palmitic acid with plain water for different periods. After 1 hour, 2 hours, and 24 hours of immersion, the specimen was removed from the water and then the sample was measured using a digital caliper. Specimens were weighed regularly at 1 hour, 2 hours, and up to 24 hours of clock exposure. The thickness of each sample is calculated through the percentage of thickness Water absorption of each specimen is calculated according to the percentage of thickness between the time intervals taken.

Figure 9 shows the thickness swelling (TS) of affected particle board when immersed in water. Percent thickness swelling trends show inconsistent results over time up to 24 hours. Particle board TS results are influenced by weight fraction. The results show that the effect of the percentage of polystyrene affects the swelling thickness and proves that the mixture of polystyrene and urea formaldehyde and impregnated with palmitic acid affects the data.

Table 6 shows that the sample containing AMR 1 (10%) polystyrene in the first 1 hour showed an increase in TS of 6.02 mm compared to the initial TS of 5.8 mm, an increase of 0.22 mm. The increase in TS continued to occur at 2 hours later by 6.40 mm compared to TS at 1 hour which was 6.02, and showed an increase of 0.38. Then 24 hours (6.65 mm). This makes the sample have a modest increase of 0.25. After being entered into the percentage Thickness swelling (TS) formula, the estimated distance between the percentage of TS 1 hour to 2 hours and 2 hours to 24 hours is not much different which is 2.51 and 2.4 respectively. Therefore, with particle board containing AMR 1 (10%) polystyrene, this sample has a bond that makes this data increase at a low rate and has resistance from soaking water because the percentage swelling of the thickness does not show a high increase.

Figure 9 shows the TS results for the AMR 2 (15%) particle board for the measurement process of samples measuring 6.97 mm, 7.2 mm, and 7.6 mm that were soaked according to the predetermined time which is 1 hour, 2 hours, and 24 hours. The observation found that the percentage swelling of the thickness of the TS data increased when compared to the AMR 1 (10%) polystyrene sample. AMR 1 (10%) shows an increased percentage of TS compared to AMR 10%. percentages are taken from time intervals, which are early to 1 hour, 1 hour to 2 hours, and 2 hours to 24 hours. The percentages taken in table 6 for AMR 2 (15%) are 7.33 and 2.26 respectively. This shows a high percentage increase compared to AMR of 10%. The probability of a high TS percentage is due to the unevenness of the resin (polystyrene) mixed into the particle board. It makes the rate of water absorption a lot in the TS process. This process is a common behavior in wood composites during TS testing.

Additional measurements were performed for samples containing AMR 3 (20%) polystyrene, with observed thicknesses of 6.3 mm, 6.8 mm, and 7.3 mm. The presence of AMR 3 (20%) polystyrene in the particle board causes a reaction with the rubber wood particles, resulting in accumulation and penetration of the pores of the particle board. However, at the appointed time, the sample began to grow, but not to a large extent. The presence of polystyrene in the pores of the sample prevents water infiltration. The percentage of TS shows slight and moderate fluctuations, which are 2.94% and 0.59% from the first hour to the second hour and

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from the second hour to the twenty-fourth hour, respectively. It can be proven that the incorporation of wood dust with polystyrene and urea formaldehyde, along with the addition of palmitic acid, improves the integrity of the particleboard structure and reduces water infiltration, outperforming samples containing AMR 1 (10%) and AMR 2 (15%) polystyrene.

particle board will swell when the composite is exposed to moisture. But with the presence of polystyrene and urea formaldehyde impregnated with palmatic acid (PCM), it can reduce the particle board's water absorption. In the AMR 10% and AMR 15% samples, there may be a percentage distance that is not significant because maybe during the 'hot pressing' process, the state of polystyrene is more in the part taken to carry out this TS experiment.

4.7 The moisture content of particleboard

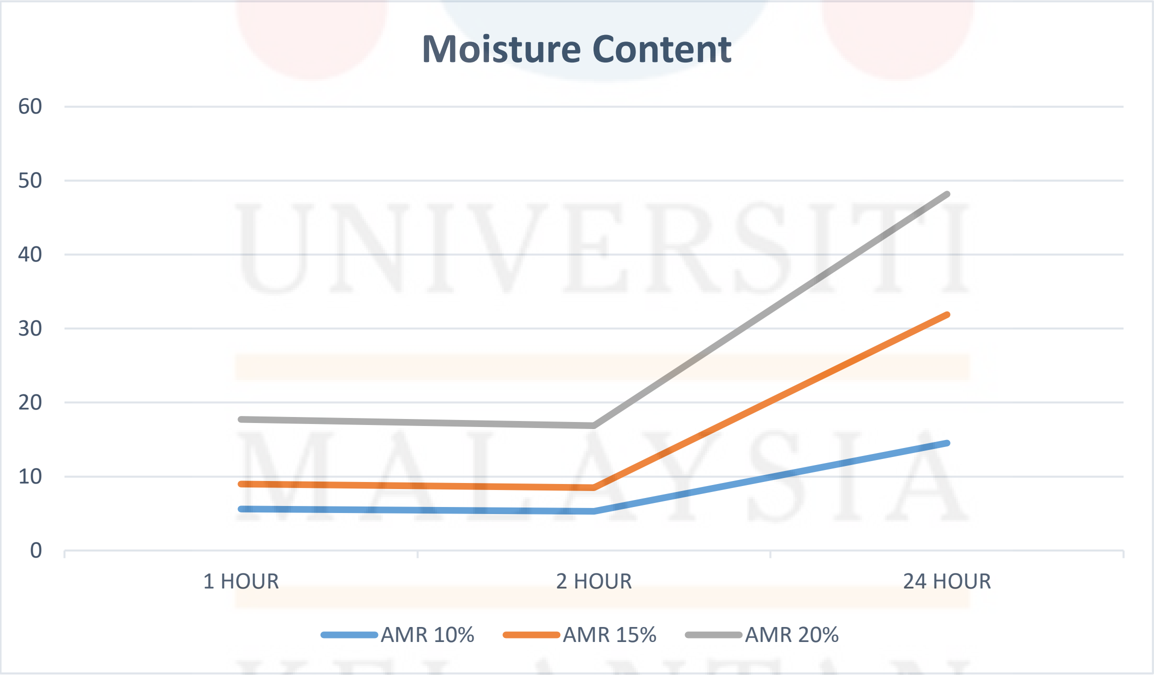

Figure 11 : The percentage of moisture content for sample AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%)

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Sample / Hour	AMR 10%	AMR 15%	AMR 20%
1 hour	5.63	3.37	8.73
2 hour	5.3	3.20	8.38
24 hour	14.53	17.36	16.30

Table 4 : The percentage data of moisture content for sample AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%)

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An investigation was conducted to examine the water absorption characteristics of wood composites. Specifically, the water absorption of particle board samples, which were composed of a combination of polystyrene and urea formaldehyde and treated with palmitic acid (PCM), was studied. The specimens were immersed in water at ambient temperature to investigate the kinetics of their water absorption characteristics. At regular intervals of 1 hour, 2 hours, and 24 hours, samples are taken, and the particle board is promptly weighed using precise weighing equipment at the designated time. Wood composites exhibit water absorption when immersed in water owing to the hydrophilic properties of wood, characterised by the presence of accessible hydroxyl groups on the surface. Water absorption and thickness are crucial properties to investigate in any form of particle board to ensure the production of high-quality particle board.

Water absorption tests were conducted on controlled wood composite samples with different concentrations of AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%) using normal water. Each 5x5 cm sample was subjected to observation regarding water absorption when placed in normal water. According to figure 10 and table 7, there is a significant increase in absorbance after 2 hours for the AMR 2 (15%). The reduced water absorption in the sample may be due to the presence of adhesive components, including polystyrene with urea-formaldehyde, and palmitic acid (PCM), which coat the wood composite. Furthermore, sample AMR 2 (15%) probably exhibited the greatest rate of moisture absorption due to the uneven adhesive mix, resulting in significant water absorption. In addition, these modifications are usually implemented to evaluate the effectiveness of components in producing a high-quality product. While doing this test, the sample shows that the material.

Next, this test continues by referring to figures 10 and 7. Sample AMR 1 (10%) and sample AMR 3 (20%) show the sample in a stable state where there are not many changes or significant changes. The sample was absorbed with a little water after 1 hour, 2 hours, and 24 hours for the AMR 1 (10%) and AMR 3 (20%) samples. This is because the content of the material mixed with particle board is more integrated than the AMR 2 (15%) in the 24-hour test. This shows that the material used, which is polystyrene with urea formaldehyde and palmitic acid (PCM), plays an important role in this moisture content test. This test also shows samples that may have imperfections at 24 hours, which are increased by 14.53%, 17.36%, and 16.30%, respectively. The recorded data showed that the percentage of water absorption in the

sample increased significantly compared to 1 hour and 2 hours. This is because each sample that is AMR 1 (10%), AMR 2 (15%), and AMR 3 (20%) after 24 hours becomes

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swollen because the part of the particle board that is not coated with additives starts to decompose.

After completing this test, make a good sample and less water absorption is AMR 3 (20%). Therefore, polystyrene plays an important role in testing the moisture content in samples. The lack of water absorption in the sample will make this particle board suitable for commercialization in the market. The physical and mechanical quality of particle board is significantly affected by its time and ratio.

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CHAPTER 5

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

This research aims to study the phase change properties of rubber wood dust mixed with polystyrene acid and a mixture of materials such as urea formaldehyde and palmitic acid (PCM). To the extent that wood dust can be replaced as the main component of particle board and building materials, furniture, accessories, and other items made of wood can also be replaced, sawdust from rubber wood waste can be used to create particle board as an alternative engineering material. To see the differences produced by all the test results, this study focused on tests such as TGA, FT-IR, and XRD performed on rubber sawdust samples mixed with polystyrene. In general, the results show significant differences. In all experiments from TGA, FT-IR, and XRD data studies. In addition, a test like this can improve the physical and mechanical quality of this particle board. Therefore, the study of wood composites can produce products that can be competitive with other products. According to this study, the manufacture of wood composites from sawdust shows a weakness in the AMR 1 (10%) sample because it contains less polystyrene. The composite is also slightly weaker because the pore space of the

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sample is combined with polystyrene. The lack of polystyrene in the sample proves that the sample will have physical properties.

5.2 RECOMMENDATION

Phase change materials are advantageous. They can be used to control temperature in a variety of applications because they are liquid and solid at certain predetermined temperatures. Compared to materials that perceive heat energy, materials that melt when heated are much more effective at absorbing heat energy. A large amount of energy can be stored and released using PCM. Materials undergo a relatively stable temperature transition from solid to liquid and back again during this process. During this transition, the internal structure of the material changes. Compared to sawdust that is less mixed with polystyrene, sawdust that has pores on its body has more space to store materials such as palmitic acid to make a composite that is stronger and resistant to heat or heat insulation.

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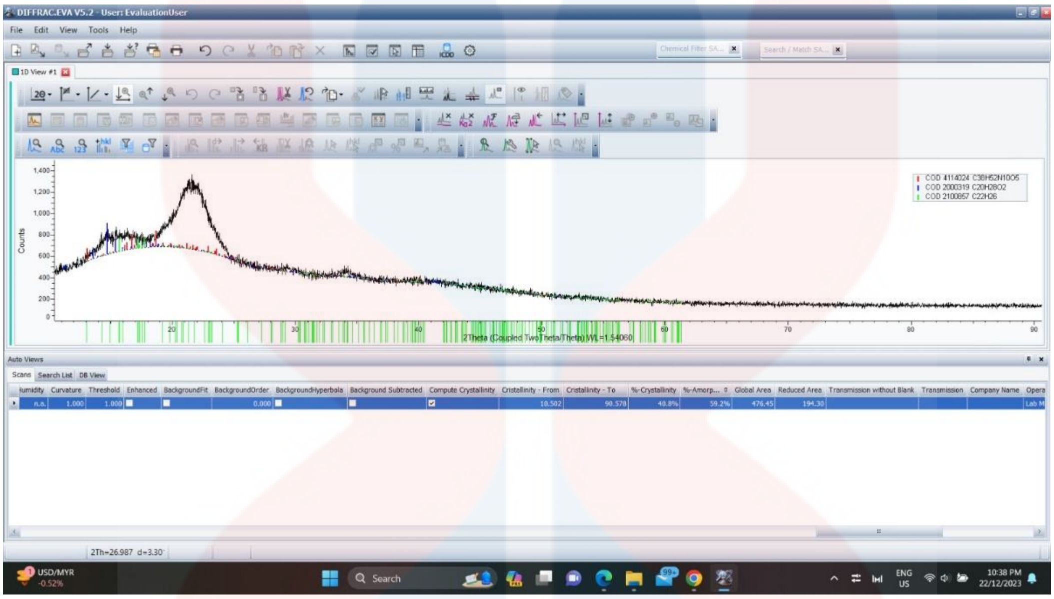
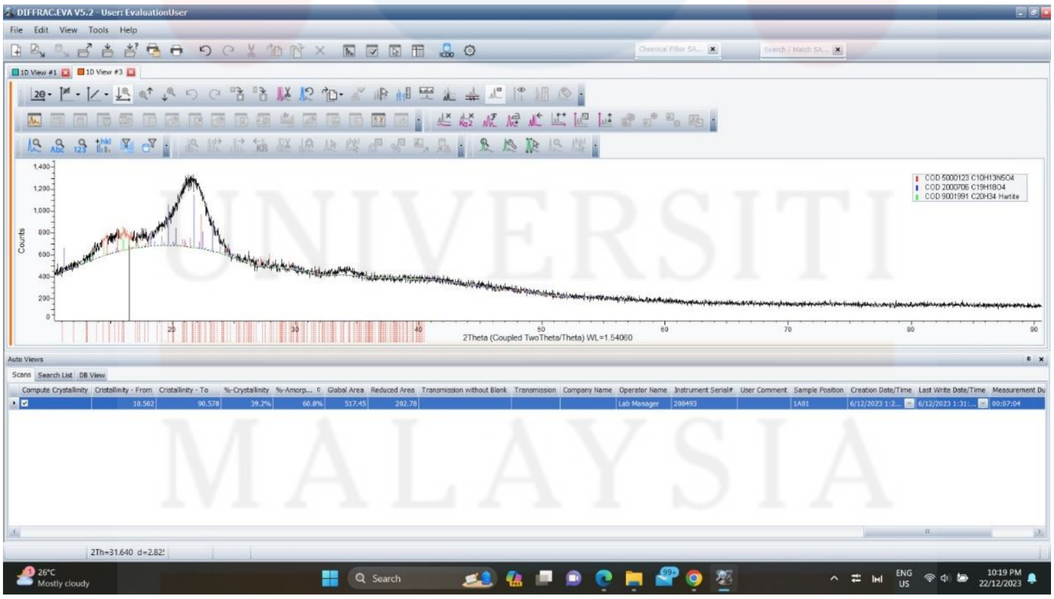
7 APPENDIX



umidity	Curvature	Threshold	Enhanced	BackgroundFit	BackgroundOrder	BackgroundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystallinity	%-Amorp...	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Opera
n.a.	1.000	1.000	☐	☐	0.000	☐	☐	☑	10.502	90.578	40.8%	59.2%	476.45	194.30				Lab M

Figure 12 : XRD analysis for AMR 1 (10%)



Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystallinity	%-Amorp...	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name	Operator Name	Instrument Serial#	User Comment	Sample Position	Creation Date/Time	Last Write Date/Time	Measurement Du
☑	10.502	90.578	39.2%	60.8%	517.45	202.78				Lab Manager	208493		1A01	6/12/2023 1:2...	6/12/2023 1:31:...	00:07:04

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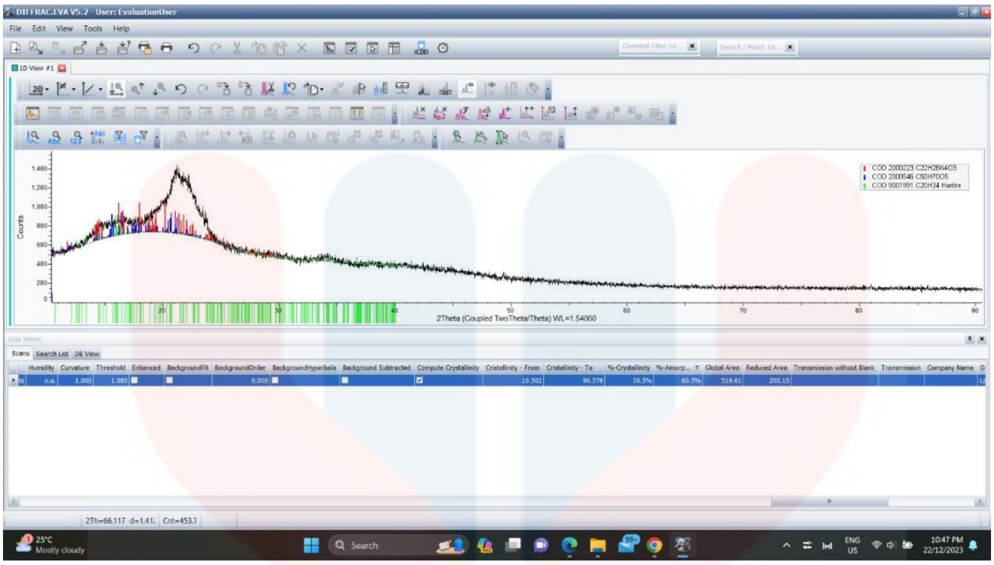
Figure 13 : XRD analysis for AMR 2 (15%)



	Humidity	Curvature	Threshold	Enhanced	BackgroundFit	BackgroundOrder	BackgroundHyperbola	Background Subtracted	Compute Crystallinity	Cristallinity - From	Cristallinity - To	%-Crystallinity	%-Amorp...	Global Area	Reduced Area	Transmission without Blank	Transmission	Company Name
ts	n.a.	1.000	1.000	☐	☐	0.000	☐	☐	☑	10.502	90.578	39.5%	60.5%	519.61	205.15			

2Th=66.117 d=1.41; Cnt=453.7

Figure 14 : XRD analysis for AMR 3 (20%)

Figure 15 : FT-IR analysis for AMR 1 (10%)

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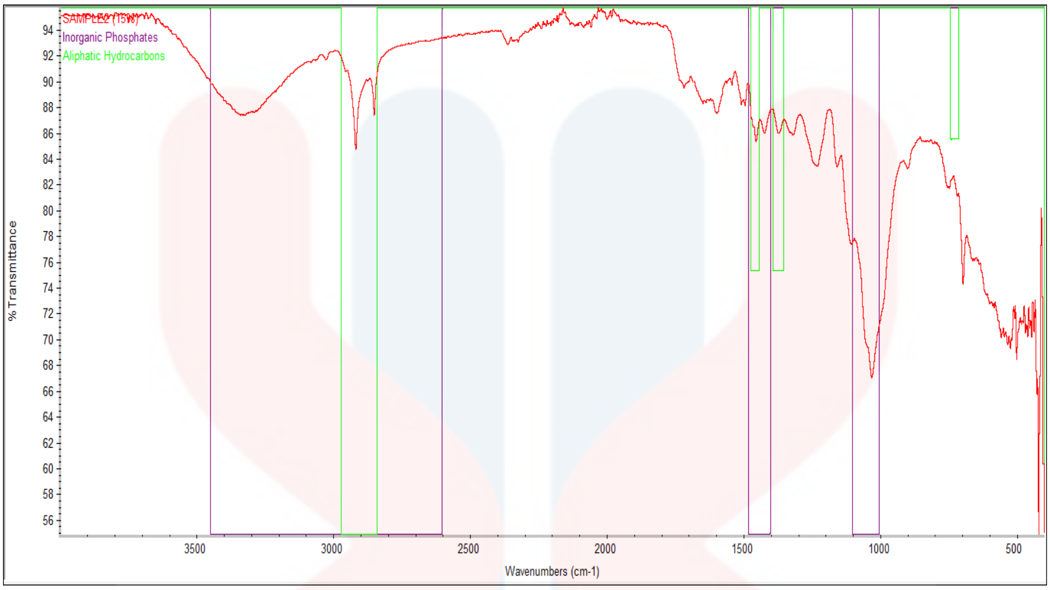

Figure 16 : FT-IR analysis for AMR 2 (15%)

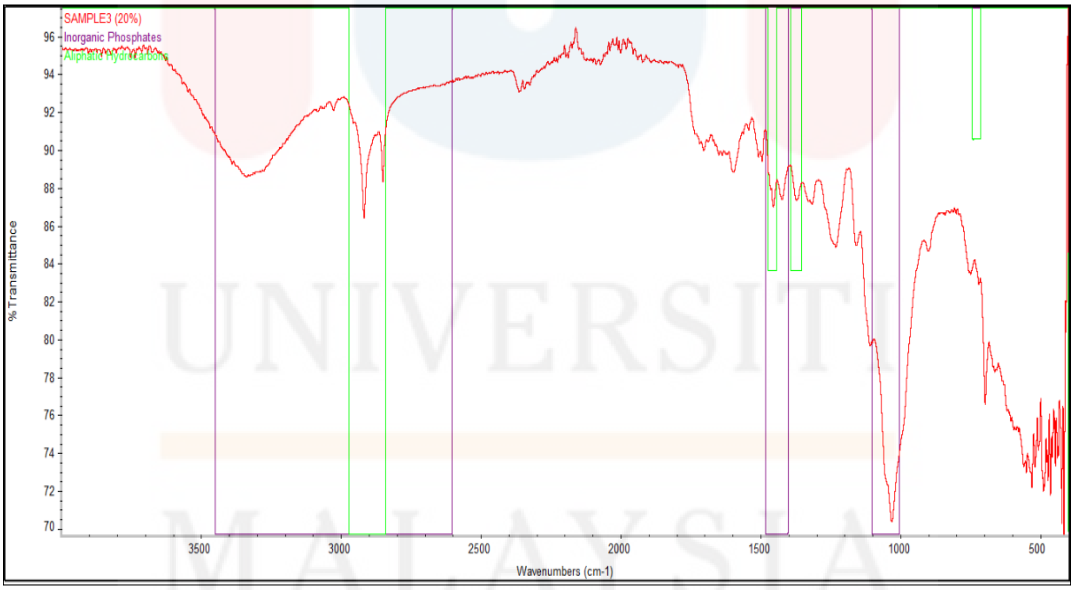

Figure 17 : FT-IR analysis for AMR 3 (20%)

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Figure 18 : Vibration Sieve machine

Figure 19 : Hot Press

Figure 20 : Bending test machine

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