Properties and Experiment of Oriented Strand Board Made from Rice Straw and Maize Husk

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Abstract

The objective of this research is to study the properties of oriented strand board made from rice straw and maize husk. The board is produced like a flat monolayer. Regarding the process of producing, they use synthetic adhesive urea-formaldehyde resin (UF) and synthetic adhesive Polymeric Diphenylmethane Di-isocyanate resin (pMDI) 10% for 5 minutes. The board has a density at 600 kg m^{-3} and 15 mm. thickness. After that, it is tested for physical, mechanical and Thermal properties, according to the Industrial Standards of TIS.876-2547, ASTM D 1037-1999, ASTM D 256-2006a. The thermal properties are also tested, according to ASTM C 177-2010.The study reveals that rice straw and maize husks can be pressed into an oriented strand board. They have required physical the properties, and mechanical the properties meet the Industry Standard TIS 876-2547. The properties taken into consideration are; a density, moisture, water absorption and thickness swelling, bending force resistance and modulus of elasticity resistance, the bond strength of screws, tensile strength being perpendicular to the surface, tensile strength and impact strength. According to the study using two types of adhesives, it is found that synthetic Polymeric Diphenylmethane Di-isocyanate resin provides the best mechanical properties. For the thermal the properties, it is found that the thermal conductivity and resistance of the board made from rice straw is better than the maize husk. According to the economic analysis of producing a piece into an oriented strand board of rice straw and maize husks, forming size at 40 × 40 cm^2, when comparing with the market price, it is found that the production cost of a board of 15 mm. thick, with adhesive urea-formaldehyde resin is 43.12 baht. Similarly, the board using adhesive synthetic Polymeric Diphenylmethane Di-isocyanate resin costs 45.78 baht.

KEYWORDS: Oriented strand board; Physical properties; Mechanical properties; Thermal properties; Economic analysis

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Introduction

Thailand is one of the countries that has a lot of agricultural waste materials. However, such materials are rarely re-used and are neglected on cultivation areas which ends up being burnt. At present, agricultural waste materials are scattering all over the country, depending on agricultural product quantity of each particular area. In the past, it was found out that there were a lot of waste materials more than 43 million tons/year. [1] Such agricultural waste materials with huge quantity are sugarcane, rice straw, and maize husk. [2, 3] Nowadays, people bring some types of materials like rice straw and maize husk to use in the industry of producing oriented strand boards. [4] For example, maize husk is transformed into long sheet of 10 – 20 cm. It composes of gathering fiber which can divide into single one. Some maize husk is used to feed animals. Some are used to get benefit and become approach to develop new products of industrial sectors. [5] Maize husk is a kind of agricultural waste material with high nutritional value, compared with fresh grass. Dry maize husk contains high protein of 12.60%, though it contains high humidity of 82%. In the same way, rice being the staple food of Thai population is

grown in every part of the country. And rice straw becomes a waste material which is considered as outgrowth product. We can find rice straw easily, especially in the rice growing area. Farmers keep rice straw to feed animals, in particular during the dry season. Rice straw contains low nutritional value. That is, it contains crude protein approx. 2.76%, total digestible nutrient 40.20%, and crude fiber 38.13% of dry materials. [6] However, as the two types of materials have high quantity and very low value, these waste materials are suitable to use as low materials to produce fiberboard. This can increase value to the waste materials. In fact, fiberboard is developed to substitute natural wood which gradually reduces the high cost. Fiberboard can be produced by using wood or other agricultural plants as low material. People separate fiber from plants. Then, they mix the fiber with adhesive. After that the materials are prepared with heat and pressure to become flat. [7] Regarding the benefits of such waste materials, this study is the guideline for such possibility to use waste materials to produce oriented strand board. The invention can make promotion of creating a new product in construction industry. Likewise, people can save natural resources. [8] [3]

The researchers are interested in taking agricultural waste materials i.e. rice straw and maize husk to mix with adhesives. Then, the materials are formed into oriented strand board. Using local materials can generate great benefits. It is also considered as adding value to natural waste materials. [9] The researchers study how to produce oriented strand board made from rice straw and maize husk. Regarding the adhesives, they use synthetic adhesive Urea-Formaldehyde (UF) 10% and synthetic adhesive Di-isocyanate resin (pMDI) 10%. Then the two types of adhesives are compared with same quantity. After that the material is formed with 15 mm. thickness. Total hot compress duration is set for 5 minutes with 120 °C. The pressure of hot compression is 150 kg sq^{-1} centimeters. (The outcome product of oriented strand board is set in 15 minutes with a pressure of 150 kg sq^{-1} centimeters, at temperature of 120 °C. If the standard is higher than this, the board will deteriorate.) Finally, it is tested for physical, mechanical, and thermal properties, according to the industry standard.

Materials and Methods

Chemicals used in the experiment

Reaction Catalyst: This type of chemical is the accelerator of the reaction rate of adhesive solidity. It can reduce the time period of hot compressing. There are two types *i.e.* Common catalyst and Latent catalyst. The two types of catalyst are mixed with adhesives to accelerate the materials as soon as the materials get heat. Such catalysts mixing in general glue are; ammonium sulfate, ammonium chloride, and sizing agent which helps reducing water absorption. In addition, paraffin emulsion is used in the study. The researchers also use adhesive urea-formaldehyde resin and synthetic adhesive Di-isocyanate (pMDI) for the experiment.

Materials and Research Equipment

The research equipments used are as follows; iron plate of 400 × 400 mm, wood frame of 400 × 400 mm, digital Vernier caliper which can measure in details of 3 digits. Also, the equipment include micrometer which can measure in details of 1.01 mm, and weight scale which can measure in details of 0.001 g. The researchers use natural waste materials i.e. rice straw and maize husk from Waritchabhum District, Sakon Nakhon Province.

Fig. 1 Physical Feature of Rice Straw


Fig. 2 Physical Feature of Maize Husk

Eeperimental Procedure

First, the researchers use hammer mill machine to crush rice straw and maize husk. The materials are crushed and then become smaller. Then, they are sifted in order to split size by screening machine with grills. For rice straw, the fiber size for sheet compression is approx. 0.44 mm wide, 12.02 mm long, and 0.20 mm thick. The utmost volume is 45.85%, with proportion of slender 60.10 as much. Regarding maize husk for sheet compression, the fiber size is approx. 0.44 mm. wide, 13.53 mm long, and 0.12 mm thick. The maximum volume is 59.58% with 12.75 proportion of slender as much. The humidity of both rice straw and maize husk before mixing adhesive is 3.5%, and 10 – 12% after mixing. After that 1% of paraffin emulsion and 2% of catalyst are infused in the materials. Then, the researchers prepare to form the board by cold pressing method. They sprinkle the fiber with adhesives and other mixture into wooden box of 400 × 400 mm then, they put the sheet on hot compressors. It is the process of hot pressing by hydraulic compressor set. After hot pressing, the sheet is adjusted moisture condition at the room temperature for 24 h.

After adjusting the sheet's temperature, 4 edges are cut. To get standard size, each edge is cut off 2.5 mm by sawing machine. Finally, the sheet or board is tested for physical, mechanical, and thermal properties, according to the industry standard.


Fig. 3 Tilting Blade Machine for Oriented Strand Board, Model Panel Saw SC 30 ITALY

Results and Discussion

According to the process, the researchers form a sample of oriented strand board. The size is 15 mm thick. The duration of hot compressing is 5 minutes with 120 °C temperature. The pressure of hot compressing is 150 kg cm^{-3}. Then, sample is tested according to the industry standards of TIS. 876-2547[10], JIS A 5908-2003 (8 types) [11], ASTM C 177-2010[12], ASTM D 256-2006a [13], and ASTM D 1037-1993[14].

Results of Physical Properties

It is found that the physical properties of the oriented strand board made from rice straw and maize husk compose of density, moisture content, water absorption for 1 and 24 h, and thickness swelling for 1 and 24 h, according to the standard test of TIS 876-2547[10], and JIS A 5908-2003 (8 types) [9]

Table 1 Details of Testing an Oriented Strand Board

Type and Quantity of Adhesives (%)	Types of Materials	Average Density	Fiber Ratio	Symbols
Urea formaldehyde UF.10	Rice straw	645.42	100	a
Di-isocyanate pMDI.10	Rice straw	645.45	100	b
Urea formaldehyde UF.10	Corn husk	637.44	100	c
Di-isocyanate pMDI.10	Corn husk	645.21	100	d
TIS. 876-2547 JIS A 5908:2003	TIS Oriented Strand Board	400-900	100	e

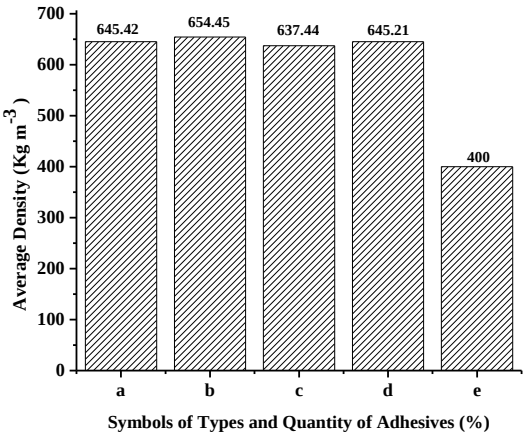

Fig. 4 Average of Density

The study shows that the board made from rice straw with synthetic adhesive urea-formaldehyde resin has average density at 645.42 kg m^{-3}. And the rice straw board with synthetic adhesive isocyanate resin has average density at 654.45 kg m^{-3} respectively. Regarding the board made from maize husk with synthetic adhesive urea-formaldehyde resin, the average density is found at 637.45 kg m^{-3}. Similarly, the maize husk board with synthetic adhesive isocyanate resin has average density at 645.21 kg m^{-3} respectively. The oriented strand board can pass the standard level of TIS 876-2540 [5] which defines the density value at 400 – 900 kg m^{-3}.

It is found that the moisture content of the board made from rice straw with synthetic adhesive urea-formaldehyde resin consists of average moisture content at 9.55%. And the rice straw board with synthetic adhesive isocyanate resin contains average moisture content at 8.29% respectively. Whereas the board made from maize husk with synthetic adhesive urea-formaldehyde resin has average moisture content at 9.53%. And the maize husk board with synthetic adhesive isocyanate resin has average moisture content at 7.72% respectively. The value can pass the standard level of TIS 876-2547 [5] which defines the moisture content at 4 – 13%.

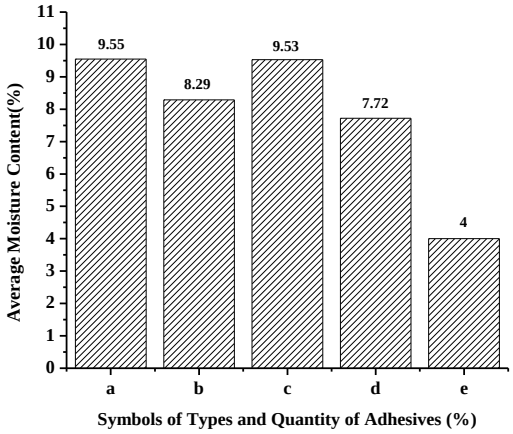

Fig. 5 Average Moisture Content

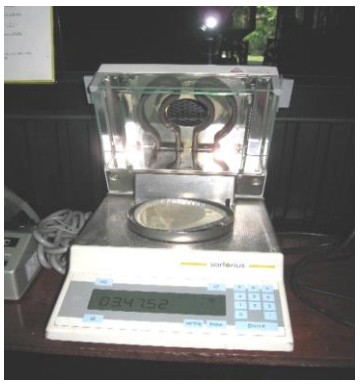

Fig. 6 Instron Set Moisture Analyzer

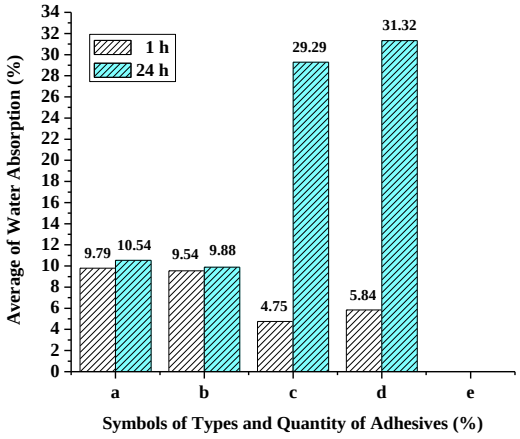

Fig. 7 Average of Water Absorption for 1 and 24 h.

In terms of water absorption for 1 and 24 h, the board made from rice straw with synthetic adhesive urea-formaldehyde resin has average of water absorption for 1 h at 9.79%, and for 24 h at 10.54%. Similarly, the rice straw board with synthetic adhesive isocyanate resin contains average of water absorption for 1 h at 9.54%, and for 24 h at 9.88% respectively. However, the board from maize husk with synthetic adhesive urea-formaldehyde resin has average of water absorption for 1 h at 4.75%, and for 24 h at 29.29%. Regarding the board made from maize husk with synthetic adhesive isocyanate resin, the average for 1 h is 5.84% and for 24 h is 31.32% respectively. The value meets the standard level of TIS 876-2547[5]. The flat pressing board does not define the value of water absorption for 1 and 24 h.

Fig. 8 Instron Set Water Absorption

Regarding thickness swelling for 1 and 24 h, the rice straw board with synthetic adhesive urea-formaldehyde resin contains average of thickness swelling for 1 h at 4.78%, and at 9.61% for 24 hours. Similarly, the rice straw board with synthetic adhesive isocyanate resin contains average for 1 h at 3.52%, and at 9.15% for 24 hours respectively. By comparison, the board made from maize husk with synthetic adhesive urea-formaldehyde resin has average of thickness swelling for 1 h at 3.98%, and at 8.34% for 24 hours. Likewise, the maze husk board with synthetic adhesive isocyanate resin has average for 1 h at 4.51% and at 7.79% for 24 h respectively. The value is considered to pass the standard level of TIS 876-2547[5]. That is the thickness swelling value of a flat pressing board for 1 – 24 h must not exceed/or equal 12%.

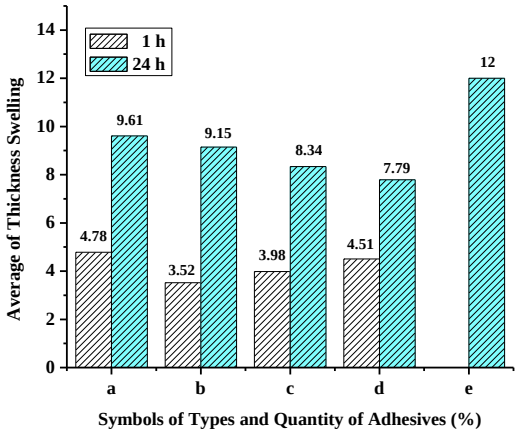

Fig. 9 Average of Thickness Swelling for 1 and 24 h

Fig. 10 Cutting Parts to be Tested for Physical Properties, size 50 × 50 mm.

Fig. 11 Digital Weight Scale: Scout Pro Model 400

Results of Mechanical Properties

The researchers test the board to find mechanical properties. Such properties compose of bending force resistance, modulus of rupture and elasticity, as well as impact strength which are tested by Universal Testing Machine. In addition, the tests cover tensile strength being perpendicular to the surface, bond strength of screws, and tensile strength. The tests depend on the standard test of TIS 876-2547[10], JIS A 5908-2003 (8 types) [11], ASTM D 256-2006[13], and ASTM D 1037-1993[14].

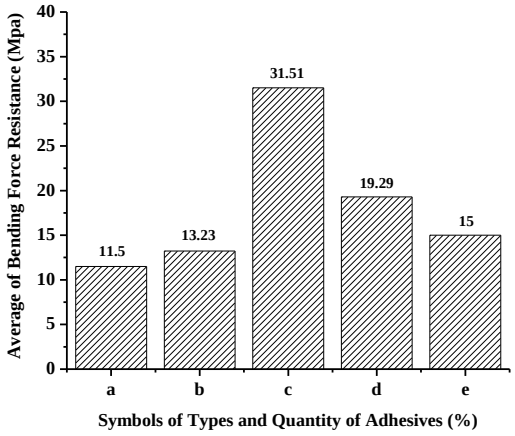

Fig. 12 Average of Bending Force Resistance

Regarding bending force resistance and modulus of elasticity, the board made from rice straw with synthetic adhesive urea-formaldehyde resin consists of average at 11.15 MPa and 1435 MPa. Whereas the board with synthetic adhesive isocyanate resin consists of average at 13.23 MPa and 1280 MPa respectively. However, the board made from maize husk and synthetic adhesive isocyanate resin shows the average of bending force resistance and modulus of elasticity at 31.51 MPa and 2128 MPa. At the same time, the maize husk board with synthetic adhesive isocyanate resin shows the average at 19.29 MPa and 1852 MPa respectively. So, it can be said that the board from maize husk can pass the standard level of TIS 876-2547[10].

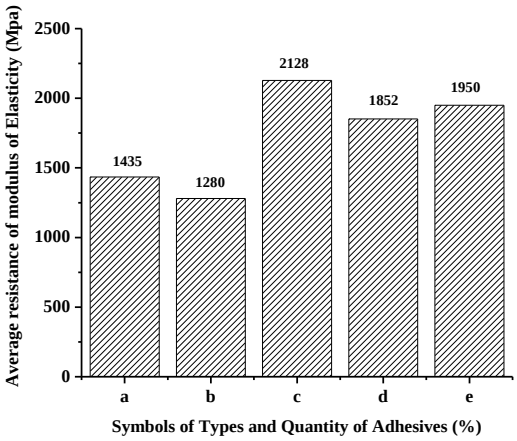

Fig. 13 Average of Modulus of Elasticity

The standard clarified that a flat compressing board must contain bending force resistance required that is more than/or equal 14 MPa. In addition, the modulus of elasticity must be more than/or equal 1600 MPa. Unfortunately, the rice straw boards with synthetic adhesive urea-formaldehyde resin and synthetic adhesive isocyanate resin do not reach the standard level of bending force resistance and modulus of elasticity.

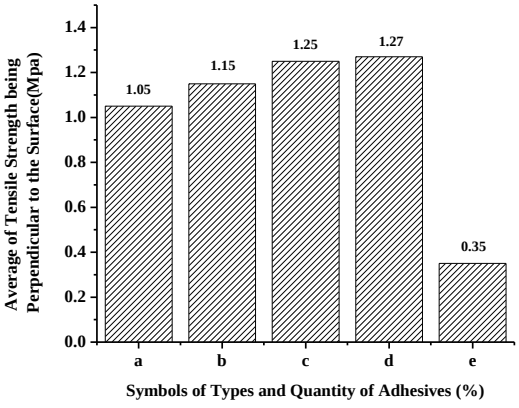

Fig. 14 Average of Tensile Strength being Perpendicular to the Surface

In term of the value of tensile strength being perpendicular to the surface, the rice straw board mixed with synthetic adhesive urea-formaldehyde

resin has average at 1.05 MPa. And the rice straw board with synthetic adhesive isocyanate resin has average at 1.15 MPa respectively. By comparison, the maize husk board with synthetic adhesive Di-isocyanate resin holds the value of tensile strength being perpendicular to the surface at 1.25 MPa. Likewise, the one with synthetic adhesive isocyanate resin has the average at 1.27 MPa respectively. The average can pass the standard level of TIS 876-2547[5] which is remarked that a flat compressing board's standard value must be more than/or equal 0.35 MPa.

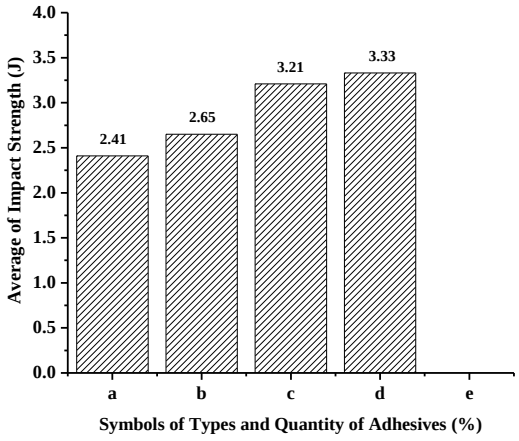

Fig. 15 Average of Impact Strength

Considering the value of impact strength, the result shows that the board of rice straw with synthetic adhesive urea-formaldehyde resin contains the average of impact strength at 2.41 J whereas the one with synthetic adhesive isocyanate resin contains 2.65 J respectively. Comparing with the maize husk board mixed with synthetic adhesive urea-formaldehyde resin, it is found that the average of impact strength is 3.21 J Similarly, another one with synthetic adhesive isocyanate resin holds impact strength at 3.33 J

In the point of tensile strength, it is found that the rice straw board with synthetic adhesive urea-formaldehyde resin composes of the average of tensile strength at 2.45 N mm^{-2}. And the one with synthetic adhesive isocyanate resin, the average is 3.16 N mm^{-2} respectively. Besides, the board made from maize husk and synthetic adhesive isocyanate resin contains the average of tensile strength at 2.46 N mm^{-2}, whereas the one with synthetic adhesive isocyanate resin contains 2.72 N mm^{-2}.

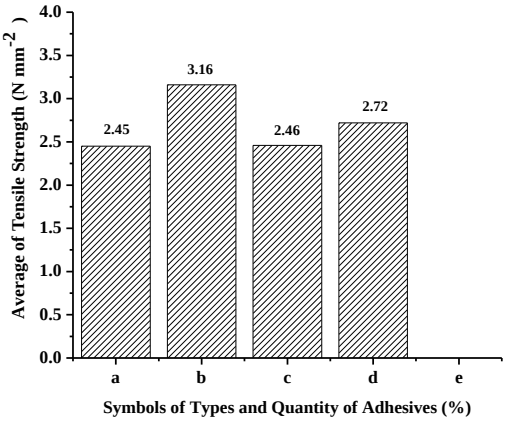

Fig. 16 Average of Tensile Strength

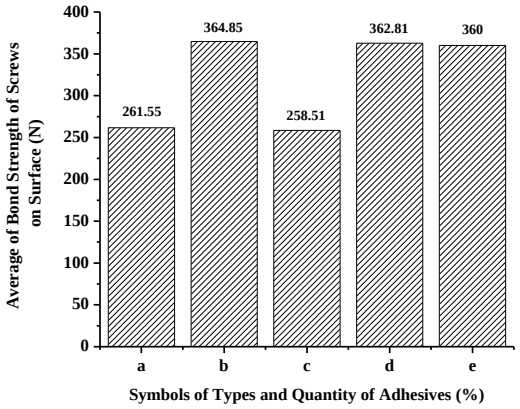

Fig. 17 Average of Bond Strength of Screws on Surface

Focusing on the aspect of bond strength of screws on surface, the result shows that the rice straw board with synthetic adhesive urea-formaldehyde resin contains the average value at 261.55 N. Similarly, the board with synthetic adhesive isocyanate resin contains the average at 264.85 N respectively. Regarding the board of maize husk, the one with synthetic adhesive urea-formaldehyde resin holds the average of bond strength at 258.51 N. And the one with synthetic adhesive isocyanate resin hold the average at 362.81 N respectively. The average is in accordance with the standard which is defined the figure at 360 N.

Fig. 18 Instron Set (Tensile Iestel Model 5560), to Test Bond Strength

Fig. 19 Instron Set (Tensile Iestel Model 5560), to Test Tensile Strength being Perpendicular to the Surface and Bond Strength of Screws

Fig. 20 Impact Tester

Result of Testing Thermal Property, the researchers operate thermal analysis by Thermogravimetric Analysis (TGA) Instrument. It is the process to measure thermal conductivity and thermal resistance. The researchers test the cutting part of oriented strand board of size 300 × 300 mm, referring to the standard of ASTM C 177-2010[12].

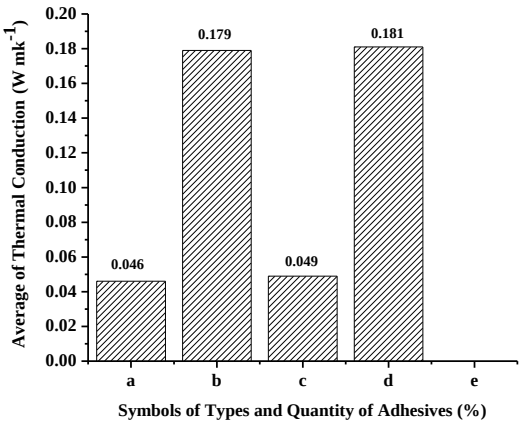

Fig. 21 Average of Thermal Conduction

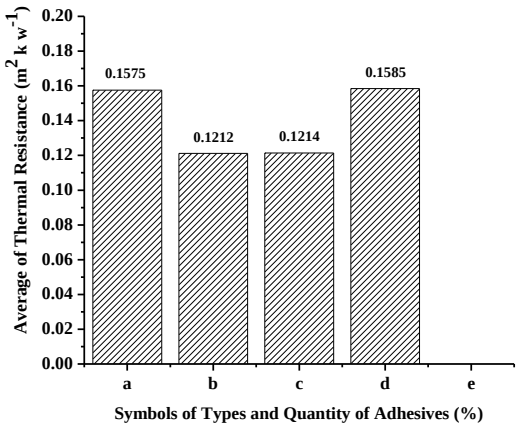

Fig. 22 Average of Thermal Resistance

As a result, the average of thermal conduction and thermal resistance for the board of rice straw mixed with synthetic adhesive urea-formaldehyde resin indicates at 0.046 W m k^{-1} and 0.1575 m^2 k W^{-1}. And the maize husk board with synthetic adhesive isocyanate resin consists the average at 0.179 W m k^{-1} and 0.1212 m^2 k W^{-1} respectively. By comparison, the rice straw board with synthetic adhesive urea-formaldehyde resin shows the average at 0.049 W m k^{-1} and 0.1214 m^2 k W^{-1}. And another one with synthetic adhesive isocyanate resin shows the average at 0.181 W m k^{-1} and 0.1585 m^2 k W^{-1} respectively.

Fig. 23 Instron Set (Model TC-48-20) to Test thermal conduction and thermal resistance

The study of producing oriented strand board from rice straw and maize husk aims at studying the quantity of adhesives. That is synthetic adhesive urea-formaldehyde 10% and synthetic adhesive isocyanate resin 10%. The study deals with testing physical, mechanical, and thermal properties, according to TIS 876-2547 [10], and JIS A 5980-2003 (8 types) [11], and ASTM C 177-2010 [12], and ASTM D 256-2006a [13], and ASTM D 1037-1993 [14]. Also, the aim is to find out the economics cost. According to the test, it is found that the oriented board from rice straw and maize corn with synthetic adhesive isocyanate resin 10% contains higher properties than the one with synthetic adhesive urea formaldehyde 10%. That is synthetic adhesive isocyanate resin provides higher mechanical properties. The board is durable for serious situations. It is dense and hard. The surface is strong enough to anchor screws, have resistance of surface perpendicular force, and well flexible. Regarding thermal properties, it is found that thermal conductivity is at nearly level as insulation of commercial production 0.1212 – 0.1585. (Value of thermal resistance of other types of commercial production materials 0.023 – 0.280 W m k^{-1}) According to the analysis of economic cost, the researchers estimate all expenses of producing oriented strand boards from rice straw and from corn husk. Such expenses include equipment, instruments, chemicals, raw materials, electricity, wages, and other miscellaneous materials. Altogether, the cost or capital of an oriented strand board with 400 mm width, 400 mm thickness, and 15 mm thickness, can be concluded as the following details.

Taking everything into consideration, the cost or capital of an oriented strand board with 400 mm width, 400 mm thickness, and 15 mm thickness, can be concluded as follows;

1) Show the oriented strand boards from rice straw and from maize husk mixed with synthetic adhesive urea-formaldehyde resin cost 43.12 baht

Fig. 24 An oriented strand boards from rice straw

2) Show the oriented strand boards from rice straw and from maize husk mixed with synthetic adhesive isocyanate resin cost 45.78 baht.

Fig. 25 An oriented strand boards from maize husk

Conclusion

The oriented strand board from rice straw and maize husk has smooth external surface. The material in pieces and inside the sheet touch each other closely. The board passes the standard level of TIS 876-2547 dealing with flat plywood. [10] It is obvious that natural fiber has specific property. Which means, it is helpful for heat insulation, light, resistant to bending and pulling force. It is a way to increase alternative material which is inexpensive and has good quality for building material. [17] [15] Hence, it is another alternative material that will reduce capital cost. People can select agricultural waste material which are easy to find in locality. [16] Appropriate material and production technology can be operated. Besides, the most important thing, the product will make people more

understand and realize the value of using natural resources. [3] [18] The product is also regarded as another choice to add value for farmers. Finally, there are many advantages of the flat plywood or wood substituted materials from waste agricultural materials. That is to say, the board has beautiful traceries, outstanding colors, and being natural. [8] Moreover, the burr traceries can be seen. So, people can use the board for decoration without any painting over.

Fig. 26 Using oriented strand boards from rice straw and maize husk to install with building wall

Furthermore, the oriented strand board from rice straw and from maize husk are useful to decorate an exhibition of architecture. For instance, the boards are covered over external walls of lecturer rooms of the Department of Basic Mechanics, Kanchanaburi Polytechnic College, in Kanchanaburi Province.

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