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Physical and Mechanical Properties of Fiber Boards from Oil Palm Empty Fruit Bunch Fibers Mixed with *Water Hyacinth* Fibers

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Abstract

This research aims were to produce and study properties of fiber boards from oil palm empty fruit bunch fibers mixed with *Water hyacinth* fiber, by using 13% adhesive substances comprising urea formaldehyde (UF) and polymeric diphenylmethane diisocyanate (PMDI) resins. The boards had a density of 400, 600 and 900 kg m^{-3} and a thickness of 15 mm. Physical and mechanical properties tests were performed according to industry standards, TIS 876-2547, ASTM D 1037-1999 and ASTM D 256-2006a. The physical properties investigated were moisture content, water absorption and thickness swelling of the plates. The results revealed that plates with high density had low moisture content, low water absorption and low thickness swelling. PMDI resin provided the best adhesive quality. For the mechanical properties investigation, modulus of rupture, modulus of elasticity, the tensile strength perpendicular to the surface, impact strength, the nail and screws holding power were covered. It was found that the higher density they had, the better mechanical properties they owned. The PMDI-based boards with 900 kg m^{-3} density achieved the best mechanical properties. They can highly possibly be used instead of wood.

Keywords: Physical properties; Mechanical properties; Fiber boards

1. Introduction

Thailand is predominantly an agricultural country. Apart from food crops, farmers also plant a great diversity of industrial crops such as sugar cane, corn and oil palm. The massive agricultural residues from these small and large-scale and mechanized farms traditionally considered as waste is increasingly viewed as potentially raw materials for value-added products. The idea of waste transformation is also applied to treat serious problem of disposal caused by invasive *Water Hyacinth* in natural water resources. Some of these biomass residues have been proved to be great sources of high quality natural fibers which can be used in many sustainable product lines. This research has attempted to develop fiber boards from oil palm empty fruit bunch mixed with fiber extracted from *Water Hyacinth*. PMDI and UF were used for board forming process. They are the most used binders from high performing thermosetting adhesives utilized in fiber board industry. The physical and mechanical properties were then tested. Supuan et.al. [1] stated that woven banana fiber boards with epoxy adhesive yielded stable mechanical properties while PMDI was likewise popular in wood

panel industry (particle board, Medium Density Fiberboard [2 – 4]). UF resin was also popular due to its easy processing, low cost and good performance in panel production [5]. The properties of fiber boards depend largely on the adhesive systems, and also the adhesion between the fiber to adhesive bonding ability.

2. Materials and Methods

Preparing the fiber boards

In preparing the fiber boards, 2 types of thermosetting polymer were used 13% diphenyl methane diisocyanate (PMDI) resin and 13% urea formaldehyde (UF) resin were added to the first and second fiber mixtures, respectively. For additives, 2% ammonium chloride as a hardener and 1% paraffin emulsion as a waterproof coating agent were incorporated. The required conditions for the entire process were as follows.

- The mixing ratio of oil palm empty fruit bunch fiber and Water Hyacinth fiber was 50:50 wt%.
- The fiber board density was 400, 600 and 900 kg m^{-3}.
- The boards with dimensions of 400 mm in width, 400 mm in length and 15 mm in thickness were produced.
- The fiber moisture content ranged from 3 – 5% and up to 10 – 12% before and after adhesive additions.
- The fiber boards were formed by hot press machine. The force of 150 kg m^{-3} was applied at 120 °C for 5 minutes.

Methods

- Both oil palm empty fruit bunch and *Water Hyacinth* were cut into small size not bigger than 15 mm. The oil palm empty fruit bunch fiber had to be cleaned to remove the residual oil before fiber processing. They were then dried to obtain 3 – 5% moisture content before mixed together at 50:50 wt% ratio.
- 13% UF resin with 1% paraffin emulsion and 2% ammonium chloride were thoroughly combined and then sprayed onto the fiber mixture from first paragraph in *Methods*. The PMDI-based batch was prepared in the same fashion as described.
- For a density of 400 kg m^{-3}, the board was molded from 600 g of each fiber. The fiber amount was increased to 800 g and 1100 g to produce the boards with a density of 600 kg m^{-3} and 900 kg m^{-3}, respectively.
- In order to make a board, the mold with the dimensions of 400 mm in width, 400 mm in length and 15 mm in thickness was used. The adhesive-coated fibers was spread evenly in the mold. The obtained-board was called a "preform board". The hot press machine was used to manufacture the desired board by applying the force of 150 kg m^{-3} at 120 °C for 5 minutes.
- The achieved boards had to be stored at ambient temperature for 24 hours to be ready for moisture content test. The achieved boards are shown in Fig.1.

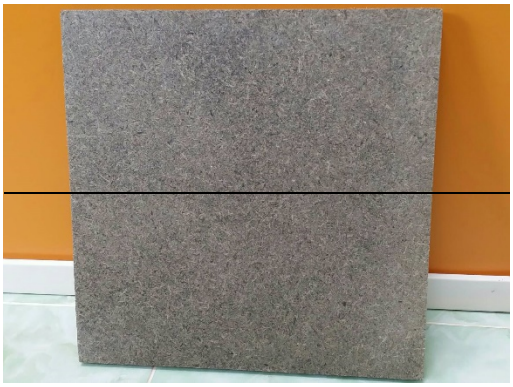

Fig.1 Fiber board from oil palm empty fruit bunch mixed with *Water Hyacinth* fiber, 50:50

- For the test specimen's preparation, the fiber boards were cut into the exact dimensions described in related standards. The specimen for physical and mechanical properties testing was 50x50x15 mm. The specimen with the dimensions of 12.70 ± 0.20 mm wide by 63.50 ± 2.0 mm long and 15 mm thick was prepared for impact strength test. For tensile strength test, the specimen was 50x200x15 mm.

- The physical and mechanical properties were tested as follows.

Physical properties testing: Water absorption test was performed according to TIS 876-2547. The moisture content and thickness swelling was tested according to JIS A 5908-2003 (8 type).

Mechanical properties testing: Modulus of rupture (MOR), Modulus of elasticity (MOE) and tensile strength perpendicular to plane of board were tested according to TIS Standard test procedure 876-2547 and JIS A 5908-2003 (8 type). The Impact strength test followed ASTM D 256-2006a standard while the tensile strength used ASTM D 1037-1999. All the test was repeated on 3 specimens for average value finding.

3. Results and Discussion

The Results of physical properties testing

Moisture content

The average moisture contents of fiber boards using UF resin as the adhesive were 13.42, 9.52 and 7.48% for the boards with the density of 400, 600 and 900 kg m^{-3}, respectively. For the PMDI-mixed group, the values were 10.21, 8.29 and 6.92%, respectively.

Water absorption tested at 1 and 24 hours soaking time

At 1 and 24 hours soaking time for the UF-mixed boards, the three consecutive 400, 600 and 900 kg m^{-3} lots thus had the average water absorption of 29.53, 9.79 and 7.98% and 51.61, 10.54 and 9.86%, respectively. For the PMDI-mixed boards at the two soaking time, the three batches with 400, 600 and 900 kg m^{-3} in density thus had the average water absorption of 13.12, 9.54 and 5.54% and 48.32, 9.88 and 8.98%, respectively. The results showed that higher density boards yield lower water absorption value.

Thickness swelling tested at 1 and 24 hours soaking time

For boards with three different densities, 400, 600 and 900 kg m^{-3}, the UF-mixed lots thus had the thickness swelling of 12.14, 4.32 and 3.14% at 1 hour soaking time. The overall values went up to 24.84, 9.61 and 8.43%, respectively, at 24 hours soaking time. The PMDI-mixed boards results with the same manner. After being soaked for 1 and 24 hours, the three batches gained 8.12, 4.11 and 2.42% and 17.52, 9.15 and 5.02% in thickness swelling, respectively. Physical properties of fiber boards from oil palm empty fruit bunch fiber mixed with water hyacinth fiber were shown in Table 1.

Table 1 Physical properties of fiber boards produced from oil palm empty fruit bunch fibers mixed with *Water hyacinth* fiber

Physical properties		400 (kg m^{-3})		600 (kg m^{-3})		900 (kg m^{-3})	
		UF	PMDI	UF	PMDI	UF	PMDI
Moisture content (%) -TIS 876-2547 (value 4-13) -JIS A5908-2003 (value 5-13)		13.42	10.21	9.52	8.29	7.48	6.92
Water absorption (%)	1 h.	29.53	13.12	9.79	9.54	7.98	5.54
	24 h.	51.61	48.32	10.54	9.88	9.86	8.98
Thickness swelling (%) -TSI 876-2547 and -JIS A5908-2003, 24 h. (value 12)	1 h.	12.14	8.12	4.32	4.11	3.14	2.42
	24 h.	24.84	17.52	9.61	9.15	8.43	5.02

The results of mechanical properties testing

Modulus of rupture and modulus of elasticity

The average modulus of rupture (MOR) of fiber boards using UF resin as the adhesive were 3.75, 12.18 and 18.52 MPa for the boards with the density of 400, 600 and 900 kg m^{-3}, respectively. For the PMDI-mixed group, they were 4.29, 15.27 and 25.47 MPa, respectively. For the average modulus of elasticity (MOE) of three mentioned densities, they were 181, 1,357 and 2,469 MPa for the UF-mixed boards while those using PMDI had 186, 1,492 and 2,579 MPa respectively. It can be seen that the PMDI-utilized group possessed higher density and also MOR and MOE compared to the UF-mixed one.

Tensile strength perpendicular to plane of board

For boards with three different densities, 400, 600 and 900 kg m^{-3}, the UF-mixed batches thus had the average tensile strength perpendicular to plane of board of 0.19, 1.25 and 1.74 MPa. The PMDI-mixed batches gave higher values at 1.15, 1.45 and 2.32 MPa, respectively. The results illustrated that the higher density boards yielded higher tensile strength perpendicular to plane of board. And PMDI-mixed boards also presented higher tensile strength than those with UF adhesive.

Impact strength

For the three sets of UF-mixed boards according to their densities, 400, 600 and 900 kg m^{-3}, the average impact strength were thus 1.12, 2.48 and 3.28 MPa. The PMDI system obtained 2.36, 2.75 and 3.38 MPa, respectively. As indicated by tensile strength measurement, the higher density boards provided the higher impact strength. The PMDI-based boards also presented the higher impact strength than the UF system. However the achieved impact strength was substandard due to typical particleboard specification standards.

Nail and screw holding power

The average nail and screw holding power of 400 kg m^{-3} density fiber boards using UF and PMDI adhesive was 251.29 and 252.31 N respectively. For the 600 kg m^{-3} boards, they were 260.15 and 363.25 N while the 900 kg m^{-3} boards had the highest values at 364.18 and 367.64 N, respectively. It also showed that the higher the board's density, the better the board's nail and screw holding power. The PMDI system presented the greater nail and screw holding power than the UF system as well.

Tensile strength

The average tensile strength of the produced boards with the density of 400 kg m^{-3} were 1.28 and 1.39 N mm^{-2} for the UF and PMDI systems, respectively. For the 600 and 900 kg m^{-3} fiber boards, they resulted with 2.54, 3.26 N mm^{-2} and 4.32, 5.78 N mm^{-2}, respectively. As the previous tests has suggested, the higher density board introduced the better tensile strength, and again the

PMDI present the higher value as UF adhesive. The tensile strength was also not specified in particleboard specification standards. The results of mechanical properties were shown in Table 2.

Table 2 Mechanical properties of fiber boards produced from oil palm empty fruit bunch fibers mixed with *Water hyacinth* fiber

Mechanical properties	400 (kg m^{-3})		600 (kg m^{-3})		900 (kg m^{-3})	
	UF	PMDI	UF	PMDI	UF	PMDI
Modulus of rupture (MPa) -TIS876-2547, (value ≥ 0.14) -JIS A 5908-2003 (8type), (value ≥ 8)	3.75	4.29	12.18	15.27	18.52	25.47
Modulus of elasticity (MPa) -TIS876-2547, (value ≥ 1600) -JIS A 5908-2003 (8type), (value ≥ 2000)	181	186	1357	1492	2469	2579
Tensile strength perpendicular to plane of board (MPa) -TIS876-2547, (value ≥ 0.35) -JIS A 5908-2003 (8type), (value ≥ 0.15)	0.19	1.15	1.25	1.45	1.74	2.32
Impact strength (J)	1.22	2.36	2.48	2.75	3.28	3.38
Nail and screw holding power (N) -TIS876-2547 -JIS A 5908-2003 (8type), (value 360)	251.29	252.31	260.15	363.25	364.18	367.64
Tensile Strength (N mm^{-2})	1.28	1.39	2.54	3.26	4.32	5.78

Most of physical and mechanical properties of fiber boards from oil palm empty fruit bunch mixed with *Water Hyacinth* at 400 and 600 kg m^{-3} density don't pass the particleboard specification. For the 900 kg m^{-3} density group, all physical properties except the thickness swelling pass the standard. However, all mechanical properties of the 900 kg m^{-3} density fiber boards meet the requirements. Anyhow, the boards with increasing amount of fiber and adhesive have an issue of dissolving.

4. Conclusion

In this study, the physical and mechanical properties of oil palm empty fruit bunch mixed with *Water Hyacinth* fiber boards were investigated. It showed that the boards with 900 kg m^{-3} in density yielded the best performance. The moisture content, modulus of rupture, modulus of elasticity, tensile strength perpendicular to plane of board and nail and screw holding power pass the standard specifications while water absorption, impact strength and tensile strength don't. Nevertheless, the mechanical properties of the 900 kg m^{-3} density fiber boards were considered to be in the qualified range. The achieved fiber boards were suitable for furniture making and renewable interior decoration in replace of nature wood.

5. Acknowledgements

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