Mechanical and physical properties of particleboard made from scirpus grossus and coconut fiber

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Abstract. In this research of study mechanical and physical properties of particleboard made with scirpus grossus and coconut fiber. The particles were manually mixed at a weight ratio of C1 (100:0), C2 (90:10), C3 (75:25), C4 (25:75), C5 (10:90) and C6 (0:100) and glued adhesive with methylene diphenyl diisocyanate (MDI) 7% (by weight). Physical and mechanical properties were evaluated following Thai industrial standard (876-2547). To measure the mechanical properties, 6 samples were tested to determine the modulus of rupture – MOR and modulus of elasticity – MOE by using samples with a nominal size of 250×50 mm and physical properties, 3 samples were tested to determine the were determined: density, water absorption (WA) and thickness swelling (TS). The physical properties result of all ratio is according to the standard, which the highest density, thickness swelling and water absorption are C3 (849.01 kg/m³), C6 (6.55 %) and C6 (9.92 %) respectively. The mechanical properties result of Modulus of rupture (MOR) for proportion to C4, C5 and C6 have a higher than standard, while C1, C2 and C3 are lower. All ratio for modulus of elastic (MOE) are lower than standard. The ratio of C6 is the highest modulus of rupture (21.60 MPa) and the highest of modulus of elastic is C1 (360.20 MPa). The experimental investigation indicated that the excellent particleboard properties are obtained with a mixture ratio of C5 (10:90).

1. Introduction
Successful development of composite panels in the last decades could be attributed to the economic advantage of low-cost wood and other lignocellulosic raw material and inexpensive processing with various types of binder [1]. Advantages of biomaterial over synthetic counterparts are their high toughness, low density, good specific strength properties, and good processability [2]. However, in this study, a scirpus grossus and coconut are used as a raw material for particleboard. Scirpus grossus is a very useful natural fiber that can be used as a reinforcing material because of its interesting features: lignin content of 13.44% and tensile strength value of 1.52 kN/m² [3]. Among the bio fibers, coconut fiber is nowadays widely used in many industrial applications [4]. Coconut fiber possesses elongation at break highest among typical bio fibers [4]. The high lignin content in coconut fiber is responsible for other beneficial properties such as weather resistance [5]. There fore, in this work, the study to the influence of scirpus grossus hybridization with coconut for particleboard were compared in terms of physical and mechanical properties.
2. Materials and methods

2.1. Raw materials

The materials used for the production of composite particleboard from coconut fiber and Scirpus grossus fiber were obtained locally from Noonsomboon village Roi-Et province and Jumnuk village, Maha Sarakham province. The age of both type fibers are around 2-4 years and it used to range in fiber lengths between 1-4 cm, which was collected at an average moisture content of 4-13 %. Methylene diphenyl diisocyanate (MDI) was provided from Bangkok, Thailand and used at a level of 7 %wt for the construction of particleboards.

2.2. Particleboard manufacturing

Firstly, both fibers were extracted from the plants with a hand. Fibers were oven dried at 80 °C to reach the target moisture content. Secondly, the fibers were placed in a drum mixer and blended with MDI. Next, the fiber then were pressed into panel mat using a hydraulic hot press. Teflon sheet was applied on the MDI-mat to avoid the adhesive sticking to the hot press plates. The suitable moisture content of the MDI-mat for particleboard manufacturing was adjusted at 8 % [6]. The experimental design is shown in table 1. The dimensions of the produced particleboards were 450 × 450 × 10 mm³. The panel production parameters were also displayed in table 2.

| Particleboard type | Scirpus grossus (%) | Coconut (%) |
|--------------------|---------------------|-------------|
| C1                 | 100                 | 0           |
| C2                 | 90                  | 10          |
| C3                 | 75                  | 25          |
| C4                 | 25                  | 75          |
| C5                 | 10                  | 90          |
| C6                 | 0                   | 100         |

Table 2. Production parameters of particleboard.

| Parameter           | Value |
|---------------------|-------|
| Press temp (°C)     | 120   |
| Press temp (min)    | 5     |
| Max pressure (bar)  | 147   |

The flexural properties (modulus of rupture (MOR) and modulus of elasticity (MOE)) of the samples were performed according to Thai industrial standard test (876-2547). Physical properties, namely, density, thickness swelling and water absorption test were carried out according to EN317 (1993). The data obtained was statistically analyzed using One-way ANOVA with considered confidence level significant differences at the data 95 %.

3. Results and discussion

3.1 Physical properties

3.1.1 Density. The density of particleboard made with scirpus grossus and coconut fiber are shown in figure 1, it showed that different particleboard type has an effect on the density of particleboard. The C3 show density of about 849.01 kg/m³ higher than other particleboard. According to Thai industrial standard (876-2547) [7], the lignocellulosic materials obtained in this research are classified as flat pressed (FP) particleboards (density range from 400 kg/m³ to 900 kg/m³) are reported in figure 1. The detail statistical analysis showed that significant differences (p<0.05) variation between the mean density values with all panel types as shown in table 3.
3.1.2 Thickness swelling. The data obtained for thickness swelling of the particleboards for the different treatments evaluated did differ statistically ($p < 0.05$). The thickness swelling is shown in figure 2, in the bar chart of the figure as shown values of the experimental particleboards ranged from 3.60 to 6.55 MPa. The highest thickness swelling value was observed for C6 while the lowest was recorded for C1. The thickness swelling values increased with the increasing the fiber ratio. This can be reasoned by the presence of scirpus grossus and coconut fibers in the particleboards with weaving pattern which is a component of the particleboards that have high force transfer in both the longitudinal and transverse direction and defect in fiber is low [8].

3.1.3 Water absorption. Figure 3 shows the addition of particleboard strongly reduces water absorption of the specimens from 7.09 % to 9.92%. The statistical analysis showed that C3 had the lowest effect on water absorption. The decreasing water absorption was the C3 exposure to water lower than other particleboard. However, in contrast to the increasing water absorption due to particleboard was immured by water before specimens test, these causing were affected mechanical properties because the weak interface of fiber/matrix which occurred void in fracture surface and construction bonding between water molecules/cellulose [8]. Therefore, it is clear that the water absorption of the composite decreased with the increase of mechanical properties. Further, from table 3, the statistical analysis shows that significant ($p < 0.05$) with different fiber ratio.

3.2 Mechanical properties

Modulus of rupture (MOR) was seen to increase with the addition of scirpus grossus up to 100 %, C6 had the highest value for MOR which is higher than the Thai industrial standard value as shown in figure 4. Modulus of elasticity (MOE) value for all ratios are lower than the Thai industrial standard as shown in figure5. Low efficiency in MOE and MOR could be due to the relationship among the bond quantity and low density caused by a gromatic residues [9].

**Table 3.** Physical and mechanical properties of particleboard type.

| Specimens | Density (kg/m$^3$) | Thickness swelling (%) | Water absorption (%) | Modulus of rupture (MPa) | Modulus of elasticity (MPa) |
|-----------|--------------------|------------------------|----------------------|--------------------------|---------------------------|
| C1        | 683.11±23.10       | 3.60±0.64              | 8.79±1.80            | 9.81±0.10                | 360.20±34.36              |
| C2        | 712.23±46.04       | 5.35±0.77              | 8.75±0.63            | 10.61±0.65               | 257.66±41.68              |
| C3        | 849.01±15.35       | 5.63±0.42              | 7.09±1.69            | 13.71±1.31               | 264.88±3.92               |
| C4        | 701.87±42.81       | 5.92±0.89              | 9.85±0.88            | 14.14±1.92               | 306.94±58.71              |
| C5        | 695.51±48.74       | 6.13±0.36              | 9.30±2.23            | 17.56±0.91               | 261.68±7.71               |
| C6        | 634.13±44.8        | 6.55±0.33              | 9.92±0.90            | 21.60±0.35               | 250.96±5.69               |
| Standard  | 400-900            | ≤ 12                   | ≤ 12                 | ≥ 14                     | ≥ 1800                    |
| p-value   | 0.01*              | 0.01*                  | 0.264                | 0.00*                    | 0.01*                     |

Where, * is significantly difference at $p < 0.05$ (The value of $p < 0.05$ is about the statistical significance of test).
Figure 1. Density of particleboard made with scirpus grossus and coconut fiber.

Figure 2. Thickness swelling of particleboard made with scirpus grossus and coconut fiber.

Figure 3. Water absorption of particleboard made with scirpus grossus and coconut fiber.

Figure 4. Modulus of rupture of particleboard made with scirpus grossus and coconut fiber.

Figure 5. Modulus of elasticity of particleboard made with scirpus grossus and coconut fiber.
4. Conclusion
The effect of fiber ratios on physical and mechanical properties of particleboard by the fibers of scirpus grossus and coconut were investigated. Based on the results, the following concluding remarks can be mentioned: the physical properties of particleboard produced with both fibers are in Thai industrial standard every sample. The companion of MOR showed that C6, which it shows the maximum value (21.60 MPa). The MOE of all samples show values lower than Thai industrial standard.

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