

## การทำไม้อบกาวอัดจากไม้ยางพารา COMPREG MADE FROM RUBBER WOOD VENEER

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### บทคัดย่อ

การศึกษาเพื่อพัฒนาการผลิตไม้อบกาวอัดจากไม้ยางพารา (*Hevea brasiliensis* Muell & Agr.) ได้ทำการศึกษาปัจจัยที่มีผลต่อการซึมซาบของเนื้อกาวสังเคราะห์เข้าสู่เนื้อไม้ยางพารา 3 ปัจจัย คือ ปริมาณความเข้มข้นของสารละลายกาวฟีนอล ฟอรัลดีไฮด์ ที่ร้อยละ 20, 30 และ 40 ระยะเวลาการแช่ที่ 5, 10 และ 15 ชั่วโมง และสภาวะของไม้ยางพาราที่สภาวะสดและสภาวะผึ่งแห้ง โดยใช้แผนการทดลองแบบแฟคทอเรียล (สุ่มทดลองอย่างสมบูรณ์)

ผลการศึกษาพบว่า ไม้ยางพาราสด แช่ในสารละลายกาวฟีนอล ฟอรัลดีไฮด์ ความเข้มข้นร้อยละ 40 เป็นระยะเวลา 10 ชั่วโมง มีความเหมาะสมต่อการผลิตไม้อบกาวอัด เพราะมีปริมาณเนื้อกาวที่ซึมซาบเข้าสู่เนื้อไม้ยางพาราร้อยละ 33.18 จากการทดสอบแรงคัดสลัดของชิ้นตัวอย่างตามมาตรฐาน ASTM พบว่า ไม้อบกาวอัดแบบเสี้ยนขนานมีค่าเฉลี่ยมอดูลัสแตกร้าว เท่ากับ 126.16 เมกะปาสคาล ค่าเฉลี่ยมอดูลัสยืดหยุ่นเท่ากับ 14.22 จิกะปาสคาล สูงกว่าค่าเฉลี่ยมอดูลัสแตกร้าว และมอดูลัสยืดหยุ่น ของไม้อบกาวอัดแบบเสี้ยนตั้งฉาก และไม้ยางพาราอย่างมีนัยสำคัญยิ่ง ( $P < 0.01$ ) ค่าเฉลี่ยมอดูลัสความแข็งของไม้อบกาวอัดแบบเสี้ยนตั้งฉากเท่ากับ 98.32 เมกะปาสคาล แตกต่างจากค่าเฉลี่ยมอดูลัสความแข็งของไม้อบกาวอัดแบบเสี้ยนขนาน ซึ่งมีค่าเท่ากับ 87.38 เมกะปาสคาล อย่างไม่มีนัยสำคัญ ( $P < 0.05$ ) ทั้งนี้ค่าเฉลี่ยมอดูลัสความแข็งของไม้อบกาวอัดทั้งสองแบบมีค่าสูงกว่าค่าความแข็งของไม้ยางพารา (ด้านสัมผัส) ซึ่งมีค่าเท่ากับ 38.54 เมกะปาสคาลอย่างมีนัยสำคัญยิ่ง สกภาพสมบัติของไม้อบกาวอัดทั้งสองแบบ เช่น ความถ่วงจำเพาะ การดูดซึมน้ำ การพองตัววถกการคั่นตัว และการคั่นตัวตามความหนา มีความแตกต่างกันอย่างไม่มีนัยสำคัญ โดยการพองตัววถกการคั่นตัวตามความหนาของไม้อบกาวอัดที่ศึกษา มีค่าใกล้เคียงกับไม้อบกาวอัดของต่างประเทศ และมีกลสมบัติที่ต่ำกว่าไม้มากนั้ก

### ABSTRACT

Rubber wood (*Hevea brasiliensis* Muell & Agr.) is suggested on as a new raw material for the manufacturing of compreg to aim at a new product in Thailand. Some factors affecting the resin

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retention in rubber wood veneer were examined by using the factorial experimental design (completely randomized technique). The three factors chosen were the concentration of phenol formaldehyde resin at three levels, (viz.) 20%, 30%, and 40%, soaking time at 5, 10, and 15 hours, and the veneer condition either air-dried or green.

The results of this study indicated that the green veneer treated with a 40% resin solution and soaked for 10 hours produced a high quality compreg since the veneer showed a resin retention of 33.18 %. The average of modulus of rupture and modulus of elasticity in a static bending test of parallel-laminated compreg were 126.16 MPa, and 14.22 GPa respectively, this was highly-significantly ( $P < 0.01$ ) different from the values of the cross-laminated compreg and the solid rubber wood. The average modulus of hardness of cross-laminated compreg was 98.32 MPa, not significantly ( $P < 0.05$ ) different to 87.38 MPa for the parallel-laminated compreg. Values for both compregs were, however highly-significantly different to those for solid rubber wood. The physical properties of both the compregs, such as specific gravity, water absorption, swelling, and recovery of thickness similar.

**Keywords :** *Modified wood, Compreg*

## INTRODUCTION

Methods for improving physical and mechanical properties of wood or wood-based materials, such as polymer impregnation, synthetic resin treatment, and wood compression under specially controlled conditions often combined with chemical treatment, are increasingly being investigated by scientists in Thailand. Conventionally, wood and wood-based materials were treated to meet desired requirements for specific mechanical properties, in particular high bending strength (Galperine *et al.*, 1995; Kollmann *et al.*, 1975). Commonly, a synthetic resin treatment, phenol formaldehyde resin has been used combined with a high compression in order to improve the physical and mechanical properties of wood or wood-based material (Kumar, 1994; Meyer, 1984; Stamm and Harris, 1953).

Compreg is a phenol formaldehyde resin impregnated wood-veneer laminate; compressed under high heat and pressure to a high specific gravity, thus the properties of wood and a synthetic resin polymer network are combined (McLean, 1949). These products normally have mechanical properties (modulus of rupture (MOR), modulus of elasticity (MOE), and modulus of hardness) higher than untreated wood due to their higher specific gravity (Galperine *et al.*, 1995; Kollmann *et al.*, 1975; Kumar, 1994; Stamm, 1977). Generally, compreg has been used for special purposes, such as aircraft parts, concrete shuttering, deck, electrical insulator, fan blade and silent gear. The final products are more expensive than normal wood or wood-based panel because of the high production cost of the chemicals and the special processing (Rowell and Konkol, 1987;

Tsoumis, 1991).

Rubber wood (*Hevea brasiliensis* Muell & Agr.) harvested from rubber tree plantations has been substituting natural forest wood in Thailand's wood industry since the early 1980's, it is regarded as a major raw material and a stable supply at low prices ensures its profitability. Therefore, this research focused on the development of an efficient manufacturing process for compregs made from rubber wood veneer.

## OBJECTIVES

1. To ascertain the optimum conditions for treating rubber wood veneer with phenol-formaldehyde resin to produce a product suited to further compreg processing.
2. To determine the properties of two types of compreg, parallel-laminated-veneer, and cross-laminated-veneer.

## MATERIALS AND METHODS

### 1. Materials

1.1 Rubber wood veneers (0.15 cm x 30 cm x 30 cm) in both air-dried and agreen conditions.

1.2. Phenol formaldehyde resin at 20%, 30%, and 40% concentrations (w/w).

### 2. Methods.

2.1 The study of the optimum conditions for treating rubber wood veneer with phenol formaldehyde resin to produce a product suited to further compreg processing.

The factors affecting resin retention in wood veneer were determined in a factorial

experimental design (completely randomized). There were three factors phenol formaldehyde resin at three concentration levels, (viz.) 20%, 30%, and 40%, soaking time at 5, 10, and 15 hours, and veneer condition in air-dried and green. There were 4 replicates in each treatment.

2.2 The preparation of compreg samples for determining their properties.

The order of methods for producing the compreg sample were as follows:

2.2.1 The most suitable rubber wood veneer sample for further compreg processing was selected from 2.1. This was a green veneer soaked in a 40% resin solution for 10 hours, with a minimum resin retention over 30% (based on oven dry weight).

2.2.2 The resin-treated veneer was conditioned for 1 day to allow the resin to diffuse uniformly, over the entire veneer.

2.2.3 After conditioning the resin-treated veneer was dried in a well-ventilated electric oven at 50 °C for 16.5 hours.

2.2.4 Five plies of resin-treated veneers at 150 °C and at a pressure of 6.6 MPa to produce parallel-laminated compreg. Six panels of the parallel-laminated compreg were subjected to subsequent tests for physical and mechanical properties.

2.2.5 Six panels of cross-laminated compreg were prepared following the procedures in 2.2.1 to 2.2.4

2.3 Physical and mechanical property tests :

The American Society for Testing and Materials (ASTM) standards were used for testing the physical and mechanical properties of both the types of compreg as follows:

#### A. Physical properties.

- ASTM D 3502-76 to determine moisture absorption (ASTM, 1982 a).

- ASTM D 3503-76 to determine swelling and recovery of thickness (ASTM, 1982 b).

- ASTM D 2016-74 method A to determine moisture content (ASTM, 1987 a).

- ASTM D 2395-83 method A to determine specific gravity (ASTM, 1987 b).

#### B. Mechanical properties.

- ASTM D 1324-83 to determine hardness (ASTM, 1987 c).

- ASTM: D 3034-76 method A for determine static bending (ASTM, 1987d).

#### 2.4. Statistical analysis.

An analysis of variances (ANOVA) of the factorial randomized design and a least significance difference method were used to analyze the factors affecting resin retention of the resin-treated wood veneer.

The difference of average value of the physical and mechanical properties, between rubber wood compreg and solid rubber wood, and both the types of rubber wood compreg each, were tested using a one-tailed hypothesis the t-test method (with  $P < 0.05$  as significant result and  $P < 0.01$  a highly significant result).

## RESULTS AND DISCUSSION

A green veneer treated with a 40% resin concentration for 10 hours, had a resin retention of 33.18 % (based on oven-dry weight). This was selected as the most suitable compreg treatment as a resin retention of more than 30%, was deemed desirable for compreg production (Stamm, 1964).

As shown in Table 1, the specific gravity of cross-laminated compreg was not significantly different parallel-laminated compreg. However, both compregs had a specific gravity highly-significantly different to solid rubber wood. The effect of specific gravity and the wood-phenol formaldehyde resin network showed a great influence on MOR and MOE of parallel-laminated compreg when compared to solid rubber wood. However, the MOR and MOE values of cross-laminated compreg were not significantly different to those of solid rubber wood. The veneer grain direction in each ply of the parallel-laminated compreg had significant effects on the mechanical properties, except modulus of hardness, in the bending mode with the grain direction of all the plies parallel to the span of the static bending test. As shown in Table 2, the average MOR and MOE values of parallel-laminated compreg were 126.16 MPa and 14.22 GPa respectively, which were highly-significantly different to those of the cross-laminated compreg and the solid rubber wood.

The average modulus of hardness cross-laminated compregs were similar, 87.38 MPa, and 98.32 MPa respectively. These values were highly-significantly different from solid rubber wood (38.54 Mpa) due to differences in specific gravity (see Table 1 and Table 2).

With regard to the other physical properties, such as water absorption, swelling, and recovery of thickness, the values for the two types of

compreg were not-significantly different as they were produced under the same condition (see Table 1).

**Table 1.** Average physical properties of rubber wood compreg.

Properties	Parallel-laminated compreg		Cross-laminated compreg	
	Mean (n = 6)	Standard error of mean	Mean (n = 6)	Standard error of mean
Equilibrium moisture content (%) <sup>a</sup>	11.91	0.13	13.39	0.26
Specific gravity <sup>b</sup>	1.10	0.009	1.13	0.018
Water absorption(%)	23.67	0.86	22.23	0.91
Swelling and recovery of thickness (%)	16.64	0.39	20.55	0.86
Recovery of thickness (%)	-3.25	0.14	-3.35	0.49

<sup>a</sup> moisture content at equilibrium condition with the surrounding water vapor pressure in testing room.

<sup>b</sup> specific gravity of both the compregs were highly-significantly ( $P < 0.01$ ) different to 0.6 of solid rubber wood.

**Table 2.** Mechanical properties of rubber wood compreg and solid rubber wood.

Properties	Parallel-laminated compreg		Cross-laminated compreg		Solid rubber wood <sup>1</sup>
	Mean (n = 6)	Standard error of mean	Mean (n = 6)	Standard error of mean	
MOR (MPa)	126.16 <sup>c</sup>	2.17	95.62	4.41	87.00
MOE (GPa)	14.22 <sup>c</sup>	0.51	10.05	0.53	9.217
Modulus of hardness (MPa)	87.38	4.91	98.32	5.61	38.54 <sup>c,d</sup>

<sup>c</sup> labeled average values are highly-significantly ( $P < 0.01$ ) different the others. Average value without <sup>c</sup> are not-significantly ( $P < 0.05$ ) different to each others.

<sup>d</sup> modulus of hardness in tangential direction.

Source: <sup>1</sup> Raktiprakorn and Sri-a-ram (1970).

As table 3 indicates the yellow birch wood compreg may be superior to rubber wood compreg, as MOR, MOE, and modulus of hardness are higher. These results confirmed the effect of specific gravity and moisture content upon mechanical properties. The moisture content of wood or wood-based materials tends to be inversely proportional to their

strength, i.e., the higher the moisture content, the lower the strength. The yellow birch wood and rubber wood compreg did however have similar values for swelling and recovery of thickness, this may due to different conditions during production and testing of the compreg.

**Table 3.** Comparison of the physical and mechanical properties of rubber wood compreg and yellow birch wood compreg.

Properties	Rubber wood compreg		Yellow birch wood compreg <sup>1</sup>	
	Parallel-laminated	Cross-laminated	Parallel-laminated	Cross-laminated
Equilibrium Moisture content (%)	11.91	13.39	5	5.00
Specific gravity	1.10	1.13	1.30	1.30
Water absorption(%)	23.67	22.23	2.70	-
Swelling and recovery of thickness (%)	16.64	20.55	20-60	20-60
MOR (MPa)	126.16	95.62	250.00	156.90
MOE (GPa)	14.22	10.05	25.50	17.13
Modulus of hardness (MPa)	87.38	98.32	284.00	-

Source: <sup>1</sup> U.S. Forest Products Laboratory (1974).

## CONCLUSION

This study demonstrates that rubber wood veneer has the potential to be manufactured as a compreg, as the mechanical properties (MOR, MOE, and modulus of hardness) of the compreg were higher than those of the solid rubber wood. However, the mechanical properties were inferior when compared to those of yellow birch wood compregs, possibly due to differenced in production conditions. Thus, future research should concentrate upon refining production methods so that a higher quality compreg can be produced.

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