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STUDY ON THE MANUFACTURE OF PLYWOOD FROM *EUCALYPTUS CAMALDULENSIS* DEHNH.

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บทคัดย่อ

การนำไม้ *Eucalyptus camaldulensis* Dehnh. มาทดลองทำเป็นไม้อัดประเภทใช้งานภายใน จากการต้มไม้ยูคาลิปตัสที่อุณหภูมิ ๘๐° ซ. เป็นเวลา ๖ ชั่วโมง ให้ไม้อัดที่มีค่าแรงเฉือนสูง ๒๘.๘๙ กก./ซม.^{2} และค่าการแตกของไม้ใกล้แนวกาว ๖๔ % เมื่อทดสอบในสภาพเปียก แต่สภาวะของการต้มที่อุณหภูมิสูงทำให้มีรอยแตกร้าวที่เกิดจาก growth stress สูงมากขึ้น การต้มที่ ๗๐° ซ. สามารถยับยั้งการแตกร้าวให้มีเพิ่มขึ้นอีกเพียงเล็กน้อย ไม้ยูคาลิปตัสต้มในสารละลายด่าง pH 11-12 สามารถเพิ่มผลผลิตได้เล็กน้อย การต้มในด่างที่ ๗๐°ซ. ทำให้สามารถปอกไม้ได้ภายในเวลา ๖ ชั่วโมง การติดกาวของไม้อัดผสมระหว่างไม้ยูคาลิปตัสและไม้ยางพารา เมื่อทดสอบสภาพเปียก มีค่าการแตกของไม้ใกล้แนวกาวต่ำ ๑๕% ส่วนการติดกาวของไม้อัดผสมยูคาลิปตัส และไม้ยางขนเมื่อทดสอบสภาพเปียกมีค่าการแตกของไม้ใกล้แนวกาวประมาณ ๔๑%

การนำไม้ *Eucalyptus camaldulensis* Dehnh. มาทดลองทำเป็นไม้อัดประเภทใช้งานภายนอก ปรากฏว่าไม้ซุงยูคาลิปตัส ต้มที่ ๗๐°ซ. เป็นเวลา ๒๔, ๔๘, ๗๘ ชั่วโมง ต้มที่ ๘๐°ซ. เป็นเวลา ๖, ๑๒ ชั่วโมง และต้มในสารละลายด่าง pH 11-12 ที่ ๗๐°ซ. เป็นเวลา ๖, ๑๒, ๒๔ ชั่วโมง ให้ค่าความแข็งแรงทางแรงเฉือนอยู่ในระดับ ๒๐-๒๘ กก./ซม.^{2} เมื่อทดสอบในสภาพแห้ง และเมื่อทดสอบในสภาพเปียกหลังต้มในน้ำเดือด ๗๒ ชั่วโมง ให้ค่าอยู่ในระดับ ๑๐-๒๓ กก./ซม.^{2} การติดกาวภายนอกในสภาพแห้งจากค่าการแตกของไม้ใกล้แนวกาวอยู่ในระดับร้อยละ ๕-๓๑ แต่การติดกาวในสภาพเปียกหลังต้มน้ำเดือดสูงขึ้นอยู่ในระดับร้อยละ ๑๐-๔๑ เมื่อนำไม้ยางยูคาลิปตัสไปอัดผสมกับไม้ยางพาราและยางขนโดยให้ไม้ยางยูคาลิปตัสเป็นไส้ของไม้อัด ปรากฏว่าไม้อัดผสมยางพาราและยูคาลิปตัสมีค่าความแข็งแรงทางแรงเฉือน ๓๐.๑๔ กก./ซม.^{2} ค่าการแตกของไม้ใกล้แนวกาวร้อยละ ๕๔ เมื่อทดสอบสภาพแห้ง และมีค่าความแข็งแรง ๑๗.๖๐ กก./ซม.^{2} การติดกาวร้อยละ ๓๕ เมื่อทดสอบสภาพเปียกหลังต้มน้ำเดือด ส่วนไม้อัดผสมยางขนและยูคาลิปตัส มีค่าความแข็งแรงทางแรงเฉือน ๓๔.๓๕ กก./ซม.^{2} ค่าการแตกของไม้ใกล้แนวกาวร้อยละ ๖๔ เมื่อทดสอบสภาพแห้ง และมีค่าความแข็งแรง ๒๙.๖๑ กก./ซม.^{2} ค่าการแตกของไม้ใกล้แนวกาวร้อยละ ๖๐ เมื่อทดสอบสภาพเปียกหลังต้มในน้ำเดือด ๗๒ ชั่วโมง

ABSTRACT

Verifications of plywood manufacture from *Eucalyptus camaldulensis* Dehnh. were performed both interior and exterior plywood panels. Preheating of the bolt at 80°C for 6 hours produced interior plywood samples with 28.89 kg./cm.^{2} wet shear test and 64% wood failure. The preheating high temperature (80°C) caused peeling problem by expanding free

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splitting of log ends on cross cutting. Nevertheless, the preheating at 70°C could slightly prevent the area of free split expanding and preheating in sodium hydroxide solution (pH 11-12) could increase the aveneer yield. The bolts could be peeled after it had been warmed in the solution for 6 hours. Wet test gluability of interior plywood combination between Eucalyptus and Para rubber wood had low wood failure (15%) but the interior plywood combination from Eucalyptus and Dipterocarpus sp. showed 41% wood failure.

Investigations of exterior plywood from the bolts preheated at 70°C for 24, 48, 78 hr., 80°C for 6, 12 hr. and warmed in sodium hydroxide solution (pH 11-12) at 70°C for 6, 12, 24 hr. brought about 5-31 % wood failures, 20-28 kg./cm.^{2} dry shear strengths and showed the shear strengths between 10-23 kg./cm.^{2}, 10-41% wood filtures after cyclic boil test for 72 hours. The plywood panels made from Eucalyptus-para rubber combination had dry shear strength 30.14 kg./cm^2., 54% wood failure and provided 17.60 kg./cm.^{2} shear strength, 35% wood failure after cyclic boil test. Moreover, the exterior plywood combination from Eucalyptus and Dipterocarpus sp. produced 34.55 kg./cm.^{2} dry shear strength, 64% wood failure and showed 24.61 kg./cm.^{2} shear strength, 60% wood failure after cyclic boil test.

INTRODUCTION

Basic studies of veneer and plywood manufacture from wood species have been performed for over many years. The action of gluability in plywood production has been well publicized and a fair amount of theoretical explanation on the mechanisms of adhesion and adhesives has been offered by various segments of the forest product industry. Although many studies of the mechanisms of gluing and plywood manufacturing processes have been investigated in the past, the raw material logs used for veneer are still not sufficient to supply plywood industry demand today. Recently, the demand for plywood is growing because of decreases in the amount of logs used as raw material of veneer. Part of our lack of raw material logs is due to inadequacy of forest area and the growths in population and standard of living. As we have known that wood is the most important raw material for producing plywood and veneer logs used for plywood should have uniformity large diameter, clear and cylindrical bole, long and straight in order to meet good quality criteria. As a result, the price of veneer logs is growing up and the abundance of raw material logs must be imported from the foreign countries. Nowadays, hardwoods fast growing species have been illustriously developed and provided for supporting wood local demand in Thailand. Utilization of them is perhaps one of the most significant factors for wood using industry. Since *Eucalyptus camaldulensis* Dehnh. is one of the fast growing species which is well known among forest research scientists and Thai people. Owing to its fast growing propertry and its sufficient demand, *Eucalyptus camaldulensis* Dehnh. is one of the fascinating wood raw material that may be supplied for veneer and plywood enterprise. In order to observe the role of basic property of the eucalyptus that plays suitably in veneer and plywood manufacture, the Veneer and plywood Section of Forest Products Research Division has intended to investigate on the wood species which could be economically and apparently obtained at the present. This work is the beginning of a systematic approach to characterizing the process variables for preheating, peeling of the bolts, and plywood fabricating technology as a means of producing low cost plywood and furniture for wood-using commercial enterprise.

Objectives of this study are as follows:

1. To study the various facets of veneer and plywood manufacturing response and the suitable conditions for preheating of the *Eucalyptus camaldulensis* Dehnh. bolts.

2. To observe the properties of Eucalyptus veneer, as they might be appropriate for producing interior and exterior plywood.

3. To investigate on gluability of synthetic glues used in Thailand, as they might be suitable for interior and exterior Eucalyptus plywood.

EXPERIMENTAL PROCEDURE

Wood Samples Preparation

Samples of *Eucalyptus camaldulensis* Dehnh. wood were obtained from tree at Srisakes Province, the north-eastern part of Thailand. The trees approximately 35-40 cm. in diameter were cut into 50 cm. long and preheated under the conditions as shown in Table1.

Table 1. **Preheating Condition of Eucalyptus camaldulensis Dehnh. Bolts**

No.	Prcheating Solution	Temperature (°C)	Time (hr.)
1.	Water	70	24
2.	Water	70	48
3.	Water	70	78
4.	Water	80	6
5.	Water	80	12
6.	Sodium hydroxide[1/]	70	6
7.	Sodium hydroxide [1/]	70	12
8.	Sodium hydroxide[1/]	70	24

[1/] Prcheating ie sodium hydroxide solution pH 11–12

After they had already been preheated, the bolts were then peeled by rotary lathe into veneers 0.16 cm. thick. The veneers without defects were clipped into 50×50 $cm.^2$ dimensions and dried in the oven until the moisture content was about 8-10%. Then the dried veneers had been reclipped into the desired dimensions (40×40 $cm.^2$) before they were glued and pressed by hot press under the condition as follows :

Glue Mixing and Spreading

The adhesives used in the experiment were urea formaldehyde resin (Ciba (Aerolite FFD)) for interior plywood and phenol formaldehyde resin (Aerophen) for exterior plywood. The glue ingredients and mixing procedures as well as fabrication of test panel conditions were as follow :

Interior Glue Ingredient :

Aerolite FFD	Parts by weight
Aerolite FFD	100

Tapioca Flour	45
Water	100
Hardener FH 40 D	2.5
Glue Viscosity	1,600-2,100 Centipoises
Glue Spread	250 g./m.^{2} single glue line

Fabrication of Interior Test Panels

Veneer Moisture Content	8-10 %
Veneer Dimensions	40×40×0.16 cm.^{3}
Glue Spread	250 g./m.^{2} single glue line
Closed Assembly Time	10 min
Pressure	12.0 kg./cm.^{2}
Temperature	120 °C
Pressing Time	4 min.
Conditioning	7 days

Exterior Glue Ingredient :

Aerophen	Parts by weight
Aerophen pp 601	100
Water	100
Hardener HP 4	60
Glue Viscosity	1,600-2,400 centipoises
Glue Spread	180 g./m.^{2} single glue line

Fabrication of Exterior Test Panels

Veneer Moisture Content	5-8 %
Veneer Dimensions	40×40×0.16 cm.^{3}
Glue Spread	180 g./m.^{2} single glue line
Closed Assembly Time	15 min.

Pressure	12.1 kg./cm.^{2}
Temperature	140 °C
Pressing Time	4 min.
Conditioning	7 days.

Evaluation of Bond Quality

The plywood panel samples were cut into shear strength test specimens from the two test pieces for each plywood panel. One test piece was grooved in the "pull-to-close" direction of the lathe check of the corestock, while the other test piece was grooved in the "pull-to-open" direction. (5) Then the interior plywood specimens were evaluated 3-duplicated in both dry shear test and wet shear test after they had been soaked in the water at 67 ± 2 °C for 3 hr. Similarly to the external grade plywood specimens, the samples were conducted on dry shear test and cyclic boil shear test after boiling in the water for 72 hr.

RESULTS AND DISCUSSION

Interior plywood

Samples of *Eucalyptus camaldulensis* Dehnh. were obtained from the trees at Huay Ta Forest Plantation Research Center, Srisakes Province. The tree diameters were about 40 cm. at breast height and their average density was about 0.8 gm./cm.^{3}. After they had been fallen down, the logs became radially free splitting at the end of cross cutting and there was some water exuding from the cross-sectional dimension. Nevertheless, when the grease was applied to coat on both ends of cross sectional areas of the logs, it cr cks could slightly prevent further splitting. Such from the fallen logs appeared because of growth stress which occured within the wood structure. (1, 3, 9) Moreover, additional splitting could proceed during preheating of the bolts and the process at high temperature (80 °C) caused significantly expanding of the cracking. The preheating at 70°C, nevertheless, could slightly prevent the area of additional splitting. Additionally, after preheating of the bolts in sodium hydroxide solution (pH 11–12) at 70°C for 6 hr., they could be peeled by rotary lathe. The bolts preheated in the solution could increace about 5% higher veneer yield than that at the bolts preheated in water.

As shown in Table 2, glue bond of the interior plywood panels had the averages of 28–35 kg./cm.^{2} dry shear strength, particularly, the plywood panels from 80°C and 6 hr. preheating bolts dveloped the highest dry shear strength. Comparing to the wet test as shown in Table 2, the averages of strength were about 20–29 kg./cm.^{2}, likewise, the panels from 80°C and 6 hr. preheating bolts still showed the highest wet shear strength (28.89 kg./cm.^{2}). Considering to the average percentages of wood failute from dry test, the 80°C, 6 hr. preheating plywood panel also showed the highest of the average percentage about 94%. According to statistical analysis as described in Table 3. and 4., there were no significant differences within the percentages of dry test wood failure among all preheating conditions, but significant difference was found in wood failure percentage of wet test. Table 5 demonstrates that the Eucalyptus plywood which had been preheated at 80°C for 6 hr. showed the higest wood failure (64%) and was significantly different from another plywood panel preheated conditions, but it was not different from 45% wood failure of the plywood panel which had been preheated in 70°C sodium hydroxide solution for 12 hr. However, the plywood preheated in alkaline solution did not show any significant difference of wood failure from that of another plywood panels except the panels from the bolt which had been preheated at 70°C for 78 hr. and had the lowest value of wood failure (21%)

The comparison of shear sterngths and wood failures between *Dipterocarpus alatus* Roxb. and *Eucalyptus camaldulensis* Dehnh. It was noted that wood failures from wet test of the Eucalyptus

Table 2. Shear strength (kg/cm^2) and wood failure (percent) values of interior plywood panels made from *Eucalyptus camaldulensis* Dehnh. glued with urea formaldehyde resin adhesives (after dry test and wet test).

Conditions of Veneer Log Preheating	Replication			Average
	1	2	3	
	1/ 2/			
1. heating at 70°C. 24 hrs.	30.83–55	25.78–75	32.29–86	29.64–72
2. heating at 70°C. 48 hrs.	30.02–48	29.36–71	30.29–75	29.89–65
3. heating at 70°C. 78 hrs.	28.94–32	28.78–65	32.57–90	30.10–62
4. heating at 80°C. 6 hrs.	37.06–98	35.22–86	34.47–97	35.58–94
5. heating at 80°C. 12 hrs.	30.02–48	29.36–71	30.29–75	29.89–65
6. alkali heating at 70°C. 6 hrs.	31.76–64	36.52–58	30.10–58	32.79–60
7. alkali heating at 70°C. 12 hrs.	30.38–40	32.84–82	32.02–74	31.75–65
8. alkali heating at 70°C. 24 hrs.	27.03–75	31.09–84	27.22–74	28.45–78
After Wet Test				
1. heating at 70°C. 24 hrs.	17.64–29	17.86–41	19.51–45	18.34–38
2. heating at 70°C. 48 hrs.	18.57–20	20.54–35	23.45–23	20.85–26
3. heating at 70°C. 78 hrs.	19.72–19	17.76–30	18.85–15	18.78–21
4. heating at 80°C. 6 hrs.	25.53–48	32.49–73	28.66–71	28.89–64
5. heating at 80°C. 12 hrs.	18.57–20	20.54–35	23.45–23	20.85–26
6. alkali heating at 70°C. 6 hrs.	19.70–22	28.16–38	15.89–10	21.25–23
7. alkali heating at 70°C. 12 hrs.	23.14–33	30.49–66	24.60–36	26.08–45
8. alkali heating at 70°C. 24 hrs.	21.44–24	26.61–48	20.18–44	22.74–39

1/ The first figure refers to shear strength (kg/cm^2) value.

2/ The second figure refers to wood failure (percent) value. Each value is an average of 10 shear specimens.

Table 3. Analysis of variance (completely randomized design) of wood failure on interior plywood panels made from *Eucalyptus camaldulensis* Dehnh. glued with urea formaldehyde resin adhesives (after dry test).

Sources of variation	Degrees of Freedom	Sum of Squares	Mean of Squares	F Value 1/
Treatments	7	2,577.33	368.19	1.41 NS
Erron	16	4,176.67	261.04	
Total	23	6,754.00		
Coefficient of Variation = 23.08 %				

1/ NS = Not Significant.

Table 4. Analysis of variance (completely randomized design) of wood failure of interior plywood panels made from *Eucalyptus camaldulensis* Dehnh. glued with urea formaldehyde resin adhesives (after wet test in hot water).

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	F Value 1/
Treatments	7	4,348.66	621.24	4.34**
Error	16	2,288.67	143.04	
Total	23	6,637.33		
Cofficient of Variation = 33.85 %				

1/ ** = Highly Significant.

plywood (64%) was slightly lower than that of the Dipterocarpus (68%). Consequenthly, it appears that gluability of interior plywood from Eucalyptus was strong enough to operate in the industry, but it must be considered about splitting of log ends which should be seriously watchful in order to prevent problems

Table 5. Inspection of mean differences by Duncan's new multiple range test of wood failure of interior plywood panels made from *Eucalyptus camaldulensis* Dehnh. after wet test.

Treatment No. by Rank	Condition of Veneer Log Preheating	Shear Strength ($kg./cm.^2$)	Wood Failure (%)1/
1	4) heating at 80°C. 6 hrs.	28.89	64 a
2	7) alkali heating at 70°C. 12 hrs.	26.08	45 ab
3	8) alkali heating at 70°C. 24 hrs.	22.74	39 bc
4	1) heating at 70°C. 24 hrs.	18.34	38 bc
5	5) heating at 80°C. 12 hrs.	20.85	26 bc
6	2) heating at 70°C. 48 hrs.	20.85	26 bc
7	6) alkali heating at 70°C. 6 hrs.	21.25	23 bc
8	3) heating at 70°C. 78 hrs.	18.78	21 c

1/ Means followed by a common letter are not significantly different at the 95% level.

in veneer making process.

The internal grade plywood made from Eucalyptus–*Dipterocarpus baudii* Korth. species combination had high values in both shear strength and wood failure from dry test. On the otherhand, although wet test of Eucalyptus–Dipterocarpus species combination of plywood panels showed moderately high values of shear strength and wood failure, the Eucalyptus–Para rubber plywood panel combination had low wood failure. Note that low glue bond quality from wet test of the Eucalyptus –Para rubber plywood panels may be due to a large amount of carbohydrate content containing in Para rubber wood.

Exterior Plywood

As shown in Table 6, glue bond quatity of the external grade plywood panels had the averages of 20–28 kg./

Table 6. Shear strength (kg/cm^2) and wood failure values (percent) of exterior plywood panels made from *Eucalyptus camaldulensis* Dehnh. glued with phenol formaldehyde resin adhesives (after dry and cyclic boil test).

Conditions of Veneer Log preheating	Replication			Average
	1	2	3	
After Dry Test	1/ 2/			
1. heating at 70°C 24 hrs.	26.07-18	24.64-8	15.13-2	21.95-9
2. heating at 70°C 48 hrs.	23.84-12	16.74-1	22.94-12	21.78-8
3. heating at 70°C 78 hrs.	22.10-6	27.64-25	34.91-35	28.22-22
4. heating at 80°C 6 hrs.	29.50-12	22.44-1	17.96-11	23.30-8
5. heating at 80°C 12 hrs.	18.12-12	27.50-3	15.56-1	20.39-5
6. alkali heating at 70°C 6 hrs.	26.26-23	23.79-31	22.80-16	24.28-23
7. alkali heating at 70°C 12 hrs.	18.75-9	29.29-20	22.01-14	23.35-14
8. alkali heating at 70°C 24 hrs.	25.08-51	28.49-25	28.98-18	27.52-31
After Boiling Test				
1. heating at 70°C 24 hrs.	11.69-3	15.90-10	20.04-18	15.86-10
2. heating at 70°C 48 hrs.	25.51-22	18.29-6	26.43-57	23.41-28
3. heating at 70°C 78 hrs.	19.05-12	20.07-62	28.15-48	22.42-41
4. heating at 80°C 6 hrs.	26.60-45	17.96-11	10.71-14	18.42-23
5. heating at 80°C 12 hrs.	10.73-15	19.10-45	10.06-3	13.30-21
6. alkali heating at 70°C 6 hrs.	17.87-24	12.74-52	7.32-5	12.64-27
7. alkali heating at 70°C 12 hrs.	12.74-9	28.26-19	14.86-12	18.62-13
8. alkali heating at 70°C 24 hrs.	11.42-23	11.83-20	7.92-6	10.39-16

1/ The first figure refers to shear strength (kg/cm^2) value.

2/ The second figure refers to wood failure (percent) value. Each value is an average of 10 shear specimens.

cm.^{2} dry shear strength. Although the variation in wood failures showed no signifcant difference, the gluability of the exterior plywoods were rather low (5–31%). It may be due to the fact that severe spiral grain and high wood density (0.8 gm./cm.^{3}) have been observed in E. camaldulensis, as well as containing of ellagic acid which is directly correlated to gluing problems. It could be noted that under dry condition, gluability of interior plywood was stronger than that of exterior plywood.

After they had been observed under cyclic boil test, The averages shear strength (10–23 kg./cm^2.) were apparently lower than that of dry shear strength. The averages of wood failure, however, wer stronger than those of the dry test. The variation in wood failure of exterior plywood showed no signifecant difference as shown in Table 7. and 8. Considering to gluability after cyclic boil test, it could be noted that the wood failures were higher and the shear strengths were lowerthan those of dry test. In contrast to the dry test, the wood shear strength was weaker than glue bond quality. It may be due to the fact that the shear strength of wood reduced after boiling in the water for 72 hours, but the glue bond quality was still strong enough to demonstrate higher wood failures.

In consideration of plywood panels made form Eucalyptus–Para rubber species combination, they developed stronger glue bond fabricated than those of Eucalyptus exterior plywood panels as shown in Table 9. Additionally, the combination of *E. camaldulensis* and *Dipterocarpus baudii* in a single exterior plywood panel produced 34.35 kg./cm.^{2} dry shear strength, 64% wood failure and showed 24.61% kg./cm.^{2} shear strength, 60% wood failure after cyclic boil test for 72 hours.

It could be seen that the combination of Eucalyptus and the other wood species plywood panels is one of systematic approaches to increase higher glue bond quality as will as another process of utilization of *E. camaldulensis*.

Table 7. Analysis of variance (completely randomized design) of wood failure of exterior plywood panels made from *Eucalyptus camaldulensis* Dehnh. glued with phenol formaldehyde resin adhesives (after dry test).

Sources of Variations	Degrees of Freedom	Sum of Squares	Mean of Squares	F Value1/
Treatments	7	1,812.50	258.93	2.64 NS
Error	16	1,566.00	97.87	
Total	23	3,378.50		
Coefficient of Variation = 64.87 %				

1/ NS = Not Significant

Table 8. Analysis of variance (completely randomized design) of wood failure of exterior plywood penels made from *Eucalyptus camaldulensis* Dehnh. glued with phenol formaldehyde resin adhesives (after cyclic boil test)

Sources of Variations	Degrees of Freedom	Sum of Squares	Mean of Squares	F Value1/
Treatments	7	1,971.96	281.71	0.78 NS
Error	16	5,784.00	361.50	
Total	23	7,755.96		
Coefficient of Variation = 84.35 %				

1/ NS = Not Significant

One reason that should be considered, however, if the different species are combined together in a single plywood panel, the veneer shrinkage and density, as shown in Table 10. should not be extremely different from those of the other species in order to minimize the effect of wood species variability on glue bond durability.

Table 9. Shear strength (kg/cm^2) and wood failure values (percent) of exterior plywood panels made from *Eucalyptus camaldulensis* as core veneers, *Hevea brasiliensis* and *Dipterocarpus baudii* as face veneers, glued with phenol formaldehyde resin adhesives (after dry and boiling test)

Face/Core/Face Veneer Species	Replication			Average
	1	2	3	
After Dry Test	1/ 2/			
1. Hevea brasiliensis	29.23-74	26.35-15	34.84-74	30.14-54
Eucalyptus camaldulensis				
Hevea brasiliensis				
2. Dipterocarpus baudii	39.97-68	34.77-60	35.31-63	34.35-64
Eucalyptus camaldulensis				
Dipterocarpus baudii				
After Boiling Test				
1. Hevea brasiliensis	16.68-67	16.23-24	19.90-14	17.60-35
Eucalyptus camaldulensis				
Hevea brasiliensis				
2. Dipterocarpus baudii	22.55-62	26.18-72	25.11-45	24.61-60
Eucalyptus camaldulensis				
Dipterocarpus baudii				

1/ The first figure refers to shear strength (kg/cm^2) value.

2/ The second figure refers to wood failure (percent) value. Each value is an average of 10 shear specimens.

CONCLUSIONS

1. The *Eucalyptus camaldulensis* Dehnh. bolt preheated at 80°C for 6 hours produces the highest shear strength and wood failure interior plywood panel after wet test. The preheating at high temperature (80°C) causes peeling

Table 10. Veneer Density and Shrinkage

Veneer Species	Density gm./cm.^{3}	Shrinkage		
		Tangential (%)	Radial (%)	Longitudinal (%)
Eucalyptus camaldulensis	0.71	9.75	4.45	0.38
Hevea brasiliensis	0.56	6.91	2.89	0.30
Dipterocarpus baudii	0.61	9.83	3.90	0.38

problem by expanding free splitting of log ends on cross cutting.

2. Preheating of the bolt at 70°C can slightly prevent the area of free split expanding and preheating in sodium hydroxide solution (pH 11-12) can incresse the veneer yield. The bolt can be peeled after preheating in sodium hydroxide solution for 6 hours.

3. After wet test, wood failure of inteior plywood from the bolt preheated at 80°C for 6 hours (64%) is slightly lower than that of interior plywood from *Dipterocarpus alatus* Roxb. (68%). *Eucalyptus camaldulensis* bolt preheated at 70°C for 12 hours in sodium hydroxide solvtion shows 45% wood failure and the bolt preheated at 70°C for 24 hours in water shows 38% wood failure after wet test.

4. Wet test gluability of interior plywood combination between Eucalyptus and Para rubber wood has low wood failure, but the interior plywood combination from Eucalyptus and *Dipterocarpus baudii* Korth. shows 41% wood failure.

5. The gluability of Eucalyptus interior plywood, by wood failure under dry test condition, is stronger than that of exterior plywood. The gluability of the exterior plywood under cyclic bill test condition, however, is stronger that of the exterior plywood under dry than test condition.

6. The exterior plywood panels made from Eucalyptus–Para rubber and Eucalyptus–Dipterocarpus species combinations develope stronger glue bond

quality than those of Eucalyptus exterior plywood panels.

7. The gluability of plywood from *Eucalyptus camaldulensis* Dehnh. is strong enough to operate in the industry and the combination of Eucalyptus and the other wood species plywood panels is one of systematic approahes to improve glue bond. quality. It is requiring much effort to manage, nevertheless, owing to its relatively high density, free splitting of log ends on cross cutting due to growth and shrinkage stresses, and susceptibility to collapse during drying due to severe spiral grain, which cause peeling problems and adversely affect veneer quality and yield.

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