REPORT ACTIVITY 2.1.4. EVALUATE THE APPROPRIATE PROPERTIES OF PRODUCTS MANUFACTURED FROM SMALL DIAMETER LOGS IN INDONESIA

REPORT ACTIVITY 2.1.4.

EVALUATE THE APPROPRIATE PROPERTIES OF PRODUCTS MANUFACTURED FROM SMALL DIAMETER LOGS IN INDONESIA

PREFACE

This report was written based on the research activities which were conducted in Faculty of Forestry Bogor Agricultural University, Forest Products Research Centre Ministry of Forestry in Bogor, PT. Andatu Plywood Industry, PT. Sumber Graha Sejahtera, PT. Majora Inkas, PT. Paparti Pertama, and PT. Masari Dwisepakat Fiber.

The report contains five researches regarding utilization of Small Diameter Logs (SDL) for bio-composite products, namely : Plywood, Glulam (Glued Laminated Timber), Laminated Veneer Lumber (LVL), Particleboard and Medium Density Fiberboard (MDF).

On behalf of the Project Executing Agency, we would like to extent sincerely thanks to ITTO (International Tropical Timber Organization) and CFC (Common Fund for Commodities) for the financial and administrative supports as well as for good cooperation that made the research has been well executed. To the research team member under coordination of Prof.Muh. Yusram Massijaya for plywood research, Mr. Bedyaman Tambunan for LVL research, Mrs. Nurwati Hadjib for Glulam research, Prof. Yusuf Sudo Hadi for Particleboard research and Dr. Dede Hermawan for MDF research are also acknowledged for all effort that have been made during accomplishment of this report.

With strong good will from all parties, we do hope this initial effort will generate substantial benefits in utilization of Small Diameter Logs for Bio-composite Products in Indonesia and all over the world.

December 27, 2010

Project Coordinator

Prof. Yusuf Sudo Hadi

CONTENT

PART A.
PERFORMANCE OF PLYWOOD MADE OF SMALL DIAMETER LOGS

PART B. LAMINATED VENEER LUMBER

PART C.

PERFORMANCE OF GLULAM MADE OF SMALL DIAMETER LOGS

PART D. PARTICLEBOARD

PART E. MEDIUM DENSITY FIBERBOARD

LIST OF TABLE

LIST OF FIGURE

PART A. PERFORMANCE OF PLYWOOD MADE OF SMALL DIAMETER LOGS

PART B. LAMINATED VENEER LUMBER

PART C. PERFORMANCE OF GLULAM MADE OF SMALL DIAMETER LOGS

PART D. PARTICLEBOARD

PART E. MEDIUM DENSITY FIBERBOARD

PART A.

PERFORMANCE OF PLYWOOD MADE OF SMALL DIAMETER LOGS

PERFORMANCE OF PLYWOOD MADE OF SMALL DIAMETER LOGS

By :

Muh. Yusram Massijaya, Isari Wahyulia, Sukma Surya Kusumah,
Dede Hermawan, Yusuf Sudo Hadi

I. INTRODUCTION

The plywood industry in Indonesia was predicted has a bright outlook after recession period mainly due to the decreasing availability of large diameter logs from natural forests. In case of Indonesia, some plywood industries invested a big amount of fund to buy new machine and technology. The effort has been enabled the industry to utilize SDL resulted from plantation and community forest. Among the plywood industries which have been used SDL from plantation and community forest in Indonesia, PT. Sumber Graha Sejahtera (PT. SGS) in Balaraja West Java Province, PT. Andatu Plywood Industry in Lampung Province and PT. Kutai Timber Indonesia in Ponorogo, East Java Province very success in their business and shown high quality products during three years research activity.

Compared to sawn timber, plywood has several dominant advantages, namely : (a) High uniform strength. The wood is much stronger along the grain compared to those of across the grain. Crossing the adjacent sheets minimizing the strength differences between along and across the grain directions. (b) Minimizing shrinking, swelling and warping - Solid wood exhibits very stable in longitudinal direction, but considerable shrinkage and swelling in radial and tangential directions. (c) The quality can be controlled, (d) Can be produced in relatively large sizes, (d) Economical and effective utilization of fancy wood, and (e) Can be produced in curved surfaces.

Most of wood raw materials used by plywood industries in Indonesia come from plantation and community forests. The raw material is classified as small diameter logs (SDL). Therefore the utilization of SDL from plantation and community forest is very important to fulfill the raw material deficiency for plywood production. However, SDL performs low quality compared to those of large diameter logs from natural forest. The purpose of this research is to find out the fundamental properties of plywood made from SDL.

II. BRIEF DESCRIPTION OF PLYWOOD

The plywood manufacturing process is unique, as a raw material is manufactured into a product that is stronger than or as strong as the original tree (Baldwin 1981). It is manufactured by gluing together one or more veneers to both sides of a veneer or solid wood core. The grain of alternate layers is crossed, generally at right angles, and the species, thickness and grain direction of each layer are matched with those of their opposite number on the other side of the core.

The performance of plywood is affected by the species of wood as raw material, the grade of veneer used, the type and amount of adhesive used in plywood production. The manufacture of plywood can be divided into two main stages, namely : a) production of veneer and b) the assembly and pressing of veneers into plywood.

A. Production of veneer

Veneering is a highly popular way of utilizing the natural qualities of wood which utilizes nearly the whole log. The conversion process from log to veneer boasts a recovery rate of up to 95%. Wood veneer is a thin 0.3 to 6 mm sheet of wood having its grain parallel to the surface. The sheet or lay on is peeled from a selected log by using either a lathe or slicer. Historically, veneer and plywood production in Indonesia has required the use of high quality and large diameter logs harvested from natural forest. This made the cost of plywood classified as high cost raw materials. The wood raw material requirement for plywood industry varies considerably among the plywood industries in Indonesia.

An innovative peeling method was introduced in the late 1980s. In this case a spindle-less or center-less lathe using a series of roller rather than end chuck supports the veneer block during peeling. This allows peeling cores down to diameters of 50 mm (2.0 inch) or less. The increased veneer yield is especially important to mill that rely on small-diameter logs. Wood quality from these machines, however, is lower than that from larger chuck-driven lathes. The inner core wood is primarily juvenile wood, has the highest occurrence of knots, and tend to be excessively wavy, an artifact of producing flat veneer from small diameter logs (Bowyer, 2003).

Baldwin (1981), uses two sets of criteria in assessing the value of a particular timber species.

VI. Timber in log form - In general criteria relates to log size, quality and grades, log transport and handling requirements, and log protection and quarantine.

   a. Rotary cut or peeled veneer - logs above average diameter, cylindrical in shape and have minimum defects are sought after. However due to development in manufacturing techniques and equipment small diameter logs can now be economically utilized.

   b. For sliced veneers - log requirements are more specific and greater emphasis is placed on value of the end product. Elected pieces of burls, stumps and distorted logs, that provides highly figured and colored wood suitable for decorative purposes. These materials are relatively high cost raw materials. Generally raw material requirements are less stringent for the manufacture of multi-ply plywood as larger quantities of core veneers are required than for 3-ply plywood.

2. Physical characteristics of wood which determines the technical suitability of a particular species for veneer or plywood manufacture.

   - Peeling or slicing characteristics (density, grain distortion, reaction wood, knots, mineral inclusions)
   - Appearance or use characteristics (color, figure, texture, luster, odor)
   - Gluing and finishing characteristics (density, grain, glue ability, stain ability
   - Structural characteristics (strength, resistance to decay, hardness).

The quality of logs that are acceptable will vary according to the cost of the logs at the plywood industry. If this is high from a combination of stumpage, felling, and transport charges, then only selected qualities can usually be accepted. As the percentage recovery of plywood from the log becomes very important. This is particularly true for logs imported from overseas, because ocean freight may add from 50 to 100 percent to the cost. If logs are inexpensive then quality requirements may be lowered because losses caused by rounding and veneer clipping may be compensated by the log price. However it must be taken into account that the use of lower qualities involves extra labor, often with some lowering of grade of the finished product (Baldwin, 1981).

Other factors to be considered when determining the value of a species for plywood are behavior in transport and storage. Some logs develop radial or dimensional split (especially utilization of secondary growth hardwood) upon drying and most wood species are susceptible to insect attack, staining or decay.

Hadjib et al., 2009 reported several important issues related to the utilization of SDL for composite products such as glulam, laminated veneer lumber, plywood, particleboard and medium density fiberboard (MDF) are as follows :

1. Wood of small diameter logs (SDL) has very high potency and feasible in terms of physical and mechanical properties to support wood processing industry in Indonesia. Utilization of SDL especially from natural forest should be accommodated by the Indonesian Forestry Regulation.
2. Fresh wood moisture content of SDL from natural forest range from 33.00-153.81%, with average 67.20%. Air dried moisture content range from 12.00-17.48%, with average 15.23%. Wet specific gravity range from 0.21-0.79, with average 0.43 gram/cm^3. Air dried specific gravity range from 0.26-0.98, average 0.51.
3. SDL from natural forest such as meranti merah, macaranga, meranti putih, cempaka, kelampai, belatik, sampe, ubar and ketikal classified as strength class II-III which is feasible for construction material. Ketikal Wood classified very heavy, cempening wood, kelampai, belatik, sampe and ubar classified heavy wood. While pisang-pisang wood classified as medium and

the rest classified as light wood.. The rest can be used for light construction and bio-composite products raw materials.

4. Fresh moisture content SDL from plantation/community forest range from 36.50-143.75%, average 75.56%, air dried moisture content range from 11.46-17.30% average 14.30%. Specific gravity range from 0.28-0.73, with average 0.52 gram/cm^3. Based on the wood weight rubberwood, puspa, gmelina and pine classified as medium, and the rest classified as lightwood. Rubber Wood, puspa, mindi, kiseseh, mahoni and mangium are feasible for construction or light construction. Most of the SDL from plantation and community forest can be used for bio-composite products raw material.
5. Wood color of small diameter logs has a wide range of variety from light yellow to the dark brown. The wood color of small diameter logs is not significantly different from the wood of large diameter logs in sapwood. However, heartwood is significantly different due to the presence of extractives.

Concerning veneer production, there are two dominant methods of cutting veneers used in plywood industry, namely slicing and rotary peeling. Slicing veneers accounts for approximately 5% of veneer production and is mainly used to produce radially orientated, fine figured, hardwood veneers for furniture or wall paneling face plies. Rotary peeling using a lathe accounts for nearly 95% of all veneer production. It is predominantly used in the manufacture of structural plywood (Baldwin 1981). It involves centering the log or bolt onto the lathe chuck. The log is slowly rotated and the knife carriage moved into the log. The knife then converts the bolt into a cylinder. In this process of rounding, various widths and lengths of wood (fishtails) are removed from the log surface.

During the process of peeling, lathe checks can develop in the underside of the veneer, as the underside is under tension during the peeling process. The side of the veneer in which checks occur is known as the loose side, whereas the check free side is known as the tight side (Evans 1996) . The setting of the knife and nose bar pressure during peeling is important in reducing the formation of checks, and also in controlling veneer thickness. Each wood species requires certain nose bar pressure to minimize the development of lathe checks, however nose bar pressures are positively related to wood density.

Veneer recovery from bolts is variable ranging from 30 to 95% depending on bolt size and process variables. With the increase of technology the recovery rate percentage is increasing. To increase recovery, output and quality Baldwin (1981) suggests the following should be installed or maintained.

The veneer are virtually graded according to the size, number and location of the natural and processing defects that effect their strength and appearance. Knots, decay, splits, insect holes, surface roughness, number of repairs and other defects are considered. More repairs – familiar as those boat-shaped wood patches, for example – and bigger knots are allowed in the lower veneer grades (Smulski, 1997).

B. Drying of Veneers

Veneers are dried in several ways, namely (a) By simple air drying where climate is suitable. This method is not suitable in rainy season and not suited to hot pressing of high temperature setting phenolic resins. However it is reported suitable when urea formaldehyde bonding is used. (b) By compartment driers using convection heating which are somewhat similar in design to timber kilns, (c) By mechanical driers that are provided with conveyers usually in the form of mesh belts or rollers, and are fitted with both convection and/or radiant type heaters, and (d) By hot press dryer. This kind of machine was developed to address the problem raised in drying veneer from SDL which tend to wavy and contains high portion of juvenile wood.

C. Clipping of Veneer

There are two types of clipping in the manufacture of veneer.

- Wet clipping is used to cut the rough green veneer to approximate width and to remove defects before drying.

- Dry clipping squares and cuts veneer sheets to close tolerance in width, with any defects also being removed. Dry clipping as the name suggest occurs after the sheet as been removed from the drier.

D. Veneer Jointing

The jointing of veneers is carried out in order to provide square, straight edges. So that two or more veneer sheets can be taped or spliced to form a wider sheet with inconspicuous glue joints.

E. Veneer Taping, Splicing, and Edge Gluing.

Narrow pieces of veneer are built up to the desired widths by butting the jointed edges, and either applying tape or effecting a cured glue joint between the pieces. Splicing machines are used with the tapeless splicer type.

In splicing the veneers move in their longitudinal direction, and rates of production seem to have reached ultimate speed compatible with care in selection and handling of the veneers.

Edge gluing of veneers increases working widths plus enables some faces, formally spliced, to be edge glued. Edge gluers with heated, articulated or shoe like pressure elements have the widest application, as chain fed types have difficulties with thin veneers.

F. Preparation of Veneer Lay on for Plywood

It is seldom that logs yield all the desired veneer in whole sizes. Generally 50% is whole, while the remainder is in halves, thirds or quarters. Whole veneers are clipped to pre-determined sizes and squared after drying by a guillotine like machine. Fractional sizes are also clipped to ensure that their edges are straight prior to joining. Defective veneer is also removed at the clipper.

Narrow pieces of veneer are built up into whole sheets by machining the edge, and then adhesive or adhesive tape is applied. Dried and clipped veneer sheets are sorted visually or by computer into face and core veneer. The face veneers may be further subdivided into four or five appearance grades. Those core veneers which are to have adhesive applied may also be separated out. Veneers showing defects may be repaired to improve their grade. Some manufactures punch out unsound or large knots, replacing them with fitting plugs of the same species.

G. Application of Adhesive / Glue

Application of adhesive to veneer can be achieved by using glue spreader. The type of glue spreader are roller spreader, spray, curtain coater, or extruder glue applicator. Rollers are hard (rubber or neoprene, corrugated) or soft (sponge), curtain coating is a system where a thin sheet (curtain) of adhesive is passed onto veneer as it is conveyed under a glue reservoir, and extrusion refers to the adhesive being extruded and placed on the veneer in the form of parallel lines or rods (Tsoumis, 1991). In Indonesia, the dominant glue spreader type being used by the plywood industry is roller glue spreader compared to those of curtain coater, spray coater, liquid and foam extruder.

The target of glue spreader is to distribute of adhesive uniformly on to the veneer surface. Different wood species and grades of veneer require different levels of adhesive. Generally dense wood species and smooth cut veneers requires less adhesive than porous wood or rough veneers (Baldwin, 1981). Glue spread on the veneer surface is usually expressed in terms of grams of adhesive per square meter or grams per feet square of veneer.

H. Preparation of Veneers for Gluing

Depending on the type and quantity of plywood to be produced, the steps to be taken in preparing the veneer stock for gluing and pressing, may range from direct transfer of the dry veneer. To the glue spreader, and then a series of operations (re-drying, grading and matching, dry clipping, jointing taping and splicing, inspecting and repairing, conditioning) as required in the manufacture of high quality furniture plywood.

In general however most veneers whether rotary cut or sliced, are cut to size and squared by a dry clipper, edge jointed, taped or spliced and graded into cores, cross bands, or face veneers prior to being assembled for gluing and pressing.

Sliced veneers are processed, basically the same as rotary cutting. However, difficulties are aggravated by usually greater working lengths. Also more waste and loss are more serious when working with expansive material and large sized veneers (Baldwin 1981).

I. Glue and Gluing Procedures

The modern glues have being used for plywood production in Indonesia are Urea Formaldehyde (UF), Melamine Formaldehyde (MF) and Phenol Formaldehyde (PF). Urea formaldehyde glues are extensively used for interior and intermediate grade bonding, which covers the majority of hardwood plywood produced. This adhesive system is versatile and low cost. UF resin is acid curing and heat accelerated. Fast cure and high strength are characteristic attributes of UF resin. The lack of long-term moisture and temperature resistance is UF weakness. UF bonded plywood should not be used where exposure to weather or elevated temperature. It will not withstand continuous cycle of wetting and drying and will begin to delaminate at about 140^{o}F and 60% relative humidity (Baldwin, 1995).

MF resins classified as amino-aldehyde products. Improved durability is an important feature as compared to those of UF. However, MF is more costly to manufacture. UF/MF glue blend are used in hardwood plywood and laminating industries for applications that required improved durability while maintaining light-colored glue-lines (Baldwin, 1995).

PF glues are the principle resins used for bonding structural plywood and wafer board. PF also used to bond dense hardwood plywood. PF glue when properly cured, are waterproof and often more durable than the wood itself. The weakness of PF glue is higher cost, a dark colored glue line, and a lower veneer moisture content requirement during the gluing process. However, the superior durability of the PF glue far outweighs its disadvantages in a wide array of applications (Baldwin, 1995) .

In plywood industries, fillers may be used to assist in reducing penetration of the glues into the wood, increase its viscosity at the critical time before setting, and tend to fill small cavities between veneers, thus preventing starved joints. Fillers are usually finely ground inert minerals such as clay or wood/grain flour finer than 180 mesh.

In order to minimize the adhesive cost, some plywood industries mixed their binder with extender. In some cases, cereal flours are used as extenders. These reduce the resign content of glue to the minimum necessary for the required bond but generally require a heavier spread of glue mixture.

Glue spreading machines usually have power driven rollers, ether of steel or rubber, with groove patterns consistent with the type of glue being applied. The amount of glue spread is controlled by one or more doctor rolls and varies with the type of glue, the species and quality of the veneer, and other factors.

J. Cold Pressing

The cold press which is unheated operates at pressure slightly below that of the hot-press. Pre-pressing can takes up to 50 sheets at a time, with a pressing time of 3 to 4 minutes.(Baldwin, 1981). Prior to the development of thermo-setting resigns (UF, MF and PF), all plywood panels were simply cold pressed before being hot pressed.

K. Hot Pressing

Hot pressing is carried out in a hydraulic press incorporating multiple heated platens between which each individual panel assembly is subjected to heat and pressure. Hot press pressure for softwood pine plywood usually range between 1242 to 1380k Pa. Platen temperatures of around 120 degree Celsius are used and pressing times for panels 3.5 and 22 mm are 2.75 and 9.5 minutes respectively, Baldwin (1981). Very accurate control of pressing times, temperatures and pressure are necessary to ensure adequate adhesive bond development.

L. Conditioning of Plywood

In hot pressing a considerable amount but not all of the water in the glue line escapes in the form of steam. Moreover, hot pressed panels are often dipped or sprayed with water immediately after removal from the press in order to restore the moisture in the face plies. Consequentially, a conditioning or re-drying period is necessary and hot pressed plywood is usually hot stacked in solid piles for periods ranging from one or two hours to overnight. In this way the glue joints attain full cure and the moisture content of the panels is reduced and equalized through-out the panels before further processing is carried out.

In cold pressing, particularly all of the water from the glue line is taken up by the wood layers and re-drying is mandatory. Usually the panels are piled with tiers separating the panels at regular intervals to permit air circulation throughout the pile. Conditioning rooms are often used where panels are dried from 8 to 24 hours at temperatures up to 49 degrees Celsius Baldwin (1981).

M. Trimming Plywood

After being unloaded from the press and after cooling, the plywood is trimmed to precise sizes usually by passing through two sets of parallel gauged circular saws. The edges of an untrimmed plywood panel are more irregular, for example compared to particleboard. So the panel is ether introduced into the trimming saws by hand with the aid of shadow lines, or greater trimming margins must be allowed. This ensures that panels are rectangular and straight edged.

N. Sanding and Finishing Plywood

The wide belt sander has been used to an increasing extent. These machines have been developed from the large metal finishes used to produce flat and polished surface on sheet metals. Baldwin (1981). Their development for plywood finishes allows the manufacture to produce high quality finishes at high production rates. The machines are available with one or several belts wit feeds speeds up to about 30m/min being possible. These machines can bring the stock to its final required thickness as well as provide a final finish. For this double task the panel may best be sanded by two or more belts passes through a single head machine with finer grit papers for each succeeding operation. The top belt machine is more commonly used over the bottom belt machine as the operator can continuously observe the panel's surface. After sanding, boards are graded for defects.

III. METODHOLOGY

A. Raw Material

SDL of suitable dimension and quality for peeling are sorted as plywood raw material. The SDL come from community forest in Bogor area, Jambi and Sukabumi. The SDL is fresh cut and the diameter range between 20 – 25 cm. The SDL species were Sungkai (*Peronema canescens* Jack), Meranti merah (*Shorea lephrosula* Dyer), Jabon (*Anthocephalus cadamba* Miq), Manii (*Maesopsis eminii*), and Sengon (*Paraserianthes falcata* L Nielsen).

Three glue types were used in the plywood production, namely Urea Formaldehyde (UF), Phenol Formaldehyde (PF), and Melamine Formaldehyde (MF). All of the glue produced by PT. Pamolite Adhesive Industry, Probolinggo, West Java, Indonesia.

B. Procedure of Plywood Production

The plywood samples size were 30.0 cm x 30.0 cm x 4.0 mm, three-layer and three-ply. Treatments in this research are wood species (5 wood species) and glue types (UF, MF, and PF). Replication was 5, so in total there were 75 plywood (5 wood species x 3 glue types x 5 replications). Procedure of plywood production can be seen in Figure 1.

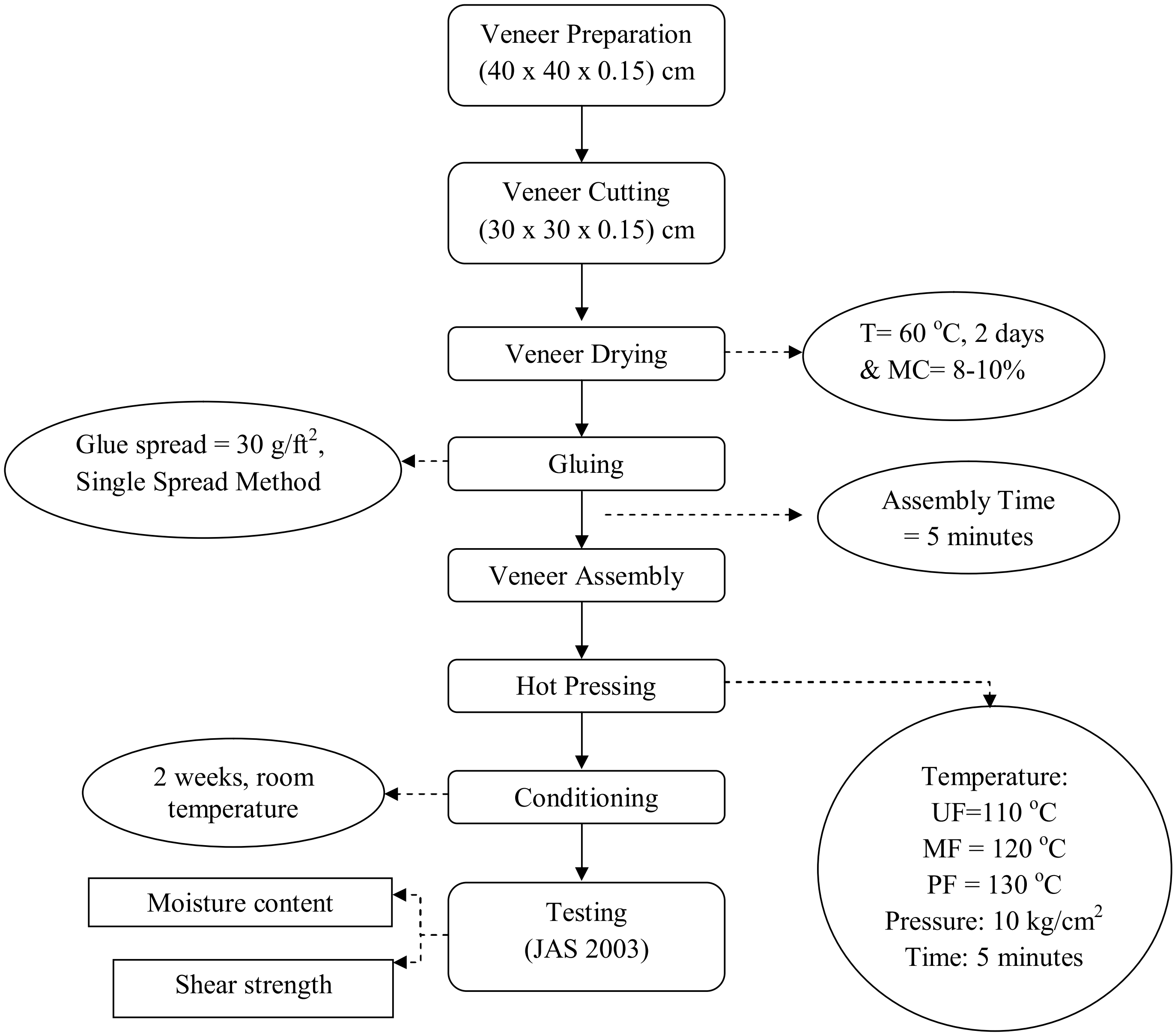


Figure 1. Plywood production process

Detail information regarding plywood production is as follows :

1. Log Preparation

Fresh cut SDL was manually debarked using short machete/chopping knife and special toll designed by PT. Andatu Lestari Plywood. The process of log debarking is not so difficult. However, it needs so much energy and skilled labor.

2. Veneer Production

The veneer used in the research were produced from fresh cut SDL using small rotary /lathe in Forest Research Centre, Forestry Department Republic of Indonesia in Bogor and PT. Andatu Plywood in Lampung. The target thickness of face and back veneers were 1.0 mm, while the core veneer was 1.5 mm.

The green veneer is then clipped to size manually or by high-speed knives, graded and stored in piles ready for drying. Any defects, such as knots and splits, are then cut out of the sheet.

3. Veneer Drying

The veneer dried in an electric oven at 60^{o}C for 2 days (48 hours). The veneer moisture content was 8 – 10%.

4. Glue Spreading and Assembly

The assembly of the plywood prior to pressing entails the jointing of the narrow strips of veneer, which are edge-glued so as to make sheets of the required size. In this research, there was no jointing veneer used in plywood production. Glue is then applied using shaving brush to the inner plies or core, which in turn, are laid between the outer veneers ready for bonding. The glue spread level used was 30 g/ft^2 for UF, MF and PF. After glue spreading process, the face, core and back veneers assembled perpendicular each other to the adjacent veneer.

5. Pressing

Once the veneers are laid-up as assembly plywood sheets, they are fed into hydraulic hot press so as to bring the veneer into direct contact with the glue, where the application of heat cures the glue. The hot press temperature was 110^{o}C, 120^{o}C, and 130^{o}C for UF, MF and PF, respectively for 5 minutes.

6. Conditioning

After hot pressing, the produced plywood then conditioned in a conditioning room for 2 weeks. Conditioning process is very important to release the remained stress after hot pressing, formaldehyde emissions and other volatile component (Kurniawan and Massijaya, 2006).

7. Testing

The plywood then tested according to Japanese Agricultural Standard (JAS) for plywood N0. 232 year 2003. The properties tested were moisture content and shear strength. The cutting pattern of plywood samples can be seen in Figure 2.

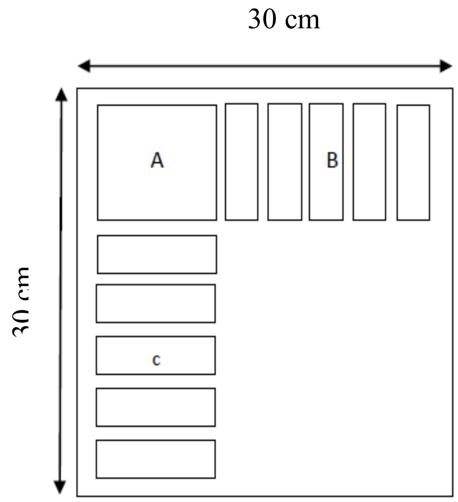
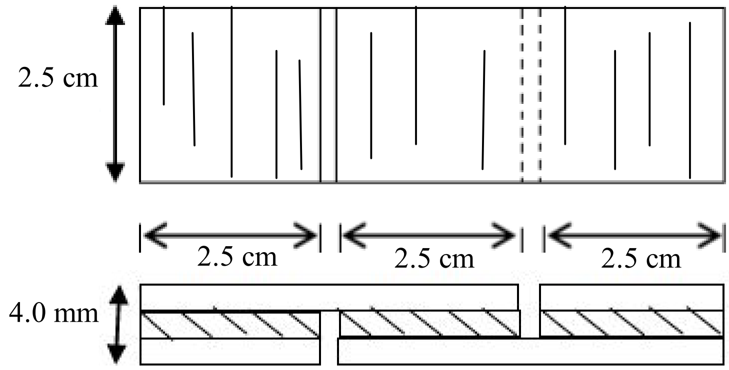


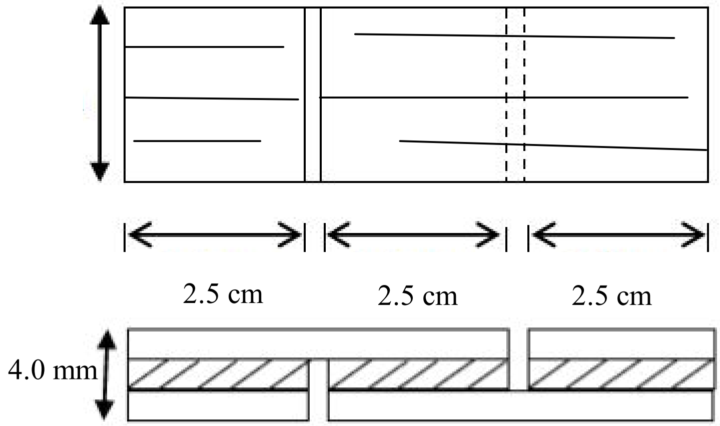
Figure 2. Cutting pattern of plywood sample

Note :
A = moisture content sample.
B = Shear strength perpendicular to the face/back veneer grain.
C = Shear strength parallel to the face/back veneer grain.

The sample cutting for shear strength perpendicular and parallel to the face/back veneer grain orientation can be seen in Figure 3.



Shear strength perpendicular to grain



Shear strength parallel to grain

Figure 3. Shear strength samples

Plywood bonded by UF and MF were tested by hot and cold water immersion test. The test pieces, after being immersed in hot water of 60 $\pm$ 3 ^{o}C, were immersed in water of room temperature for 1 hour to get cool. After that, bonding strength test were conducted in a wet condition, and measure the maximum load and then the shear strength were calculated. For plywood bonded by PF, the test pieces, after being immersed in boiling water for 4 hours, were dried at a temperature of 60 $\pm$ 3 ^{o}C at an electric oven for 20 hours. Further the test pieces were immersed in boiling water for 4 hours, and then immersed in water of room temperature for 1 hour to get cool. After that, bonding strength test were conducted in a wet condition, and measure the maximum load and then shear strength were calculated.

IV. RESULTS AND DISCUSSION

A. Veneer Yield

Nowadays, the technique used to produce veneer is rotary cut. Slicing technique only used to produce fancy veneer for face layer of fancy plywood. The SDL which was resulted from plantation and community forest, only suitable for rotary cut and not suitable for slicing. However, SDL which has high density resulted from natural forest maybe suitable for slicing technique as long as the wood color and figure classified as fancy wood.

In order to find out the yield of SDL resulted from plantation and community forest with diameter range from 22-30 cm using spindle-less rotary machine the experiment was conducted for about 100 SDL. The SDL species is mixed species with the dominant species are Jabon (*Anthocephalus cadamba* Miq), Manii (*Maesopsis eminii*), and Sengon (*Paraserianthes 17alcate* L Nielsen).

The rotary veneer yield average was 62.0 % with the standard deviation was 9.9 %. The obtained results were higher compared to the same research conducted by Kliwon and Suwandi (1998), even slightly higher compared to those of Ministry of Forestry Standard of rotary veneer yield (55 – 60%). According to Kliwon and Suwandi (1998), the rotary veneer yield of SDL using a 10 cm chuck is 40 %. The reason of the higher rotary veneer yield because the SDL chosen for the research is very well selected with minimum wood defects which was potentially minimizing the veneer results. Moreover, utilization of rotary spindle-less machine producing smaller log core waste (average 5 cm) compare to those of conventional rotary which produced a 10 cm log core waste in Kliwon and Suwandi (1998) research. The research results have shown that utilization of a spindle-less or center-less lathe allows peeling cores down to diameters of 50 mm (2.0 inch) or less. The increased veneer yield is especially important to mill that rely on small-diameter logs. Wood quality from these machines, however, is lower than that from larger chuck-driven lathes. The inner core wood is primarily juvenile wood, has the highest occurrence of knots, and tend to be excessively wavy, an artifact of producing flat veneer from small diameter logs (Bowyer, 2003).

The research results of rotary veneer yield using spindle-less rotary machine can be seen in Table 1.

Table. 1. Rotary veneer yield using SDL come from plantation and community forest.

NO.	LENGTH	LOG DIAMETER	LOG VOLUME	ROUND UP	ROUND UP	LOG CORE	LOG CORE	YIELD
	(M)	(CM)	(CM3)	DIAMETER (CM)	VOLUME (CM3)	DIAMETER (CM)	VOLUME (CM3)	(%)
1	1.3	22	49392	20	40820	5	2867	76.8
2	1.3	23	53984	20	40820	5	2067	71.8
3	1.3	24	58781	21	45004	5	2254	72.7
4	1.3	24	58781	21	45004	5	2351	72.6
5	1.3	24	58781	21	45004	4	1887	73.4
6	1.3	25	63781	22	49392	4	1887	74.5
7	1.3	25	63781	18	33064	5	2067	48.6
8	1.3	25	63781	21	45004	5	2654	66.4
9	1.3	25	63781	19	36840	5	2254	54.2
10	1.3	25	63781	20	40820	5	2254	60.5
11	1.3	25	63781	20	40820	5	2067	60.8
12	1.3	25	63781	20	40820	5	2551	60.0
13	1.3	25	63781	20	40820	5	2551	60.0
14	1.3	25	63781	19	36840	6	3200	52.7
15	1.3	25	63781	20	40820	5	2759	59.7
16	1.3	25	63781	20	40820	5	2867	59.5
17	1.3	25	63781	20	40820	5	2254	60.5
18	1.3	25	63781	20	40820	5	2351	60.3
19	1.3	25	63781	20	40820	6	3316	58.8
20	1.3	25	63781	19	36840	7	4312	51.0
21	1.3	25	63781	19	36840	6	3552	52.2
22	1.3	26	68986	22	49392	5	2976	67.3
23	1.3	26	68986	22	49392	5	2067	68.6
24	1.3	26	68986	22	49392	5	2067	68.6
25	1.3	26	68986	24	58781	5	2159	82.1
26	1.3	26	68986	18	33064	5	2351	44.5
27	1.3	26	68986	20	40820	6	3200	54.5
28	1.3	26	68986	21	45004	6	3316	60.4
29	1.3	26	68986	22	49392	6	3200	67.0
30	1.3	26	68986	21	45004	5	2254	62.0
31	1.3	26	68986	20	40820	6	3200	54.5
32	1.3	26	68986	20	40820	6	3433	54.2
33	1.3	26	68986	20	40820	6	3087	54.7
34	1.3	26	68986	20	40820	5	2551	55.5
35	1.3	26	68986	20	40820	6	3200	54.5
36	1.3	26	68986	21	45004	6	3316	60.4
37	1.3	26	68986	20	40820	6	3433	54.2
38	1.3	26	68986	20	40820	5	2254	55.9
39	1.3	27	74394	19	36840	5	2351	46.4
40	1.3	27	74394	23	53984	5	2450	69.3
41	1.3	27	74394	22	49392	5	2067	63.6
42	1.3	27	74394	22	49392	5	2254	63.4
43	1.3	27	74394	21	45004	5	2159	57.6
44	1.3	27	74394	23	53984	5	2351	69.4
45	1.3	27	74394	24	58781	5	2450	75.7
46	1.3	27	74394	21	45004	5	2551	57.1
47	1.3	27	74394	23	53984	5	2551	69.1
48	1.3	27	74394	24	58781	5	2551	75.6
49	1.3	27	74394	23	53984	5	2551	69.1
50	1.3	27	74394	24	58781	5	2551	75.6

Table 1. (*continue*)

51	1.3	27	74394	25	63781	6	3200	81.4
52	1.3	27	74394	20	40820	6	3433	50.3
53	1.3	27	74394	22	49392	7	4312	60.6
54	1.3	27	74394	23	53984	5	2450	69.3
55	1.3	27	74394	19	36840	5	2976	45.5
56	1.3	27	74394	26	68986	6	3200	88.4
57	1.3	27	74394	23	53984	5	2551	69.1
58	1.3	27	74394	22	49392	5	2551	63.0
59	1.3	27	74394	20	40820	5	2551	51.4
60	1.3	28	80007	20	40820	5	2551	47.8
61	1.3	28	80007	23	53984	5	2551	64.3
62	1.3	28	80007	23	53984	5	2867	63.9
63	1.3	28	80007	23	53984	4	1887	65.1
64	1.3	28	80007	24	58781	5	2254	70.7
65	1.3	28	80007	24	58781	5	2159	70.8
66	1.3	28	80007	24	58781	5	2067	70.9
67	1.3	28	80007	24	58781	5	2159	70.8
68	1.3	28	80007	20	40820	6	3316	46.9
69	1.3	28	80007	22	49392	6	3200	57.7
70	1.3	28	80007	26	68986	5	2551	83.0
71	1.3	28	80007	23	53984	5	2551	64.3
72	1.3	28	80007	20	40820	5	2551	47.8
73	1.3	28	80007	21	45004	5	2551	53.1
74	1.3	29	85824	25	63781	5	2551	71.3
75	1.3	29	85824	24	58781	5	2654	65.4
76	1.3	29	85824	19	36840	5	2867	39.6
77	1.3	29	85824	24	58781	5	2067	66.1
78	1.3	29	85824	24	58781	5	2067	66.1
79	1.3	29	85824	25	63781	5	2067	71.9
80	1.3	29	85824	25	63781	5	2067	71.9
81	1.3	29	85824	23	53984	5	2067	60.5
82	1.3	29	85824	24	58781	5	2067	66.1
83	1.3	29	85824	25	63781	5	2067	71.9
84	1.3	29	85824	22	49392	5	2976	54.1
85	1.3	30	91845	25	63781	5	2551	66.7
86	1.3	30	91845	26	68986	5	2551	72.3
87	1.3	30	91845	21	45004	5	2551	46.2
88	1.3	30	91845	25	63781	5	2551	66.7
89	1.3	30	91845	23	53984	5	2551	56.0
90	1.3	30	91845	23	53984	5	2976	55.5
91	1.3	30	91845	22	49392	6	3433	50.0
92	1.3	30	91845	22	49392	5	2450	51.1
93	1.3	30	91845	23	53984	5	2450	56.1
94	1.3	30	91845	25	63781	5	2351	66.9
95	1.3	30	91845	20	40820	5	2159	42.1
96	1.3	30	91845	26	68986	5	2351	72.6
97	1.3	30	91845	25	63781	5	2351	66.9
98	1.3	30	91845	20	40820	5	2067	42.2
99	1.3	30	91845	24	58781	6	3200	60.5
100	1.3	30	91845	23	53984	7	4312	54.1
AVERAGE								62.0
STANDARD DEVIATION								9.9

B. Fundamental Properties of Plywood

1. Surface Quality

The surface quality of produced plywood made of Sungkai (*Peronema canescens* Jack), Meranti merah (*Shorea lephrosula* Dyer), Jabon (*Anthocephalus cadamba* Miq), Manii (*Maesopsis eminii*), and Sengon (*Paraserianthes falcate* L Nielsen) and bonded by UF, MF and PF were presented in Table 2. The total number of plywood samples evaluated for the surface quality were 75 plywood. Due to the small size of the samples, the grade of the produced plywood was determined based on the lowest grade among the 5 samples of each treatment.

Table 2. Surface quality of the produced plywood.

Categories	Grade														
	Sungkai			Meranti			Jabon			Manii			Sengon		
	UF	MF	PF	UF	MF	PF	UF	MF	PF	UF	MF	PF	UF	MF	PF
Total number of live knots, dead knots, bark pockets and resin pockets, whose longer diameter is exceeding 5 mm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Live knots	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
	Not available														
Dead knots	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Loose knots or holes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Several plywood contain holes. However, the diameters were less than 3 mm														
Bark pocket or resin pocket	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Decay	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Open splits or chips	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														

Table 2. (continue)

Cross breaks	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Worm hole	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Several plywood contain round worm hole. However, the diameters were very small (less than 1.5 mm) and not dark rimmed.														
Open joint	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Blister	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Folds	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Press marks	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1
	Available for Jabon and Manii PF bonded plywood.														
Flaws	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Patches	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Not available														
Other defects	1	1	-	1	1	-	1	1	-	1	1	-	1	1	-
	All of the plywood bonded by PF performed dirty surfaces because PF glue penetrated until the surface of the produced plywood and clearly conspicuous.														

Based on the research results in Table 2, the produced plywood could be classified as Grade 1 for plywood bonded by UF and MF. However, for PF bonded plywood failed to fulfill the Grade 1 and Grade 2 according to JAS N0. 232 for Plywood. In case of PF bonded plywood, all of the plywood bonded by PF performed dirty surfaces because PF glue penetrated until the surface of the produced plywood and clearly conspicuous. This phenomenon happen due to the combination factors between the color of the PF glue (dark brown) which is very contrast with the SDL color, deep lathe check, and the thin face and back veneers (1 mm).

2. Moisture Content

Plywood is a hygroscopic material and has ability to exchange its moisture content with air. Many physical and mechanical properties of plywood are affected by changes in moisture content below the fiber saturation point, including formaldehyde emission. Moisture content of plywood is one of critical quality factors . Excess moisture in plywood may cause molding, decay or rotting. However, it is not correct that the lower the moisture content the better the quality. It's only partly correct . If the plywood is too dry, the plywood become very weak. For example, very dry plywood of thickness 2.4 mm can be easily broken off.

According to some plywood standard, the MC of plywood should be 6%~14%. But usually at the time of plywood leaving factory, the MC of plywood is 8%~14%.

Plywood continuously exchanges moisture with its surroundings . Plywood can absorb moisture from or give off moisture to the air . The MC of plywood will increase or decrease until the MC of plywood is in equilibrium with air humidity and temperature. The MC of plywood will change if the air humidity and temperature of its surroundings change . For instance, if plywood with lower MC were exported to a humid climate country , the MC of plywood could increase if the plywood were exposed to the air in the humid country. MC can be easily measured by a digital moisture meter.

The research results of plywood moisture content can be seen in Figure 4. Based on the research results, it was found that all of the plywood moisture content fulfilled the JAS Standard for plywood No. 232 year 2003. In general, moisture content of plywood bonded by phenol formaldehyde (PF) were higher compared to those of plywood bonded by urea formaldehyde (UF) and melamine formaldehyde (MF), except plywood made of sengon. This was because the glue distribution of the PF was poorer compared to those of UF and MF. The moisture contents of plywood made of sengon were relatively same for all of the plywood bonded by UF, MF and PF.

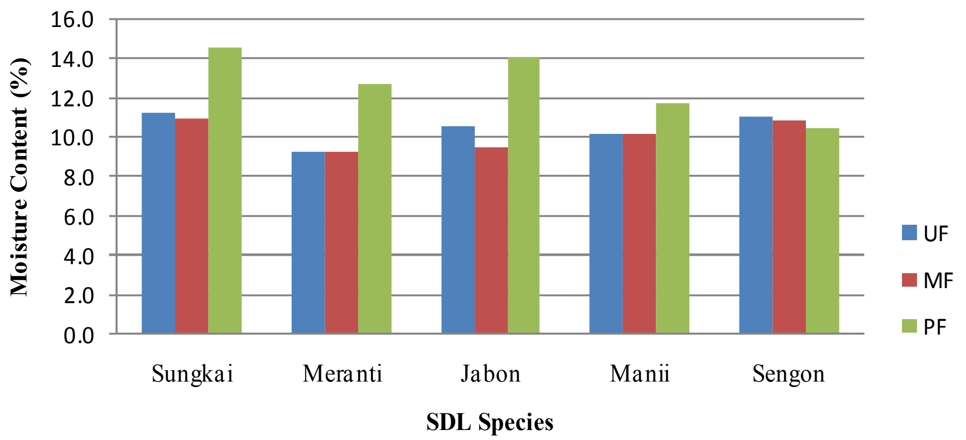


Figure 4. Histogram of plywood moisture content

3. Shear Strength

Plywood shear strength is the maximum stress that plywood can withstand while being stretched or pulled before necking which is when the specimen's cross section starts to significantly contract. Shear strength is affected significantly by glue line quality, while glue line quality affected by surface quality of the veneer, species, type of adhesive, press time, and press temperature.

It is essential to the successful production of plywood that there should be a strong glue bond between plies. Not all woods behave equally well in this connection. A strong bond is difficult to obtain with some of the heavier timbers and here a strong bond is needed most. As the greater stiffness of the denser wood causes increased strain on the bond with shrinkage and swelling tendencies in the plywood, as a result of changing atmospheric conditions (Baldwin 1981). Where gluing to the surface of plywood is necessary, as in the case of overlays, the face veneer should exhibit good gluing properties.

Some species absorb glue much more readily than others and glue viscosity has to be adjusted to meet the required of the wood being used. This can cause problem when absorbent and non-absorbent species are used in combination (Baldwin 1981). Some woods are inherently bad for gluing and finishing standpoints, because of natural constituents in the wood for example, oil or waxy materials may bleed to the surface during drying or storage and present a poor gluing surface, or result in uneven staining or painting characteristics. Steaming of logs prior to veneer manufacture, control of drying conditions, and their use as soon as possible after the production of the veneer can help in some cases.

Figure 5 and 6 show the research results of shear strength parallel to the face/back veneer grain in dry and wet conditions, respectively.

Based on the research results, it was found that all of the plywood shear strength parallel to the face/back veneer grain in dry and wet condition fulfilled the JAS Standard for plywood No. 232 year 2003. Utilization of different adhesive type resulted the same tendency to the shear strength of plywood made of Jabon and Manii. However, there was no same tendency for plywood made of Sungkai, Meranti and Sengon.

In order to find out the glue line quality of the plywood, hot and cold water immersion test for UF and MF bonded plywood and the cyclic test for PF bonded plywood were conducted. The test pieces of UF and MF bonded plywood, after being immersed in hot water of 60 $\pm$ 3 ^{o}C, were immersed in water of room temperature for 1 hour to get cool, and then tested in wet condition. For plywood bonded by PF, the test pieces, after being immersed in boiling water for 4 hours, were dried at a temperature of 60 $\pm$ 3 ^{o}C at an electric oven for 20 hours, immersed in boiling water for 4 hours, immersed in water of room temperature for 1 hour to get cool, and then tested in wet condition.

Figure 5 and 6 show that the wet shear strength sometimes higher compared to dry shear strength for the same plywood. This could happen because the glue distribution was not uniform in plywood production. However, the differences of shear strength between dry and wet testing condition is not so remarkable, except for Meranti UF bonded plywood Jabon PF bonded plywood, and Manii PF bonded plywood.

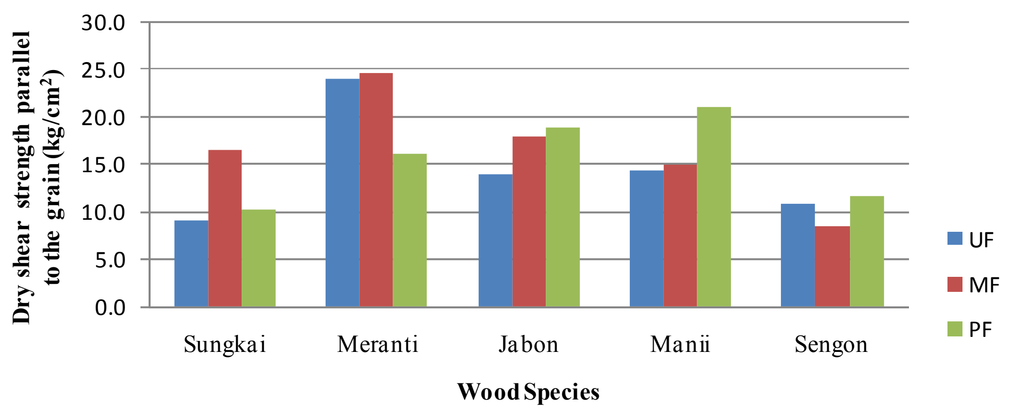


Figure 5. Histogram of plywood dry shear strength parallel to the grain

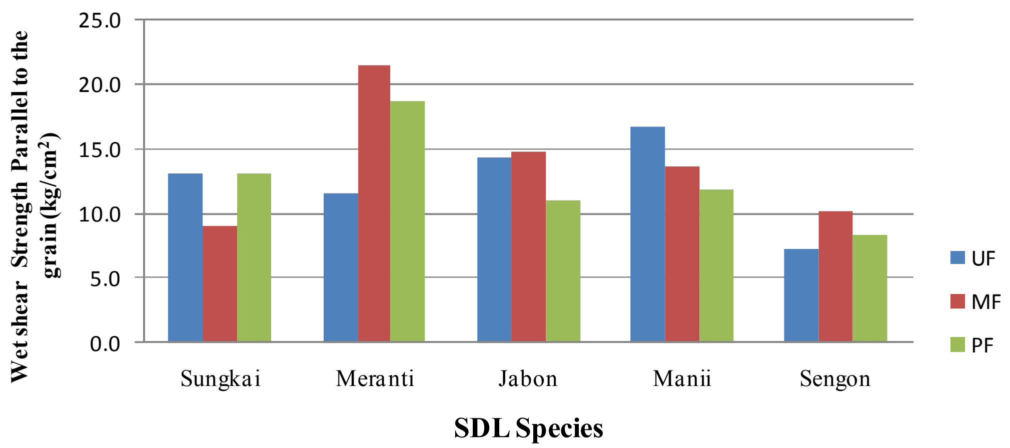


Figure 6. Histogram of plywood wet shear strength parallel to the grain

Figure 7 and 8 show the research results of shear strength perpendicular to the face/back veneer grain in dry and wet conditions, respectively.

Based on the research results, it was found that all of the plywood shear strength perpendicular to the face/back veneer grain in dry condition fulfilled the JAS Standard for plywood No. 232 year 2003. However, shear strength perpendicular to the face/back grain in wet condition failed to fulfill the standard except Meranti PF bonded plywood. In general, the shear strength parallel to the face/back grain were higher compared to those of perpendicular were at the same SDL and glue type.

The hot and cold water immersion test and the cyclic test also showed that the effect of wet test was higher in shear strength perpendicular to the face/back grain compared to those of parallel. Figure 8 shows that most of the produced plywood failed to fulfill the JAS Standard, except Meranti PF bonded plywood.

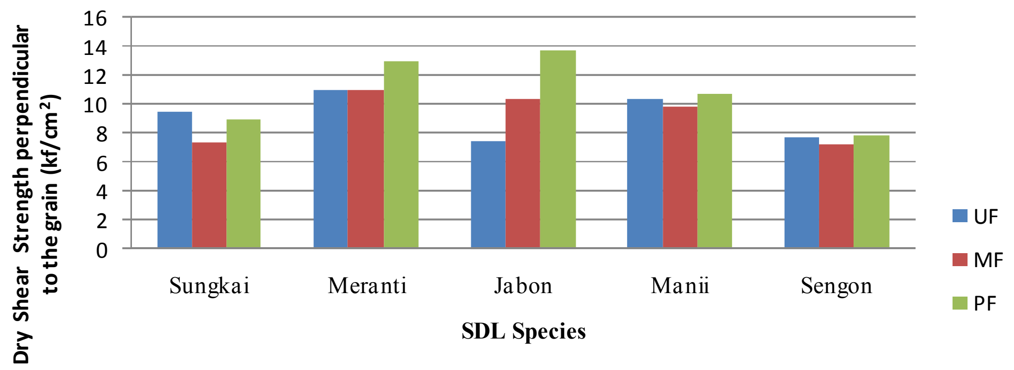


Figure 7. Histogram of dry shear strength perpendicular to the grain

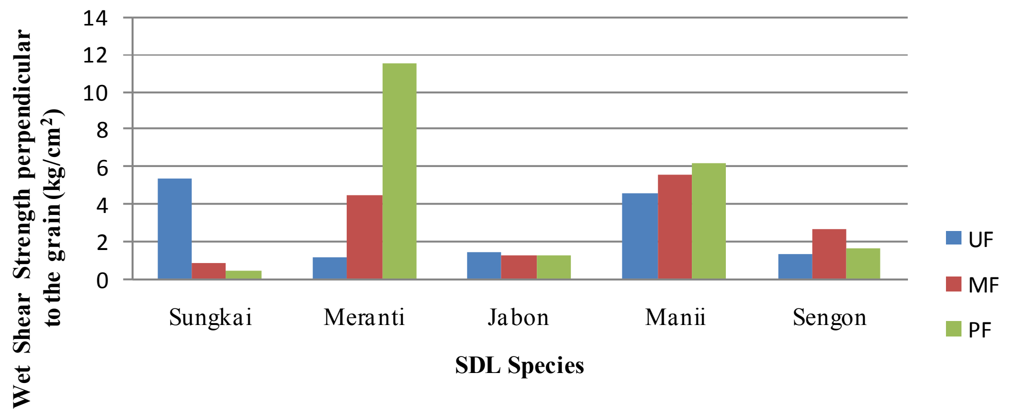


Figure 8. Histogram of wet shear strength perpendicular to the grain

V. CONCLUSIONS

1. The average rotary veneer yield of SDL from community and plantation forest using spindle-less rotary was 62 % with standard deviation 9.9%.
2. The surface quality of UF bonded and MF bonded plywood was classified as grade 1. However, the PF bonded plywood failed to fulfill JAS for plywood No. 232, 2003.
3. All of the plywood shear strength parallel to the face/back veneer grain in dry and wet condition fulfilled the JAS Standard for plywood No. 232 year 2003. Utilization of different adhesive type resulted the same tendency to the shear strength of plywood made of Jabon and Manii. However, there was no same tendency for plywood made of Sungkai, Meranti and Sengon.
4. All of the plywood shear strength perpendicular to the face/back veneer grain in dry condition fulfilled the JAS Standard for plywood No. 232 year 2003. However, shear strength perpendicular to the face/back grain in wet condition failed to fulfill the standard except Meranti PF bonded plywood. In general, the shear strength parallel to the face/back grain were higher compared to those of perpendicular were at the same SDL and glue type.

AKNOWLEDGEMENT

We thank Jajang Suryana, Isari Wahyulia, and Rima Jentika for helping us conducting the research. Additionally we gratefully aknowledge the time participants dedicated to this study.

REFERENCES

Baldwin.R.F., 1981. Plywood Manufacturing Practices Revised 2nd Edition. Miller and Freeman Publication Inc. USA.

Baldwin.R.F., 1995. Plywood and Veneer-Based Products : Manufacturing Practices. Miller and Freeman Publication Inc. USA.

Bowyer, J.L., R. Shmulsky, J. G. Haygreen. 2003. Forest Products and Wood Science : An Introduction. Fourth Edition. Iowa State Press. Ames. Iowa.

Japanese Agricultural Standard (JAS) for Plywood NO. 232. 2003. Ministry of Agriculture and Forestry. Japan.

Kliwon, S, M.I. Iskandar. 1998. The Proceedings of the Second International Wood Science Seminar. November 6-7, 1998. Serpong. Indonesia.

Kurniawan, A., M. Y. Massijaya. 2006. Introduction to Oriented Strand Board (OSB). Collaboration Between Faculty of Agriculture North Sumatra University and Faculty of Forestry Bogor Agricultural University.

Smulski, S. 1997. Engineered Wood Products : A guide for specifiers, designers and users. PFS Research Foundation. Madison. Wisconsin.

Tsoumis, G. 1991. Science and Technology of Wood : Structure, Properties, Utilization. Van Nostrand Reinhold. New York.

PART B. LAMINATED VENEER LUMBER

LAMINATED VENEER LUMBER

By :

Bedyaman Tambunan, Sukma Surya Kusumah, Muh Yusram Massijaya

I. INTRODUCTION

A. Background

Demand on composite products such as veneer laminated board (*Laminated Veneer Lumber*) for various uses (structural and non structural) shows very rapid increase in line with increasing human population. Availability of large diameter wood for board products is progressively decreasing, so that demand for small diameter wood becomes increasing. ***Laminated Veneer Lumber*** (LVL) constitutes one of the composite wood products which are arranged from several layers of veneer which are bound by using adhesives. Several advantages of LVL as compared to solid wood board are that LVL are stronger, more symmetric, more homogeneous, and their defects are easier to be distributed more uniformly along the board. Besides that, the LVL has fewer characters of rolling, twisting, bending and shrinking as compared to those of solid wood board. In general, LVL are generally used for headers, beams, rim board, and edge-forming materials.

Based on results of research which had been conducted, it was known that average specific gravity of small diameter wood was 0.52 with interval of specific gravity between 0.28-0.73[1]. Differences of specific gravity in SDL (*Small Diameter Logs*) as raw materials for LVL would affect the characteristics of LVL being produced. Therefore, there is a need for studying the characterization of LVL products which are produced from several species of SDL wood, so that utilization of SDL as raw materials for wood processing industry would become more appropriate. Besides that, the performances of SDL would affect the process of LVL manufacturing, particularly those which are related with the extent of cylindrical shape of the log, defects occurring in the log, and diameter of the log itself.

Utilization of SDL for wood based composite products (Plywood, LVL, Particleboard, and MDF) should be conducted with high mechanization processing system. One of the system of high mechanization processing in the production of LVL is in the process of peeling of logs into veneer with high efficiency, namely veneer peeling by using spindle less rotary cutting with peeling speed of 15 sheets/minutes, so that high output-input ratio is obtained. Besides that, veneers produced from SDL require several repairs on the veneer, such as patching and jointing which comprise around one third of the amount of existing works [2]. In the ordinary market, LVL are made with dimension of length of up to 25 m, width of 120 cm, and thickness which ranged from 19 mm to 75 mm. Adhesive which is commonly used in the production of LVL is phenol formaldehyde[2].

Based on the phenomena mentioned above, there is a need for research to learn the characteristics of LVL products which are made from SDL as raw materials, so that there would be obtained some information which is useful for developing LVL which are made from SDL materials.

B. Objectives

The objectives of this research were determining the performance of small diameter wood as raw materials for LVL, and the characteristics of LVL being produced.

C. Literature Review

The uses of LVL as substitution product for solid wood for structural purpose are increasing from time to time, by utilizing raw materials in the form of small diameter wood. Hng,P.S., M.T. Paridah and K.L. Chin in the year 2010[3] had conducted research on the utilization of small diameter and low specific gravity wood as raw materials of mixed wood in the production of LVL from keruing wood. Species of small diameter wood being used were pulai (*Alstonia* sp), sesendok (*Endospermum* Sp), and kekabu hutan (*Bombax* sp). In this research, species of small diameter wood were used in core layer of LVL, whereas the surface layer used keruing wood with phenol formaldehyde as adhesive. In relation with environmental issues, the kind of adhesive being used in LVL production should be environmentally friendly, or in other words, should be free from formaldehyde emission which endanger human health. One of the research which had ever been conducted was comparison of the use of various combination of adhesives in the production of LVL, namely the uses of urea formaldehyde (UF), UF added with melamine (UF + M), melamine-urea formaldehyde (MUF), and phenol formaldehyde (PF). From the research results, it was known that LVL formaldehyde emission which used adhesive PF, had smaller magnitude as compared with LVL which used other adhesives, and had greater shearing strength, modulus of rupture and modulus of elasticity [4].

LVL could be used for various purposes, such as in the form of beam I, box beam, stairway, and window / door frame. The main advantage of shape I and box are their straighter shape, more uniform thickness of board, high stability of dimension, and lighter weight as compared to solid wood at the same size, and can be perforated for joint design. LVL could also be used as structural beam – floor joint and support, wall girts, pole, and roof frame. Structural LVL have many advantages when they were used as frame for door or window, where they have structural reliability and high strength, dimension stability, and little tendency to bend, warp and twisted [5].

Several new equipments in the production process of LVL have been in existence in large quantity in accordance with the available raw materials. Equipments which have been available in large quantity in the market are among other things veneer peeling machine without *spindle*, which is known by the name *spindless veneer peeling lathe*, and veneer drying machine with hot press method known as *veneer drying press* (*hot press drying*)[6].

II. METHODOLOGY

A. Materials and Equipments

a. Materials

Raw materials used in this research were 5 species of small diameter log, namely pulai (*Alstonia scholaris*), sengon (*Paraserianthes falcataria*), jabon (*Anthocephalus cadamba*), manii (*Maesopsis eminii*), and sungkai (*Peronema canescens*). Adhesive being used in the production of LVL was phenol formaldehyde (PF) with solid content of 50% (PT. Pamolite Adhesive Industry).

b. Equipments

Equipments being used in the testing of LVL were rotary veneer cutting, hot and cold press, circular saw, roller glue spreader, moisture meter, sander, universal testing machine (UTM), caliper, digital weighing scale, and oven.

B. Production of LVL

The produced LVL were categorized into three groups on the basis of specific gravity and their raw materials, namely LVL from wood with low specific gravity (0,2-0,39) comprising kayu pulai and sengon, moderate specific gravity (0,40-0,60) which was represented by manii and jabon, and high specific gravity (> 0,60) which was represented by sungkai. Species of wood being used in the production of LVL constituted a factor in this research which had three replications, so that the number of LVL being used was as many as 15 LVL (5 x 3).

LVL was made with the following process:

Log Preparation

SDL which had been logged (cut) were measured for their diameter with method of measuring the diameter of stem base and stem tip, and stem length up to the first branch.

Stems of SDL which constitute fresh wood were examined in terms of their physical condition, extent of cylindrical shape of stem, diameter and stem length, as well as checking also the defects occurring in the SDL stem. Veneer for face layer were prepared from logs which were straight, round, cylindrical; and free from crack or split in the tip end of the log, diagonal grain, and unhealthy knot. On the other hand, veneers for the core part were obtained from logs which were allowed to have defects of healthy knot and heart rot which had diameter less than 1/3 diameter of the stem.

Log Precondition

To ease the cutting of wood, softening of the wood was conducted by heating with several media, namely hot water, hot steam, high pressure hot vapor, and electricity.

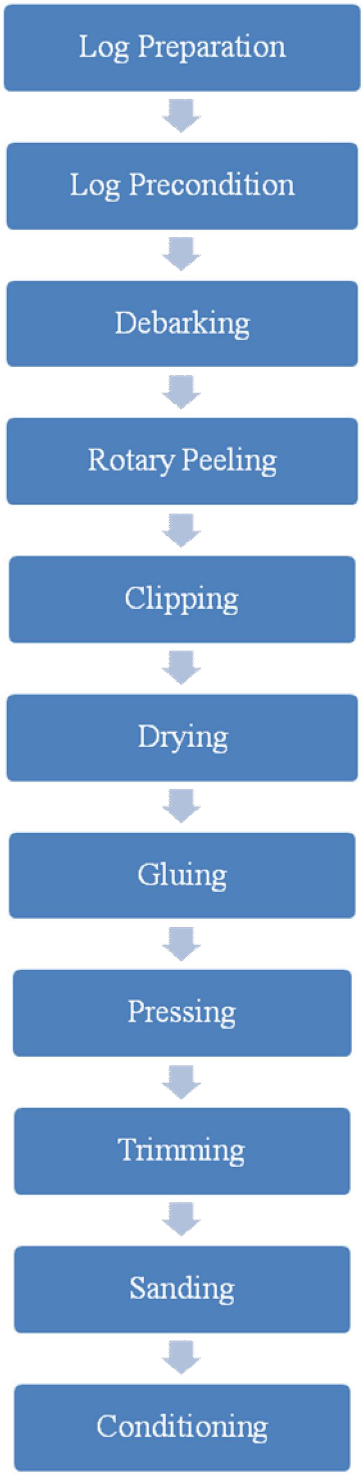


Figure 1. Diagram in the process of LVL production.

Debarking

Debarking is peeling of bark before the peeling of log into veneer.

Rotary Peeling

Logs whose outer bark had been peeled, were further peeled into veneer with thickness of 2,2 mm using rotary peeling and spindle-less rotary peeling so that the diameters of the remaining logs were around 5-10 cm.

Clipping

Veneers which had been peeled were afterwards cut into sizes of 30 cm x 120 cm. Veneers which had been cut were sorted on the basis their quality. The veneers were categorized into three groups, namely face veneer, core veneer, and back veneer. Sorting of veneers were conducted on the basis of defects occurring in the veneer. Veneers, whose surface are free from defects are categorized as face veneer. Veneers with little defects were categorized as back veneer, and veneers which had many defects on their surface were categorized into core veneer on the basis of standard of JAS SE-11 2003 and SNI 01-6240-2000.

Drying of Veneer

Veneers which have been cut and sorted, were dried until reaching moisture content of 8 % using hot press dryer with temperature of 1000C for 30 minutes and were pressed until the limit of veneer thickness.

Gluing

Veneers which had reached moisture content of 8% were afterwards arranged into 12 layers with fiber direction parallel to each other (1 layer in the face part, 10 layers in the core part, and 1 layer in the back part) and were glued using adhesive phenol formaldehyde with spreading weight of 182,5 g/m^2 with double spread method and assembly time of 10 minutes.

Pressing

Veneers which have been arranged and spread with adhesives were put inside cold pressure with pressure of 10 kg/cm^2 for 20 minutes. After being cold pressured, LVL were put inside hot pressure with pressure of 7,65 kg/cm^2 at temperature of 140^{0}C for 26 minutes.

Trimming

LVL which had been trimmed were then had their edge been straightened by using circular saw.

Sanding

Surface of face veneer and back veneer of the LVL were smoothened by using sander.

Conditioning

LVL which have been hot pressed were afterwards conditioned with the surrounding environment for 14 days.

C. Testing of physical and mechanical properties of LVL

Physical and mechanical properties of LVL were tested on the basis of standard of JAS SE-11 2003 and SNI 01-6240-2000 for structural LVL 2003, comprising variables of moisture content, delamination, vertical and horizontal shear strength, Modulus of Rupture (MOR), and Modulus of Elasticity (MOE).

D. Analysis

Data from observation results were then analyzed and compared with standard of JAS SE-11 2003 and SNI 01-6240-2000.

III. RESULTS AND DISCUSSION

A. Performance of small diameter wood materials for production of LVL

a. Physical condition

According to measurement results, average diameter of each wood species being used in the production of LVL, ranged between 20,78 cm – 30,33 cm. Complete data of wood diameter data resulting from measurements are presented in Table 1.

Table 1. Length, diameter and specific gravity of five species of small diameter wood.

Wood species	Log length	Diameter	Specific gravity
	(cm)	(cm)	
Pulai	104	20,78	0,38
Sengon	124	26,27	0,33
Jabon	127	24,00	0,42
Manii	125	30,33	0,48
Sungkai	125	25,10	0,63

According to measurement results, pulai wood possessed many loose knots with diameter of ± 0,5 cm. In sungkai wood, there were stem surfaces which were rather rough and rather hard so that there was a need for preliminary softening in the form of boiling or soaking in water before the peeling process. Besides that, sungkai wood which were obtained from people's forest contained many nails and wires in their stem, so that there was a need for preliminary removal of wire and nail from inside the stem before the peeling process. There was also 1 sungkai wood which became split during the peeling process because of existence of crack defects in butt part. The incident of sungkai wood which became split during peeling was due to occurrence of crack or broken defect in the butt part. For manii species, there was 1 wood which had hollow defect with diameter of 10 cm in the central part of the wood, and therefore, there was only small portion of the wood which could be peeled into veneer. Sengon and jabon wood had stem surfaces which were free from defects, so that this made the process of veneer peeling easier. Manii wood had rough texture in the stem surface.

Figure 2. Physical condition of small diameter wood stems which were used as raw materials of LVL

b. Characteristics of veneer production processing for production of LVL

- Characteristics of veneer being produced

  In general, veneers which were produced from the five species of small diameter wood, were easily torn, so that they need to be joined by using adhesive tape in the parts which were easily torn. Average moisture content of veneers after being peeled was still relatively high, namely around 15% – 38%. Therefore, veneers which had been peeled should be dried promptly to prevent fungal attack.

  Loose knots in pulai wood stem caused the produced veneer to have many wood knot holes. Therefore, there was a need for puttying on those parts of loose knots. Veneer which have many loose knots were used for core layers in the production of LVL.

Figure 3. Knot defects in veneer of pulai wood.

- Output-input ratio (yield)

Measurement results showed that output-input ratio (yield) of small diameter wood ranged between 27 – 59 %. Pulai wood exhibited greater yield as compared to other species of wood, because the defects in pulai wood were only in the form of loose knots which could still be repaired by patching, so that not many of the produced veneer be discarded and hence, many were still be able to be used for LVL raw materials. On the other hand, for sungkai wood, the yield was smaller as compared to other wood species, and this was caused by the presence of many nails and wires which were embedded in the stem so that many of the produced veneer were discarded. Data on the yield (ouput-input ratio) of the produced veneer are presented completely in Table 2.

Table 2. Output – input ratio (yield) of five species of small diameter wood

Wood species	Volume of log	Volume of produced veneer	Output –input ratio (yield)
	(m3)	(m3)	(%)
Sengon	0,20	0,076	37,40
Manii	0,27	0,076	27,70
Jabon	0,17	0,071	41,15
Pulai	0,07	0,042	59,35
Sungkai	0,25	0,084	33,68

c. Drying

Veneers of small diameter wood which were dried by using oven dryer became wavy. Therefore, those veneers were then dried by using press dryer at temperature of 100^0C for 30 minutes until reaching moisture content of 8%.

d. Assembly of veneer

During assembly of veneers which have knot holes and torn parts, there were activities of patching by using putty, and joining by using adhesive tapes.

e. Glue spreading

Weight of adhesives being spread was 182,5 g/m^2, with double spread method. Spreading of adhesives in several veneers from species of manii and sungkai wood experienced a little bit difficulties because the veneer surface contained fine hairs, so that there was a need for more energy during the spreading of adhesives.

B. **Physical and mechanical properties of LVL made from SDL**

a. Physical properties

i. Moisture content

LVL which were made from SDL possessed moisture contents which fulfilled the standard of JAS SE-11 2003 and SNI 01-6240-2000, namely under 14%, except the LVL from sungkai wood (14,76%). The values of moisture content of LVL in this research are presented completely in Figure 4.

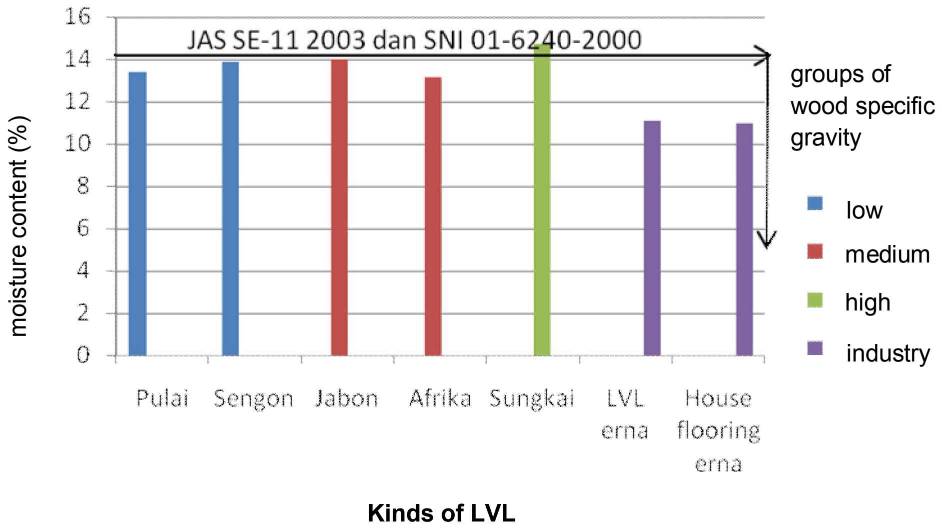


Figure 4. Histogram of moisture contents of LVL.

The high values of LVL moisture content from sungkai wood was due to values of air dry moisture content of veneer materials of sungkai wood which were greater than veneer of other wood species, so that during conditioning with the surrounding environment, the amount of water contained in the LVL from sungkai wood was greater than LVL from other species.

ii. Delamination.

From the graph of delamination percentage, it could be seen that all kinds of LVL being produced fulfilled the standard of JAS SE-11 2003 and SNI 01-6240-2000, namely below 5 %. The highest percentage of delamination occurred in LVL from sungkai wood, namely as large as 3,30%, whereas the corresponding figures for LVL of other wood species were 0%. The high scores of delamination in LVL from sungkai wood were due to the large number of joints in core veneer of LVL so that the process of adhesion occurred in less than optimum manner. This could be seen from the damage of glue line in the core layer of LVL.

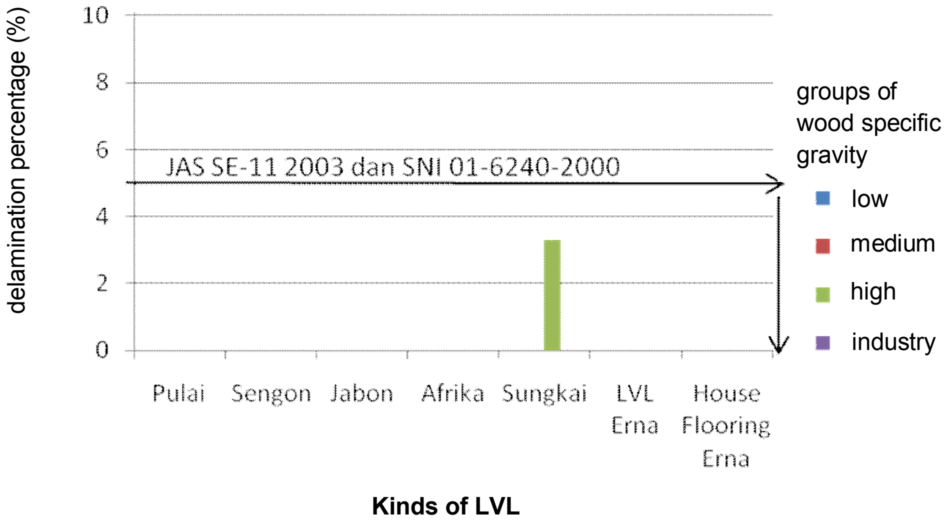
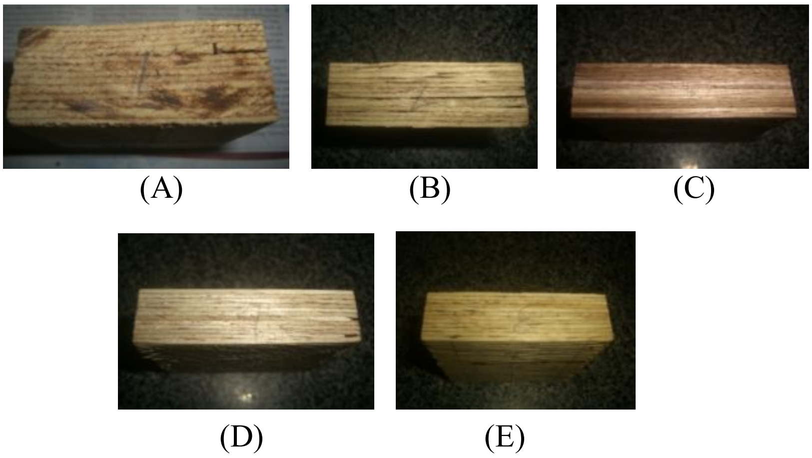


Figure 5. Histogram of delamination percentage of LVL



Note: (A) test specimen of sungkai LVL (delamination occurred in glue line), (B) test specimen of pulai LVL, (C) test specimen of kayu afrika LVL, (D) test specimen of sengon LVL, (E) test specimen of jabon LVL

Figure 6. Condition of delamination testing of LVL

b. Mechanical properties.

i. Block Shear Strength

The research results showed that LVL from SDL of pulai wood species possessed shear strength values which were greater (6,91 Mpa) as compared to LVL from other species and also were greater as compared to LVL from industry (4,2 Mpa), whereas LVL from sungkai wood possessed shear strength value which was smallest (0,67 Mpa) as compared to LVL from other species. The relatively large value of shear strength in LVL from pulai wood showed the high quality of adhesion in the LVL. This was due to wettability of pulai wood by PF adhesive, which was greater than those of other wood species. Besides that, veneer of pulai wood had more smooth surface as compared to veneer of other species, so that the distribution of adhesives to all parts of the veneer was more uniform than distribution of adhesive in veneer of other wood species, so that the bonding between adhesive and wood in LVL of pulai wood was better as compared to other LVL.

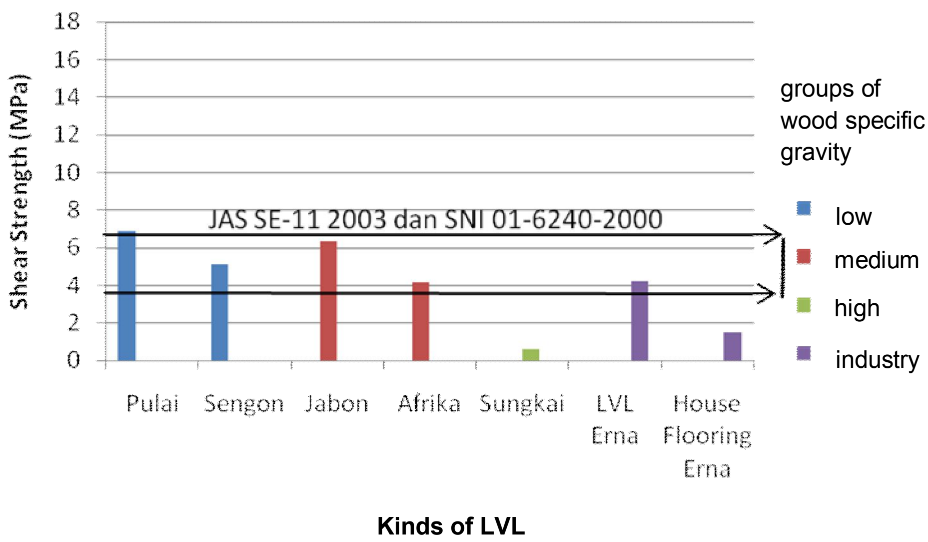


Figure 7. Histogram of Shear Strength of LVL

Figure 8. Condition of sample damage in the test of LVL shear strength.

ii. Modulus of Rupture (MOR)

Values of flatwise Modulus of Rupture of LVL from jabon woood (57 Mpa) and kayu afrika wood (53 Mpa) were greater as compared to those of LVL of other wood species. All LVL possessed values of MOR (flatwise and edgewise) which fulfilled the standard of JAS SE-11 2003 and SNI 01-6240-2000, but were smaller as compared to LVL from industry, such as those presented in Figure *9* and *10*.

The high values of MOR of LVL from jabon and kayu afrika wood were due to the fact that the two wood species belonged to group of moderate specific gravity wood, whereas those of pulai and sengon wood belonged to group of low specific gravity. Although jabon and kayu afrika wood possessed lower specific gravity as compared to those of sungkai wood, the values of MOR of LVL of the two wood species were higher as compared to LVL of sungkai wood. This was due to the fact that LVL of sungkai wood were arranged from veneers which had many torn parts, so that there were many patches in the constituent veneers. That phenomenon caused weakening in the LVL from sungkai wood.

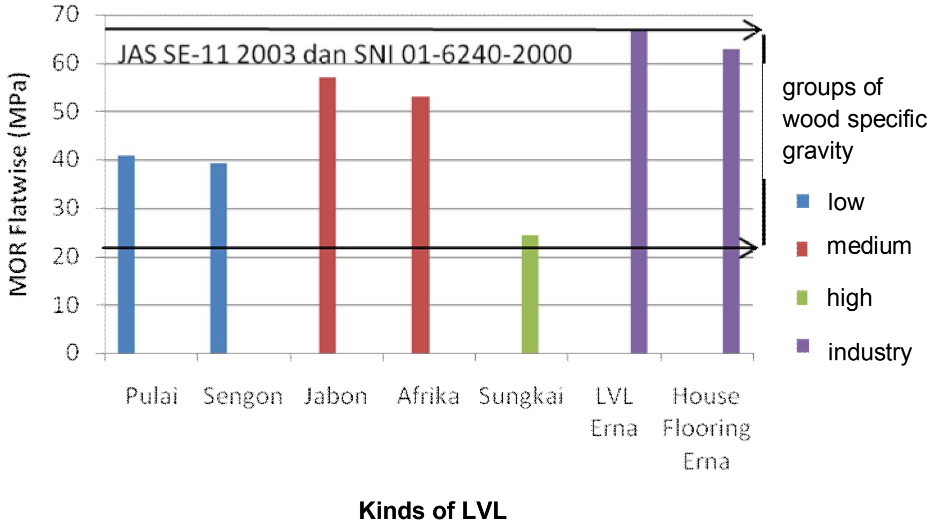


Figure 9. Histogram of Flatwise Modulus of Rupture (MOR) of LVL

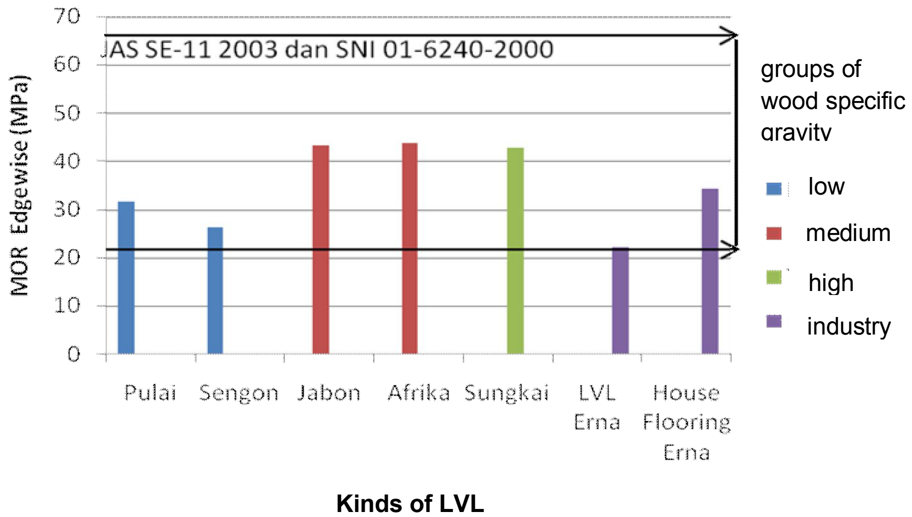


Figure 10. Histogram of edgewise Modulus of Rupture of LVL

(Flatwise Bending Test) (Edgewise Bending Test)

Figure 11. Condition of sample damage in bending test of LVL

iii. Modulus of Elasticity (MOE)

LVL from kayu afrika and jabon wood possessed MOE (flatwise and edgewise) values which were higher than those of LVL of other wood species, and fulfilled the standard of JAS SE-11 2003 and SNI 01-6240-2000, and were higher as compared to those of LVL from industry, as presented in Figure 12 and 13.

Specific gravity of jabon and kayu afrika wood which were higher (group of moderate specific gravity) than those of pulai and sengon (group of low specific gravity) caused the high values of MOE of LVL from jabon and kayu afrika wood. In relation with characteristics of raw materials composing the LVL, condition of veneers of LVL from jabon and kayu afrika wood were better as compared to veneers composing LVL which came from sungkai wood which possessed more torn defects. This phenomenon caused weakening in the LVL of sungkai wood, so that although the specific gravity of jabon and kayu afrika wood were smaller as compared to that of sungkai wood, the MOE values of LVL of jabon and afrika wood were higher as compared to LVL from sungkai wood.

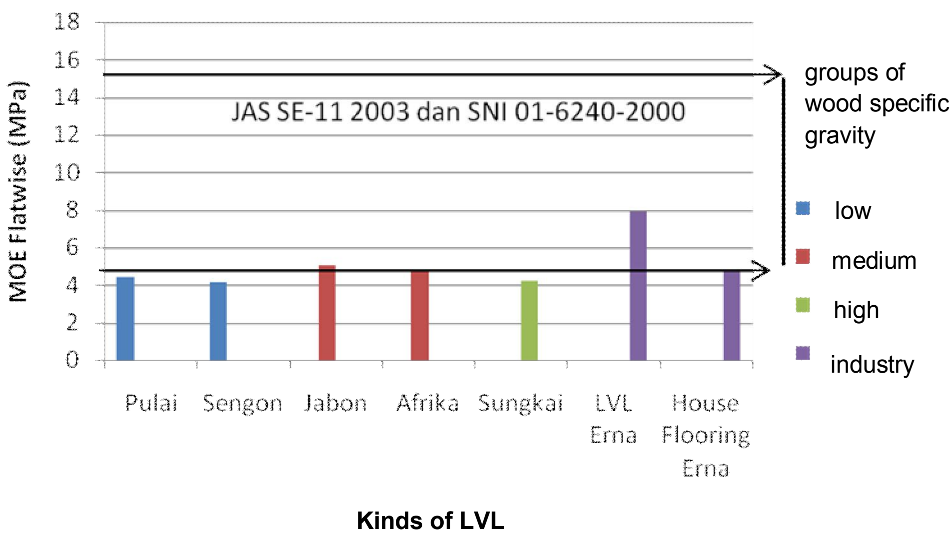


Figure 12. Histogram of flatwise Modulus of Elasiticity (MOE) of LVL

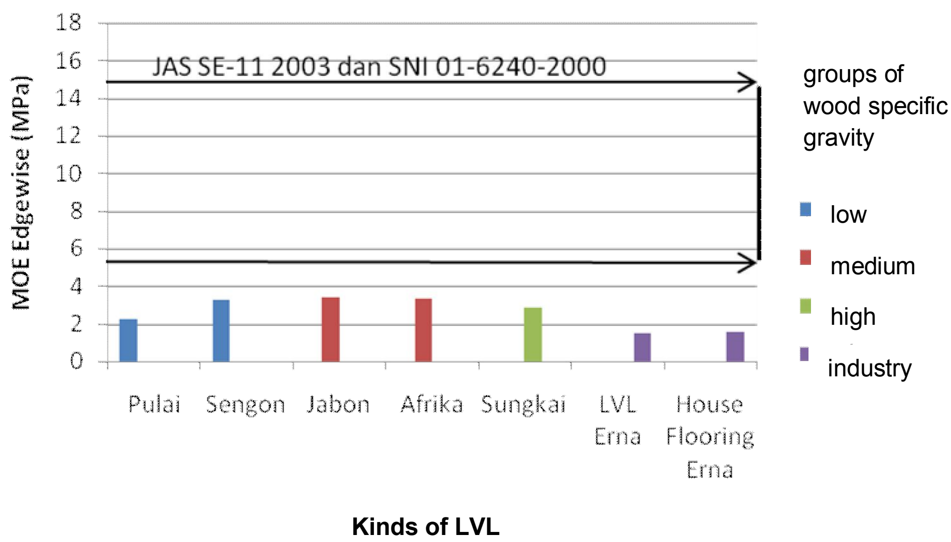


Figure 13. Histogram of edgewise Modulus of Elasticity (MOE) of LVL

IV. CONCLUSION

Small diameter wood being used in this research possessed length ranging between 104 – 125 cm, and diameter between 20,78 cm – 30,33 cm. Wood species which possessed many defects and small yield of veneer, was sungkai. LVL from small diameter wood and moderate specific gravity wood possessed better characteristics as compared to those of LVL from other specific gravity group, and fulfilled the standard of JAS SE-11 2003 and SNI 01-6240-2000 of LVL for structural uses. On the basis of these phenomena, it could be suggested that LVL from small diameter wood, from moderate specific gravity wood (kayu afrika and jabon) were suitable to be used for structural uses such as for supporting poles, frame in house roof timbering, floor joint, and other structural uses.

AKNOWLEDGEMENT

We thank Sukma Surya Kusumah, Baso Arsadi, for helping us conducting the research. Additionally we gratefully aknowledge the time participants dedicated to this study.

REFERENCES

[1]Massijaya. M.Y., N. Hadjib, dan Y.S. Hadi. 2009. Address Technical Gaps In Producing Bio-Composite Products Identify Suitable Wood Species And Evaluate Mechanical Properties. Technical Reports Prepared for CFC/ITTO-USDL. Utilization of Small Diameter Logs from Sustainable Sources for Bio-composite Products. Project Code : CFC/ITTO 62 – PD 40/00 Rev 4 (I).

[2]Walker. J. C.F. 2006. Primary Wood Processing: Principles and Practice (2nd Edition). Springer. Dordrecht The Netherland.

[3]Hng,P.S., M.Y. Paridah dan K.L. Chin. 2010. Bending Properties of Laminated Veneer Lumber Produced from Keruing (Dipterocarpus sp.) Reinforced with Low Density Wood Species. Asian J.Sci. Res., 3(2):118-125.

[4]Colak S., I Aydin, C. Demirkir, G. Colakoglu. 2004. Some Technological Properties of Laminated Veneer Lumber Manufactured from Pine (Pinus sylvestris L.) Veneers with Melamine Added – UF Resin. Turk. J. Agriculture., 28: 109-113.

[5][Anonim]. 2007. Laminated Veneer Lumber – from Forest and Wood Product Research and Development Corporation. (http://www.azobuild.com/details.asp?ArticleID=8020). [24 Mei 2007].

[6][Anonim]. 2010. Veneer Peeling Lathe (Rotary Lathe) – Spindless Veneer Peeling Lathe. (http://www.alibaba.com/showroom/veneer.html). [19 Juli 2010].

PART C.

PERFORMANCE OF GLULAM MADE OF SMALL DIAMETER LOGS

PERFORMANCE OF GLULAM MADE OF SMALL DIAMETER LOGS

By :

Nurwati Hadjib, Muh. Yusram Massijaya, Yusuf Sudo Hadi

I. INTRODUCTION

Until now the needs of wood still can be filled from natural forests. However, because of the velocity of harvesting is not balance enough with velocity of planting, then the pressure on natural forests will be increased and the availability of woods from natural forests will be decreased, both in terms of its quality and its volume. The needs of wood in Indonesia, both for residential or other use continue to increase along with the population. Nowadays, the lack of various types of wood as raw materials for various wood industries, such as industry of building materials, handicrafts, and wood processing industries both in small scale or large scale industries has been increasingly felt. Meanwhile, the amount of available wood progressively decreasing in quantity and quality. Therefore, the wood from plantation forests and public forests are expected to fulfill the needs of wood for various purposes. Since Pelita IV, Department of Forestry built Industrial Plant Forests (HTI), which in 2015 is expected will reach 6.2 million hectares and will produce logs up to 90 million cubic meters every year. In addition, some woods are expected can be obtained from the public forests. Wood which is produced from forests plantation is generally a fast-growing wood species, such as mangium wood (*Acacia mangium* Willd.), sengon (*Paraserianthes falcataria*), manii (*Maesopsis eminii*), pine (*Pinus*) and jabon (*Anthocephallus sp*) and etc.

Woods of fast-growing wood species are generally has small diameter, so for the needs of large-sized wood, it needs new technology in the manufacturing process. The new technology, among others, the application of various manufacturing patterns and composition of extension board and lamina beams for various components of building materials and furniture. Besides of the small diameter, woods from plantation forests contain many teenagers wood (juvenile wood). Juvenile wood weaknesses are: cell density is low, texture is coarser, more direction of spiral fiber, and contains many large eye of wood. (Senft et al., 1986) contains lignin with higher levels (Wahyudi, 2000), and its large micro fibril angle (Basri et al., 2001). These factors are generally making the woods of fast-growing wood complicated.

This research aims to make the lamina beams (Glulam) with a large expanse from wood's type of plantation forests and public forests which qualified as a building material that in the future days will be developed according to the intended use.

II. LITERATURE REVIEW

A. Glulam

Laminated timber (Glulam = Glue laminated timber) or commonly called as lamina wood is beam which obtained from the wood adhesion, in the straight form, curved, or even combination of both, with fiber direction parallel to each other (Wirjomartono, 1958).

According to Karnasdirja (1989) in terms of efficiency, laminated wood is better because its wood can be made from small in size, low quality, and the combination of low quality and high quality. Form of laminated wood has variation in its type, number of layers, size, shape, and thickness (Bharata, 1982).

Bodig and Jayne (1982) explained the existence of some examples of laminated beam that seen from the way of its placement on the loads which are vertically and horizontally laminated beam. Based on its type of cross-section, laminated beams can be distinguished into: Blocks I, Blocks T, Pipe beams, and Rectangular beams.

Glulam has more advantages compared with intact wood (solid). However, Glulam also has several weaknesses, so that in the application it needs consideration and special handling. According to Yap (1984), the application of Glulam construction has more advantages such as; it can be made to be a cross-section and greater length than a regular single beam, wood which is not included to construction wood can be used to form a cross-section that is as strong or even stronger than a single beam. Coating can be arranged so that the parts which get the biggest voltage contain a higher quality; a drag of layered complex construction wood is more resistant in the fire of a wood truss construction. Added by Wirjomartono, (1958) that the Glulam can give an impression of beautiful and decorative in the architecture of the building because the construction can be made freely. It also can make the big parts of the building (structural elements) from thin woods. The effect of wood's defect can be eliminated and minimized by selecting the layer that will be used and the strength that produced is same. It can use low quality wood with no need to reduce the strength of construction by placing the wood in the part of the construction, where the tension (stress) is not high. High-quality timber is placed in secure part of high voltage arises thus the building becomes more effective.

Besides its advantages, Yap also explained that its weaknesses, such as the preparations for making Glulam generally require greater cost than regular wood construction, because the goodness or badness of the construction depends on the strength of joints (adhesive), then the manufacture requires special equipments for these needs and extra observation by expert people.

Laminated beams are used to make frame houses, towers, bridges, framework of boats, aircraft hangar frame and so forth. In America, Glulam is used for construction of buildings and even used to make frame of car, water ski equipments, tennis racket, and anima clipper (Siddiq, 1989). While the development of Glulam application in Indonesia is still limited, which used only for tennis racket, embroidery frames and floor (Kusnandar, 1980).

B. Lamina Connections

According to Siddiq (1989) there are three types of lamina's end connection which is often used to connect the lamina to reach an appropriate length with the planned length of lamina beams, namely:

1. End of the Pivot Connection (Butt Joint)

   This connection is the weakest connection, particularly against an attractive force (axial/flexural), because the strength is ignored in the calculation of stress, which means this is not economical. This connection still can be used to lamina that receives the thrust (axial/bleeding) but not recommended for the layer of outer fiber.

2. End of the Oblique Tongue Connection

   Type of this connection is may be and often used for pull or press connections. The power of this connection is influenced by the ratio of the connection's slope with a thickness of lamina (ls/t) as shown below:

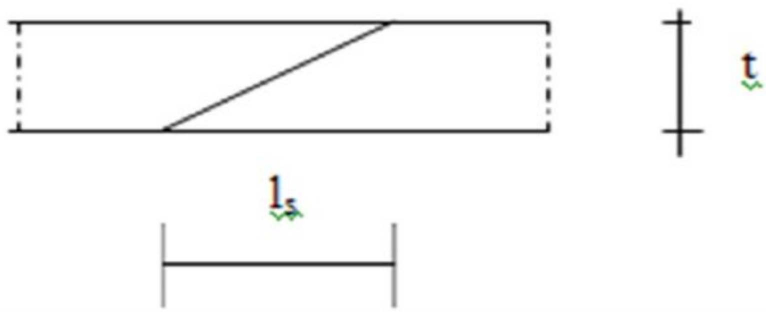


Figure 1. End of the oblique tongue connection

3. Toothed/Fingered Edge Connection (Finger Joint)

   This type of connection is more efficient in the application wood if it compared with the end of oblique tongue connection, but the manufacturing requires special equipments (currently still rarely used in Indonesia). High quality wood is not allowed to use this connection.

C. Physical Properties and Mechanical Lamina Beams

1. Physical Properties

   The physical properties of wood are closely related to the shape or appearance of a wood, content of moisture and how the influence of weather on the wood. The physical properties of wood are determined by internal factors to the wood is composed of three factors, namely:

a. The thickness of the cell wall. This determines the specific gravity (BJ) and wood density is an important clue about the physical properties of wood.

b. The composition of the micro fibril's direction in cells and tissues, which causes the anisotropic wood.

c. Chemical composition of cell wall substances that causes quantitative differences in wood properties due to differences in chemical composition to changes the specific gravity and the composition of micro fibril's direction.

d. Water content, in this case is wood water content, is defined as the amount of water contained inside the wood, which the amount is expressed in percent of dry weight of the wood furnace (Haygreen and Bowyer, 1982). Number of water content in the fresh wood is various between 40-200% or more. Variations of this water content are not found only in a kind of tree, but also in various positions within the same stem (Anonymous, 2010). Noted also that in Glulam, wood moisture content not only affects the strength of wood but also affect the results of wood adhesion. Thus, Glulam water content that required is 15% and water content differences between the boards are not more than 3% when the board glued to each other. To obtain a good adhesion result, then the water content of the Glulam former boards should be between 12-15%.

e. Specific Gravity

Wood's specific gravity is the most important physical properties of wood. According to USDA (1974) wood's specific gravity is a value comparison between wood density with the density of water at certain temperatures and pressures. While the wood density is the ratio between the mass of wood with wood's volume without free water inside the wood. While the volume of wood is the volume when the wood has certain content of moisture. In general, the mechanical properties of wood are closely connected with specific gravity and density. In addition, wood's specific gravity is the most important indicator in the use and processing of wood (Haygreen and Bowyer, 1982).In general, wood with high specific gravity has a high persistence, as well as wood that have a low specific gravity will have a low persistence. Glulam's specific gravity will have increased 16% from the lowest constituent wood's specific gravity and has decreased 12% from the highest constituent wood's specific gravity.

2. Mechanical properties

Utomo (1986) stated that the mechanical properties of Glulam have a close relationship with its physical properties and bonding process that has been done. Mechanical properties of Glulam are influenced by the laminator's material used. Mardikanto (1986) stated that the mechanical properties of wood as a measure of the ability of wood to hold the load or force from outside is likely change the size and shape of timber. In the laminated wood with a layer of adhesive that worked well sometimes increase the strength of its constituent wood.

Mechanical properties are often used to measure the strength of structural timber such as static flexural strength including stress on the limit of proportion (MPL), modulus elasticity (MOE), and stress fractures (MOR), strength of parallel press to fiber and shear strength.

3. Adhesive and Adhesion

Siddiq (1989) stated that in the complex plywood construction, adhesive quality plays an important role. Condition of laminated wood connections depends on the place of connection and the adhesive strength in carrying out its functions. Sutigno (1986) defined adhesive as a material that has ability to combine the material through the contact surface (surface attachment). The attachment of two objects that is glued, in this case wood, due to the attractive force between adhesive molecules and between adhesive molecules and wood. Stated as well before the occurrence of strong bonding process, adhesive undergoes several phases, namely:

i. Adhesive flows evenly in the bonded area.
ii. The existence of transfer adhesive from one surface to another surface.
iii. The existence of adhesive penetration through the surface.
iv. The existence of wetting adhesive on the surface to be bonded.

v. The occurrence of the hardening process.

While the adhesion processes itself there are two kinds, namely:

a. Specific adhesion is the adhesion that occurs because of the attractive forces of molecules or atoms between the adhesive and wood.

b. Mechanical adhesion, the adhesion that occurs when liquid of adhesive enters the wood pores, and then hardened so it bonds both wood that are glued.

It also said that a softer wood and much pores is more easily bonded than the hardwood. This is due to the relative mechanical adhesion process is sufficient to produce a good bond and otherwise probably would not cause the formation of a thin layer on an adhesive surface.

Selection of adhesive must consider several factors such as type and the characteristics of adhesive, type of glued wood, conditions where the products are used, processes and tools used and the cost of adhesion (Bharata, 1982). The ideal adhesive for a wood is adhesive that has specific requirements, namely: low cost, has a long expiration time, hardens quickly and mature rapidly with a low temperature, has high resistance to moisture, solvents, heat and destructive microorganisms and adhesive can be used for various purposes. Based on the way it is hardened, adhesives can be classified into:

a. Thermoplastic adhesive. This adhesive is fairly dry and become soft if it exposed to heat or high temperatures, thus binding power will be decreased or even disappear. Otherwise, if the temperature drops will harden and the binding power will increase. Example of this type of adhesive is polyvinyl acetate.

b. Thermosetting adhesive. This adhesive will harden if it exposed to heat or chemical reaction with a catalyst which is called as hardener. Example of this adhesive is urea formaldehyde adhesive.

4. A Brief Description

a. Wood Materials

1. Sengon

Sengon (Paraserianthes falcataria (L.) Nielsen Mimosaceae family. With local name jeunjing, sea sengon (Jw); tedehu Pute (Slws); rare, selawoku, selawaku merah, wipe, physics, physics bots, cycads, tawa sela (MLK); bae, bai, whogon, wai, wikkie (Papua). This species has been spread throughout Java (plants), Moluccas, South Sulawesi and Papua. Habitus tree up to 40 m high with a long branch-free stems 10-30 m, diameter up to 80 cm, white or gray outer skin, not grooved, no peeling and no buttress.

Color of terrace wood and pig has no difference; almost white or colored light brown, fairly coarse and uneven texture, straight fiber direction, wavy or combined width. Wood surface rather smooth, shiny and smelling fresh petai in wood which disappear after the wood dried. Wood density ranged from 0:24 to 0:49 rather stable and included to strong class IV-V. Durable Class III-V, rather easily preserved and easily dried. Wood sengon widely used by people of West Java for housing materials, but it is also used to manufacture crates, veneer, fiberboard, mineral board, particle board, lighters, crafts and firewood (Maratawijaya et al., 2005).

2. Pine

Pine (Pinus Jungh et de Vriese), including the Pinaceae family with the local name resin stone, amber flower, huyam, wood sala, wooden toothpick, tusam, uyam and pine (Jw). While in other countries known by the name Sral (Cam); thong mu (Vn); tingyu (BMA); tapulan, Mindoro pine (PI), Indo-China pine, Sumatran pine, Mindoro pine, Merkus pine (UK, USA); Merkustall (Sw); Sumatrakiefer, Merkusfohre (Gm).

Pine has been spread in Aceh, North Sumatra, West Sumatra, the Java (plants). 20-40 m tall trees with long branch-free stem 2-23 m, diameter up to 100 cm, and no buttress. Rough outer skin is brown-gray to dark brown, doesn't peel, wide and deep grooved. General characteristics of pine wood are its terrace is brownish-pale yellowish with darker colored ribbons and pictures wood-containing resin brown or dark brown. White or yellow-colored cambium wood with 6-8 cm thick. Texture of wood is soft, fiber direction is straight, wood surface is smooth, wood-containing resin feels like a fatty. Wood surface is shiny with the stench of turpentine.Pine wood is not porous, it tend easily dried, though its east to be concaved, cracked, broken tip, cracked surface and it is very susceptible to be attacked by blue fungi. Pine wood is included to strong class III and class V durable (Oey, 1991).

3. Jabon

   Jabon (Anthocephalus cadamba) is one type of tree from Rubiaceae family, with the local name jabon, jabun, hanja, kelampeyan, kelampaian (Jw), galipai, galupai Bengkal, harapean, johan, kelampai, kelempi, kiuna, lampaian, pelapaian, selapaian , serebunaik (Smt); ilan kelampaiyan, taloh, tawa telan, wine, tuneh, tuwak (Cathay Pacific); bance, Pute, loeraa, pontua, suge, Amai, sugi manai, pekaung, Toa (Slw); gumpayan, kelapan, mugawe , sencari (NTB); aparabire, masarambi (Papua). This species has a relatively fast growth, easy to adapt in the conditions of land with low fertility, acid soil, and rocky soil, resistible with drought and liked the open space pioneer of the open forest. Jabon tree has a natural distribution throughout Sumatra, West Java, East Java, East Kalimantan, Sulawesi, West Nusa Tenggara and Papua. Tree height can reach 45 m with branch-free stem which height up to 30 m, diameter up to 160 cm. Have straight trunk and cylindrical, crowned high with horizontal branches, buttress up to 150 cm high, outer skin of gray-brown to brown, and relatively shallow grooved.

   General characteristics of wood: the terrace wood is yellowish white, gradually became a little yellow ivory, pig wood cannot be distinguished from the terrace wood. The texture is smooth quite coarse, straight fibrous and sometimes cohesive; the wood surface is smooth or a bit slippery, shiny or slightly glossy. Jabon wood density ranged from 0:29 to 12:56 and categorized as strong wood class III-IV, the dimension is less stable, classified wood durability class IV-V rather easily preserved, easily dried. Easily sawn and done, easy to manufacture veneer 1.5 mm thick without pretreatment with peel angle 92 °, and gluing veneer with formaldehyde urea and fulfill the ISO standards, Japan and Germany (Martawijaya et al., 2005).

4. Mangium

   Mangium (Acacia mangium Willd.) is a type of the Fabaceae or Leguminosae tribe which has a relatively fast growth, easy to adapt in the conditions of land with low fertility, acid soil, rocky soil, and resistible with drought and likes the outdoors. On fertile soils, 9 years old mangium plants can reach a diameter up to 23 cm and height up to 23 m, the annual average increment (MAI) in the amount of 40 m^3/ha every year with proper maintenance can be obtained wood volume's thickness up to 415 m3/hectares. Observed from its characteristics of growth or its economic value, this type is promising for the development as industrial timber estates (HTI) and in the public lands so it can increase the income and welfare of the community. Mangium trees have a natural distribution in the Moluccas (Sula, Ceram, Aru), Papua (Fakfak, Manokwari, Merauke), Papua New Guinea to Australia. Growing up in the area of moist tropical lowland and coastal forests, so it is irresistible in winter and shade, but it can adapt to acidic soil (pH 4.5 to 6.5), grows well in fertile soil of good drainage. Habitus mangium is a form of large evergreen trees with high or even more than a half of the tree height. The trunk is cylindrical, straight, not buttressed; bark thin, grooved and rough, the color of light brown to dark brown. Mangium wood has common characteristics: the color of terrace wood is yellowish brown to dark brown, plain and brindle, dark and light alternate in the field of radial, the texture is quite coarse, straight fiber direction and there are some that are integrated, quite glossy, the impression of touch is quite slippery, and odorless. Based on the value of density, MOR and the pressure of the parallel fibers, it pertained mangium wood is included to strong class III-II. Nature mangium lumber in general gives very good results. Yield of mangium sawn timber easily dried without significant disability. Based on the strength of adhesive, then the plywood produced fulfills the standards of Indonesia (SNI), Japan (JAS) and German (DIN). Mangium wood particle board fulfills Indonesian National Standard for quality particle board I. Compared with other common types of wood pulp, such as commercial Eucalyptus, mangium requires fewer chemicals and the results of more pulp to produce pulp with the same number of Kappa. The intensity of soil termites (Macrotermes) on mangium wood 55% (great) and classified as grade IV resistance. While resistance to wood borers in the sea (Pholadidae) were classified (grade III resistance). Utility of mangium wood besides for woodworking, especially furniture, pulp, plywood and particle board, its bark can be used for the manufacture of tannin adhesives. Its branches and waste of wood processing can be used for making charcoal. Mangium trees can be used as a shade on the roadside or in parks.

5. Manii

   Manii (Maesopsis eminiii ENGL), is included into Rhamnaceae family. Height of this tree can reach 50 m and diameter at 90 cm. This species comes from West Africa, can live well at a height of 200 - 1200 m above sea level. In Indonesia, this wood can be found in many regions of West Java and East Java; they are planted in plantations as a crop protector (Anonymous, 1977). Kryn (1954) in Purwadi (1985) mentioned that the wood is slight and soft but strong enough, and it is generally stronger than the wood with comparable density. African Wood has a specific gravity of 0.45, durability class IV and class III strong. It can be used for slight construction under the roof (Anonymous, 1977).According to Andriyanto (1984), this wood has good machining properties (reaping, turning lathe, drilling and sanding).

b. Specifications adhesive used

Parameter	Unit	Specification	Result
pH (meter/25°C)		10.0 – 13.0	11.30
Viscosity (25°C)	Poise	0.5 – 1.0	0.80
Gelation time (135°C)	Minute	-	-
Water solubility (25°C)	Time	-	-
Resin content (135°C)	%	36.0 – 40.0	38.0
Free Formaldehyde	%	-	-
Specific gravity (25°C)/4°C)	-	1.150 – 1.180	1.164

Source: PT Pamolite Adhesive industry, Probolinggo

Glue spread on the wood:

- Wood moisture content: 12%
- Weight of glue spread: 40-50 gram/ft2
- Felt Pressure (cold): 8-14 kg/cm2 within 1-5 hours

III. MATERIALS AND METHODS

A. Materials and Equipment

Materials used in this study were mangium wood, manii, jabon, sengon and pine forest which harvested from Perum Perhutani and community forest. The adhesive used is Phenol Recorcinol Formaldehide (RPF) and an isocyanate adhesive for connection.

The tools used to manufacture lamina board is split saws, cutting saws, shaved machine. Dryer used to dries the plant board. Other tools are equipment for the application of adhesive (plastic container, mixer and glue spreader), felt cold, clamps, wood sorting machine (MPK), universal testing machine (UTM), oven, waterbath, scales, moisture-meters and calipers.

B. Methodology

B.1. Making Glulam

B.1.1. Making board and drying

Log of mangium wood, manii, jabon, sengon and pine were cut and sawed into sheets boards with each thick, width and length measuring 2.5 x 8.5 x 300 cm. The board are dried in the dryer with the refinery temperature and humidity are regulated. Drying is done to obtain wood moisture content ± 12%. Drying is also intended to flatten the water content in the wood.

B.1.2. Making lamina

Board that has been shaved into the lamina dry measuring 2 x 8 x 300 cm. Lamina are made, and amounts to five kinds of wood mentioned above are:

1. Mangium in amount of 96 sheets
2. Sengon in amount of 112 sheets
3. Manii in amount of 112 sheets
4. Pine in amount of 96 sheets
5. Jabon in amount of 96 sheets

Each lamina measured length, width and thickness to calculate the density of each of these lamina. The size of the final laminate made is 2 x 8 x 300 cm. For boards whose length is less than 300 cm, grafting finger (finger joint) spaced at least 100 cm FJ is made.

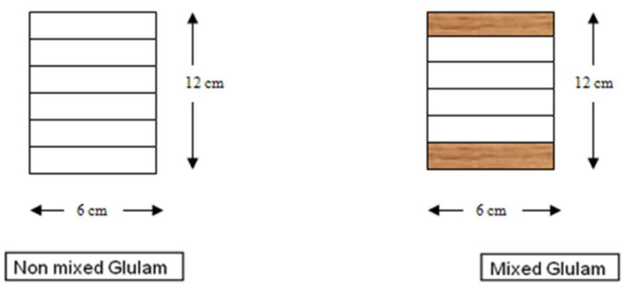


Figure 2. The composition of laminated glulam

B.1.3. Sorting lamina with wood sorting machine (MPK) Panther

Lamina sorted by using the Panther machine (board sorter). MOE calculation of each board using the formula:

$$\mathbf{MOE} = \frac{PL^3}{4\ \Delta Y\ b\ h^3}\, x\ \mathbf{FC}$$

Where:

MOE : modulus of elasticity, kg/cm2

P : standard load, kg

L : distance buffering, cm

Δy : deflection that occurs due to load P

b : broad cross-section, cm

h : thickness of the cross-section, cm

FC : factor correction equipment

MOE values obtained and then divided into 3 groups with a specific range symbolized by the E1, E2 and E3, where E1> E2> E3.

B.1.4. preparation of lamina

Preparation of lamina based on MOE values that have been grouped. The principle of preparation is placing the lamina which has higher MOE value on the outside of laminate beams which will be created. Meanwhile, the lamina with lowest MOE value placed on the inside of the laminated beams. Glulam composition that will be created as in Figure 3

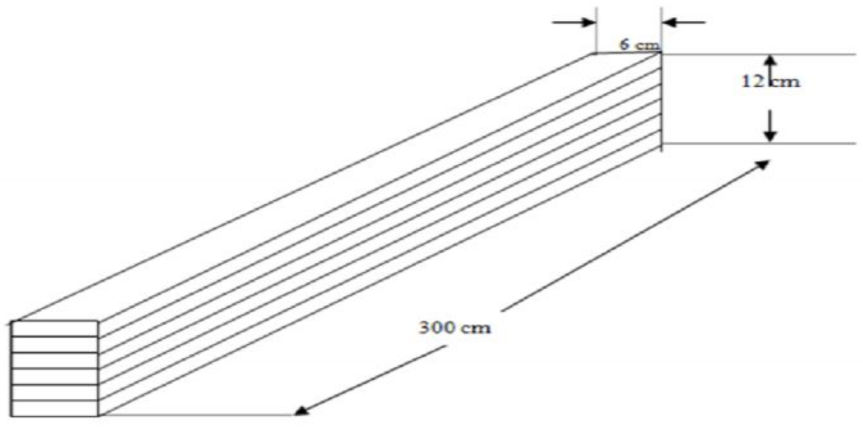


Figure 3. Glulam sample

B.1.5 Gluing

The adhesive which used is consist of two component, base resin and hardener with a ratio of 1 : 1, adhesive distribution on the surface of the lamina using a glue spreader, single glue line with a weight of 170 gram /m^2

B.1.6 Compression

Compression was done by cold compression with pressure 8 – 14 kg / cm^2 within 1 – 5 hours.

B.1.7 Conditioning

Laminated beams (glulam) were already compressed conditioned prior the testing. Conditioning was performed for 1 week in a room with temperature $(20 \pm 3)^o$ C and humidity (65 ± 5) %. This was done to further finalize adhesive.

B.1.8 Testing

a. Density

the density of laminated beams (glulam) was determined based on the weight and dimension of the beam. Density values calculated by the formula :

Density, gram / cm ^{3} = $\dfrac{B}{pxlxt}$

Which :

B : weight, grams

P : length, cm

l : width, cm

t : height, cm

b. Testing static flexural

Flexural strength testing of fracture

Static flexural testing based to the ISO 8375 FDIS use traditional brands Shimadzu UTM with 30 Ton capacity. Scheme of loading on the flexural static strength tests are presented as in figure 4

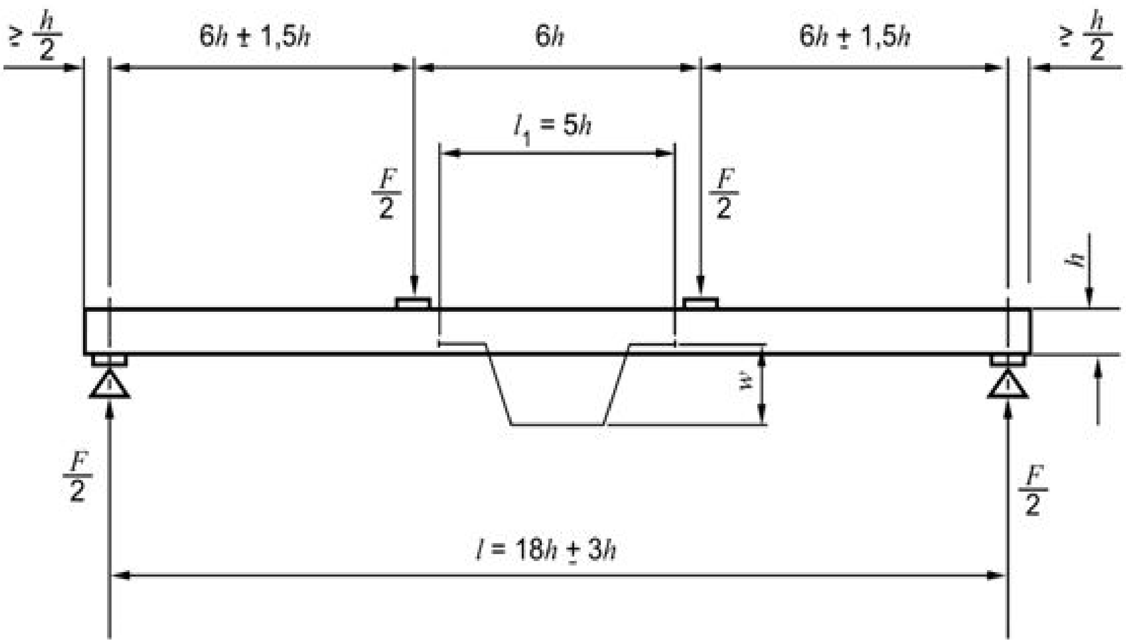


Figure 4. Scheme of loading on the static bending

Which :

l : buffering distance (span)

h : specimen height

F : load

Deformation measured on neutral axis as seen as the picture above.

Glulam MOE and MOR values are calculated based on formula :

$$E_{m,app} = \frac{l_1^3 (F_2 - F_1)}{48 I (w_2 - w_1)}$$

Which :

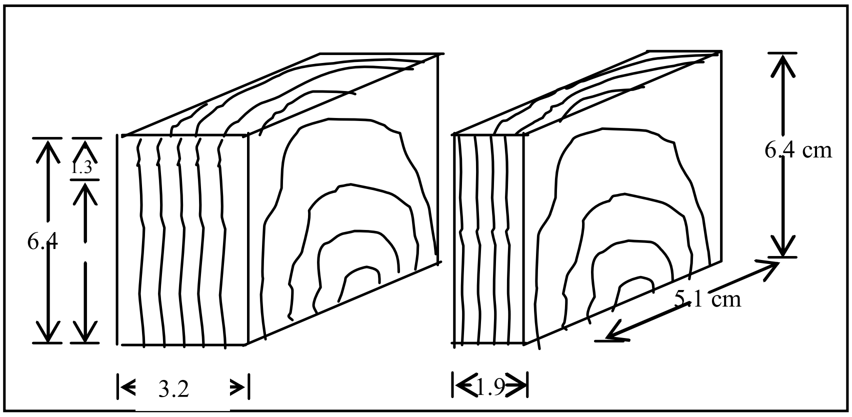
I : Moment of Inertia

F2 – F1 : Difference line portion of the excess burden of the load–deflection curve is linear, in newtons

W2–W1 : Difference of deformation due to the difference F2 – F1 in millimeters

c. Testing the shear strength adhesive blocks

the shape and the size of test sample which used in adhesive strength testing is shown below. Tests was made after the objects were condition for 1(one) week. The tests is performed to obtain the shear stress between the adhesive laminated board made under the provisions set forth in ASTM D 905 – 94 of the standard test method for strength properties of adhesive Bonds in shear by compression loading after the gluing process. Testing is done until there is damage (failure) of the objects. The damage mention in this test is due to release a connection adhesive force between the press and parallel fiber lamina, or there is damage to the wood fibers, the reading of the work load and deflection gradually happens automatically recorded and written on a computer which connected with the equipment test.



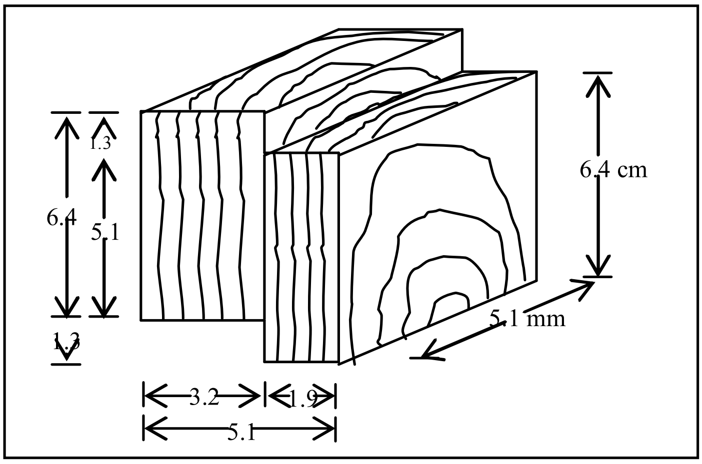


Figure 5. The shape and size of the object of wood sticking

The value of adhesive strength is based of the formula :

Strength of adhesion, kg / cm^2 = $\frac{P\ max}{A}$

Which :

P max : maximum load, kg

A : area of tacky, cm^2

IV. RESULT AND DISCUSSION

A. Recovery of board manufacturing

Small diameter sawmill recovery mountain into a board with thickness of 2.5 cm are presentable in table 1.

Table 1. Rendement sawmill

No.	Wood type	Average Diameter, cm	Recovery, %
1.	Pinus	22.7	51.3
2.	Mangium	21.5	53.57
3.	Sengon	22.8	52.50
4.	Manii	28.0	67.78
5.	Jabon	30.0	52.02

The average yield value of the wood ranged from 51.3 – 67.78 % was observed with an average of 55.4 %. This value is slightly lower than the yield of sawing result of Supriya and Rachman (1998) the amount of 56.39 %. Rendement board manufacturing glulam graft and the average ranged from 31 – 53 % with an average of 38 %. Variation of the yield value above caused mountain condition, cylinder, and wood defects.

B. Drying wood

Wood drying aim to obtain the desired moisture content and similar, the result of drying with using a solar furnace are presented in table 2. The using of diesel oil tailored to the needs. Especially at night. When the moisture content of wood has not reached 30 % the temperature was maintained so it not to exceed 50 %. The result of wood drying for each five types wood are shown in table 2. Drying rate for each type of wood was calculated on the same ratio of water content which is about 50 %. From the five types of the wood, wood drying quality of the manii is the worst. Stress of the manii timber which on the experiment was high which indicated by the broke of the end sample where quite severe. This is probably log, means higher portion of green wood (juvenile) finally result the growth of severe stress (Hilis, 1997).

Table 2. There are three types of wood drying, manii, jabon, and mangium with a combination of solar drying method and the heat from the furnace type II

No.	Type KA	Early average (%)	Long drying up KA 10% (days)	Rate of drying (%/day)	Quality
1.	Mangium	92	13	4,44	C-B
2.	Manii	86	4-5	13,53	C-D
3.	Jabon	78	7	8,00	B
4.	Sengon	69.27	6.5	8.89	C-D
5.	Pinus	85.9	8	6.67	B

Description : A. very good, B good, C medium, D Less well (Basri, 1990; 2010)

We can get the highest value rate of drying at Sengoon timber from the 5th kind of the wood. Sengoon timber has the lowest density compared to other types of wood, but it also affect by the rate of aging tree wood drying. The Sengoon timber which studied in the experiment was younger plants compared. Mangium wood drying quality, and sengoon manii considered moderate to poor this is because of the influence of the wood is still in a young age.

C. **Physical characteristic**

Water content and density of glulam which similar or mixture are presented in table 3. Glulam water content studied ranged from 9.13 – 14.87 % with an average of 10.83 %. Density range between 0255 – 0630 g /cm ^{3} with an average of 0.467. the highest content found at mangium and the lowest content of density found at Sengoon. This things has described by Bodig and Jayne (1982). Based on the value of its density, then the Glulam which has made its minor to moderate. According to Haygreen and Bowyer (1986), wood density can be used for light construction.

Table 3. density and moisture content Glulam

Type	Content of water,%	Density
Sengon(S)	10	0,295
Jabon (J)	11	0,431
Manii (M)	11	0,539
Mangium (A)	14	0,582
Pinus (P)	11	0,532
P-S	11	0,363
P-J	10	0,451
P-M	11	0,556
A-S	10	0,295
A-J	11	0,470
A-M	11	0,550

Sengoon mixture and mangium density are still relatively low, this is because of higher portion in sengoon than magium portion, so doesn't affect in the density of the formulation of glulam. Sengon density value which is observed very low so its not suitable timber for construction, even for the manufacture of structural glulam (anonymous, 2008) however the component of glulam manufacture, have been tried for use as coating inside. The result showed that using glulam density 2 / 3 part of the sengoon is still low, so that's the necessary to reduce sengoon servings.

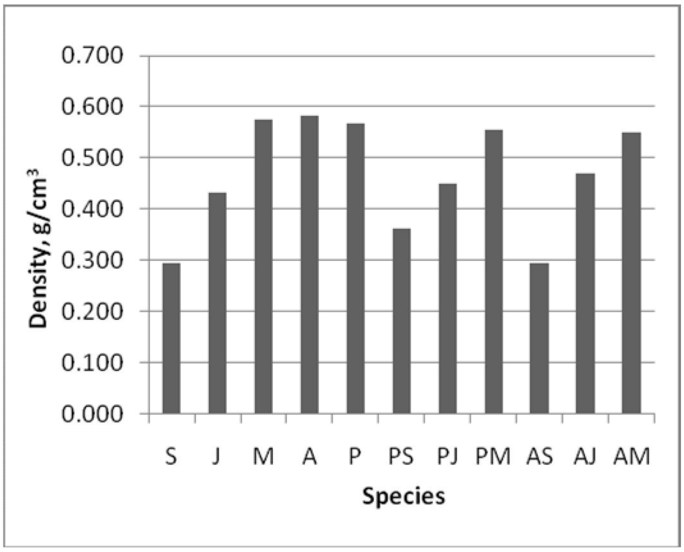


Figure 6. Histogram density glulam.

Based on statistical analysis by Duncan test, the highest density value contained in the glulam mangium. Mangium glulam density is not significantly different from the glulam manii, pine, and pine manii. The lowest density value contained in the glulam sengoon. Glulam sengoon density was not significantly different with gllam sengoon mangium and significant different with the other group of glulam.

D. **Mechanical characteristic**

The average value of mechanical characteristic including static bending strength (modulus at the limit of proportion , modulus of fracture and modulus of elasticity) glulam in the experiment are presented in table 4, figure 7 and 8

Table 4. The average value of the mechanical characteristic of glulam beams

Type	Static flexural			Paste, kg/cm^2	
	MPL, MPa	MOR, MPa	MOE,GPa	Dingin	Panas
Sengon	13,29	19,17	58,879	26,77	23,32
Jabon	25,40	37,74	89,475	34,39	23,23
Manii	13,84	28,00	53,907	30,47	34,35
Pinus	19,24	26,31	105,293	28,19	32,58
Mangium	16,08	24,75	101,133	46,47	39,26
PS (pinus-sengon)	13,88	27,68	91,231	22,21	23,09
PJ (pinus-jabon)	20,19	28,48	73,787	34,16	38,38
PM (pinus-manii)	23,04	32,97	79,047	41,42	35,59
AS (mangium-sengon)	10,03	13,47	86,476	25,70	28,24
AJ (mangium-jabon)	12,27	16,59	81,686	41,79	33,81
AM (mangium-manii)	14,36	19,99	86,861	43,39	47,77

MOE (modulus of elasticity) means the ability of wood to hold the diffraction due to loads of it without any change the forms. Higher value of MOE means stronger wood to make a change in shape (Setiawan 2008)

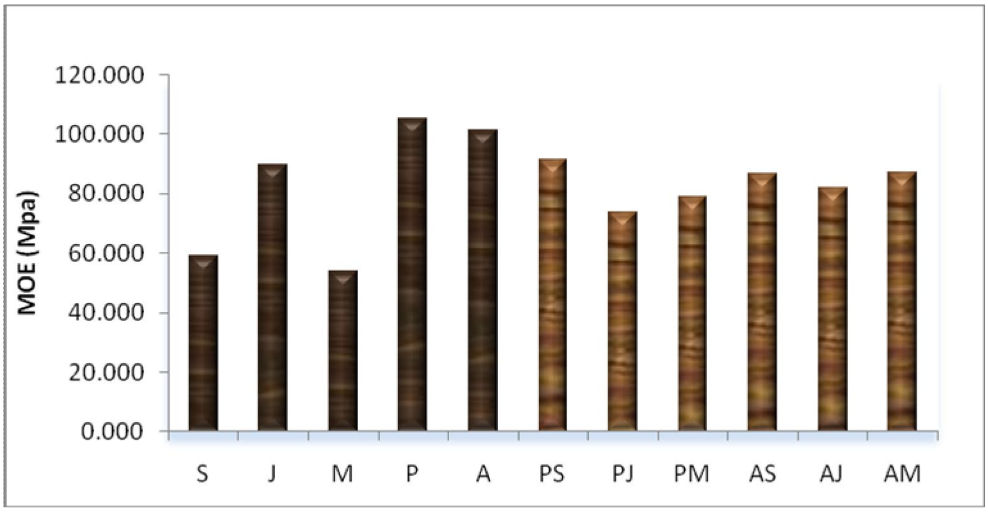


Figure 7 histogram values glulam MOE

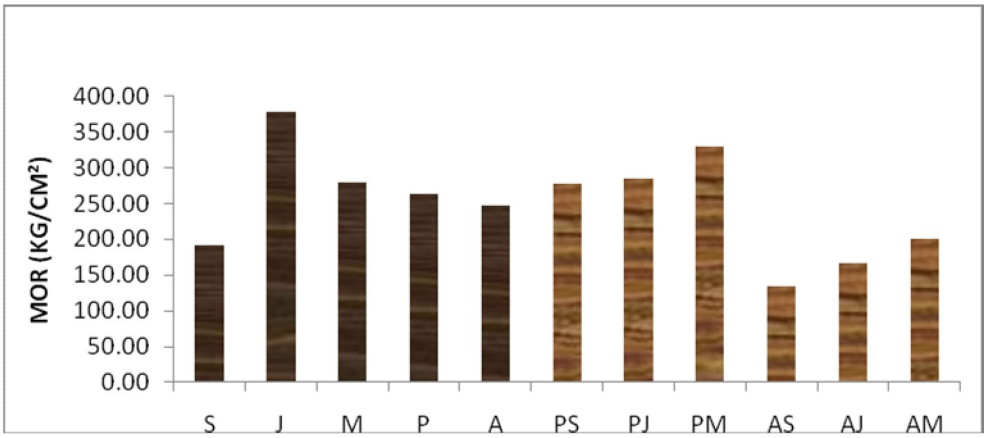


Figure 8. histogram Glulam MOR

The highest average value of glulam MOE until the lowest in a row is a pine, mangium, a combination of pine – sengoon, jabon, mangium- manii combination, combination of sengoom mangium, mangium jabon, pine jabon, sengoon and lowest MOE values held by manii wood. Based on the literature, the pine has a higher density value than mangium, but from the test result was known that the MOE mangium slightly smaller than the MOE value of the pine, MOE valueis directly proportional to density. Its caused by finger joint connection factors contained in the timber and manii mangium. From the graph it is evident that the finger joint could give a high impact on the MOE of wood. Irregularities MOE values can also be seen from the comparison between wood sengon, jabon, and manii. From the 3 types of the wood, mani has the lowest MOE value but has the highest density of the other.

MOR (modulus of Rupture) is an object ability of wishstand the maximum bending load until the object is damaged. Histogram MOR which studied presented in figure 6.

From the graph above can be seen MOR values from highest to lowest jabon, a combination of pine – manii, a combination of pine jabon,manii, a combination of pine sengoon, pine, mangium, combination – maniimangium, sengoon, mangium – jabon combination, and the last one is mangium sengoon. Based on the graph is known that the value of MOR combine pine is better than pine wich are not combined. But for glulamwhich were not cmbined, the highest MOR value generated by the jabon timber. This condition can be happened because most of the pine wood used in the process of making a fiber inclined glulam timber and having a lot of knots that affect the strength of wood. For mangium wood, MOR values are smaller than jabon. This is because tehere were finger joint in mangium which has a high level of risk damage when the test was happened. Combination of the wood sengoom – mangium, mangium – jabon and mangium manii has low MOR values when compared with wood sengoon, mangium, and jabon that are not combined. Based on an average value created glulam MOR compared with JAS (2003) only the glulam made from mangium, jabon and mixed pine – mangium are eligible for construction timber as well as adehesive strength of glulam only for manii, pine – manii, and mangium manii (anonymous 2003).

Based on the value of glulam MOE jabon, manii, pine sengoon, pine, and pine – jabon – quality manii experiment pertained E10 (MOE minimum : 90 000 kg/cm ^{2} , MOR : 270 kg / cm^{2}) thus glulam suitable for use as structural material and non – wood building structures.

Tests conducted to determine the strength of adhesive bonding strength in the binding of two timber surface and the durability of wood against the release of adhesive bonds between surfaces

The highest adhesion strength value generated by the combination of mangium and manii. This happens because the wood anatomical structure manii has good holding capacity of the adhesive. Average persistence sticking on any type of wood doesn't have significant differentiation. Generally the adhesive strength of each type of high-glulam showed that phenol Resorcinol adhesive formaldehide (RPF) is an exterior adhesive with high adhesive strength. Based on the average value of adhesive strength of the glulam made from wood sengon, a combination of pine-sengon and mangium-sengon, does not get in the standard of JAS (2003).

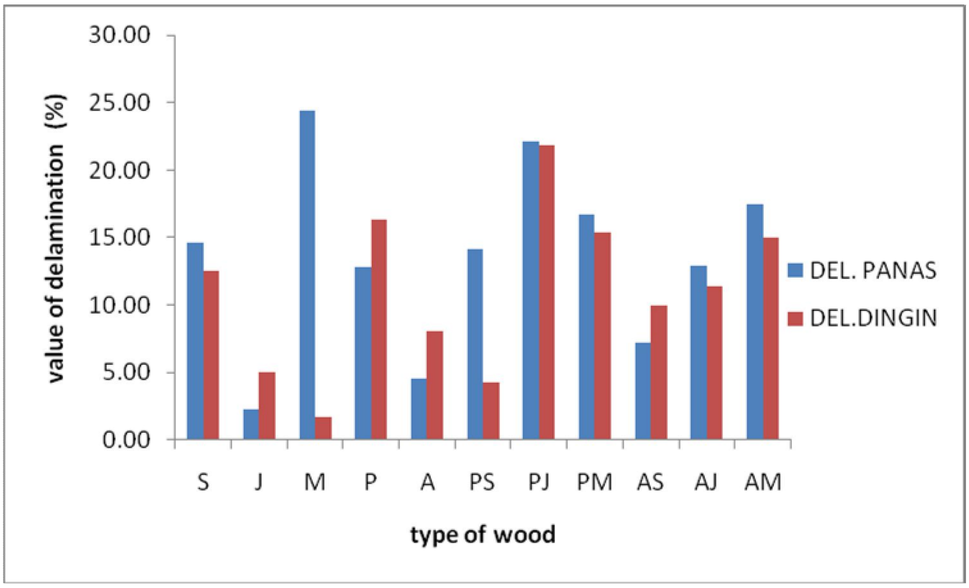


Figure 9. Histogram of Glulam Delamination

Tests conducted to determine the delamination resistance of adhesive factors of development and shrinkage due to humidity and high heat changes. From the graph above can be seen that most of the highest values of delamination always found delamination heat either . This means that the wood was more susceptible change temperature heat damage compare to cold temperatures. But there are several types of wood that have the highest value on cold than hot. Jabon wood, pine, and pine-jabon mangium has a higher cold delamination value than the heat delamination.

The highest value of heat delamination found on manii wood, while the lowest value of delamination contained in the jabon timber, this shows that the manii timber has a resistance to a lower temperature than jabon wood and the other wood. The combination of wood in glulam also showed that the delamination produced quite high. This means that the combination of glulam timber has less effect on resistance from extreme heat .Comparison of force about the weight of glulam (Strength to Weight ratio, S / W) are investigated is one of indicator of using wood strength in its use, can be seen in the histogram below.

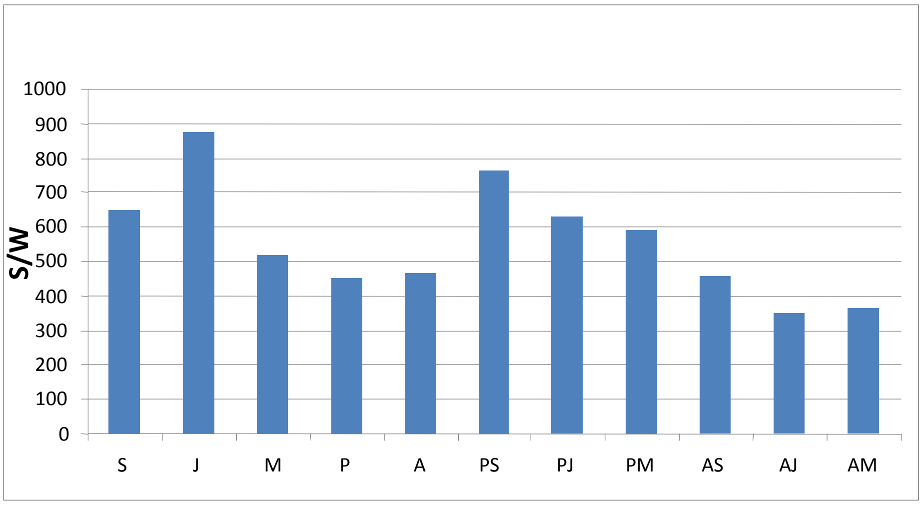


Figure 10. histogram of S / W glulam

From the figure above shows that the value of S / W glulam made ranged from 363-875 with an average of 590. Highest value of S / W contained in the jabon glulam and the lowest value is on mixture of jabon mangium glulam. This difference is influenced by differences in density and strength of the constituent pelamin board (Anonymous, 2010).

V. CONCLUSIONS AND SUGGESTIONS

1. Rendement average glulam manufacture of small-diameter timber plantations ranged from 31-53% with an average of 38%.
2. Drying mangium wood, manii, jabon, sengon and pine with a combination of solar dryers and furnaces of the water content of approximately 50% to 15% may take 4-13 days produced good results until poor result, especially on manii and sengon
3. Glulam manufacture of Sengon (S), Jabon (J), Manii (M), mangium (A), Pine (P), PS, PJ, PM, USA, AJ, and AM show that glulam made quite minor to moderate. glulam density ranged from 0295-1582 with an average of 0460

gram/cm3. The highest density of glulam, mangium, while the lowest was combine of mangium sengon

4. The average MOR 557 kg/cm2, the highest 875 kg/cm2 (glulam jabon), and lowest-jabon mangium. The average MOE value 82 525 kg/cm2, the highest in the glulam manii (105.292kg/cm2) and lowest in pine (53.907kg/cm2). Under the strong guidance of the modulus of elasticity, the glulam made pertained to the group E10-E11, but based on the value of MOR glulam is classified as E10-E17. Glulam mix-jabon mangium and mangium-manii not eligible for construction (value E <E10). Glulam is made from mangium, jabon and mixed pine-mangium that meet the JAS standard (2003) and can be used for wood construction and quality pertained E10.
5. Sticking shear firmness (dry) glulam tested ranged from 39.8 to 78.84 kg / cm 2 with an average is 55.64 kg/cm2. These values meet the requirements for flexural strength and stiffness of structural laminated wood according to JAS, 2003, RSNI-PKKI 2003, ISO / FDIS 12578 and ISO 8375. Thus the studied glulam allows for use as raw wood structures.
6. Based on the value of the ratio of force about the weight of wood (strength to weight ratio, S / W), located on glulam jabon highest, followed by a combination of pine-sengon, sengon and pine-jabon.

Suggestion

1. Wood from plantation forests can be used for building materials to make wood composites such as glulam both similar and mixed, with due regard pelaminasi konsisi and preparation, in order to obtain a qualified glulam as structural timber.
2. Wood density value and low MOE values like sengon can be placed on the inside, with a portion in such way condition force.

AKNOWLEDGEMENT

We thank Arinana, Yennova Sari, Hafidz, and Wina, for helping us conducting the research. Additionally we gratefully aknowledge the time participants dedicated to this study

REFERENCES

Abdurachman, N. Hadjib, O. Rachman and A. Santoso. 2007. Making curved glulam for the structure. Research Report. Forest Products Research and Development Center. Bogor. Unpublished

Alam, E.M. C.N Liu and M. Yamada. 2007. Bondability of tropical fast-growing tree species I: Indonesian wood species. J. Wood Sci (2007) 53:40 (40-46). The Japan Wood Research Society.

Anonymous, 1996. Japanese Agricultural Standard for Structural Glued Laminated Timber. Japan Plywood Inspection Corporation. Tokyo. Japan., 2002. Planning Procedures for Wood Construction Indonesia (PKKI NI-5).

The National Standardization Agency. Jakarta. 2003. Japanese Agricultural Standard for Glued Laminated Timber. MAFF,

Notification No. 234. Japan Plywood Inspection Corporation. 2005. Material Observation Guidelines and Industry Yield Sawing Industrial

Plywood. Directorate of Processing and Marketing of Forest Products, Jakarta. , 2008. ISO 8375. Timber structures - Glued laminated timber-Test methods for determination of phisical and mechanical properties. ISO. Geneva. Basri, E. 1990. Chart drying some type of timber plantation industry. Forest Products Research Journal 6 (7) :447-451. Center for Forest Products Research and Development. Bogor.

Basri, E, N. Hadjib. 2004. Relationships nature and properties of 5 types of wood drying mainstay of West Java. Forest Products Research Journal 22 (3): 165-166.

Abdurachman and N. Hadjib. 2001. The size and quality of timber from community forests. Paper presented at the Presentation of Research Results and Development of Forest and Nature Conservation. in Cianjur, West Java, on 4 Septembar 2001.

Martawijaya, I. Kartasudjana, K. Kadir and SAAmongprawira. 1981. Indonesian Wood Atlas. Volume I. Forest Products Research Institute, Bogor. Siddiq, S. 1989. Use of Glued Laminated Timber for structural components of buildings and housing. Paper presented at the seminar "Glulam". Dept. of Forestry. Jakarta, June 15, 1989>

Supriadi, A and O. Rachman. 1998. Application of computer simulation programs on four different types of wood sawing plantation forest industry. Forest

Products Research Bulletin 16 (1): 36-48. Center for Forest Products Research and Development. Economic and Social Forestry. Bogor.

Santoso A. 2003. Synthesis and characteristics of lignin resorcinol formaldehyde resin adhesive for laminated wood. Dissertation Faculty of Graduate Institute of Agriculture Bogor. Unpublished.

USDA, 2010. Wood Handbook: Wood as an Engineering Material. Centennial Ed. Forest Products Laboratory. USDA. Madison, USA.
Haygreen, J.G. and J.L. Bowyer. 1982. Forest Products and Wood Science. An introduction. Iowa State Univ. Press. USA

Attachment : the need for glulam timber

MIXED GLULAM

1.	Gl. Mangium-sengon					
		Length (cm)	Width (cm)	Thickness (cm)	Total (sheet)	Volume (m3)
	Mangium	300	8,5	2,5	16	0,102
	Sengon	300	8,5	2,5	32	0,204
2.	Gl. Mangium-Jabon					
		Length (cm)	Width (cm)	Thickness (cm)	Total (sheet)	Volume (m3)
	Mangium	300	8,5	2,5	16	0,102
	Jabon	300	8,5	2,5	32	0,204
3.	Gl. Mangium-manii					
		Length (cm)	Width (cm)	Thickness (cm)	Total (sheet)	Volume (m3)
	Mangium	300	8,5	2,5	16	0,102
	Manii	300	8,5	2,5	32	0,204
4.	Gl. mahoni-Sengon					
		Length (cm)	Width (cm)	Thickness (cm)	Total (sheet)	Volume (m3)
	Mahoni	300	8,5	2,5	16	0,102
	Sengon	300	8,5	2,5	32	0,204
5.	Gl. Mahoni -Jabon					
		Length (cm)	Width (cm)	Thickness (cm)	Total (sheet)	Volume (m3)
	Mahoni	300	8,5	2,5	16	0,102
	Jabon	300	8,5	2,5	32	0,204
6.	Gl. Pinus-Manii					
		Length (cm)	Width (cm)	Thickness (cm)	Total (sheet)	Volume (m3)
	Mahoni	300	8,5	2,5	16	0,102
	Maesopsis	300	8,5	2,5	32	0,204

PART D

PARTICLEBOARD

PARTICLEBOARD

By :

Yusuf Sudo Hadi, Dede Hermawan and MuhYusram Massijaya

1. INTRODUCTION

Log production activity in Indonesia is carried out by Stated Owned Enterprises in conjunction with the private sector using a Forest Concessionaire System, under direct control of the Ministry of Forestry. In the early 1970 to 2000, the dominant wood supply came from natural forest which were high quality trees with large diameter logs, sound, cylindrical, and straight. The logs are primarily to support plywood industries and sawmills. However, after 2000 the trend of wood supply from natural forest decreased and on the contrary the wood supply from plantation forest increased. The Indonesian logs production, in between 2000-2006, reached 9.0 to 24.2 million m^3 and about 60% come from plantation forest (Indonesian Ministry of Forestry, 2009). Changing in wood supply from natural forest to plantation forest affect the wood characteristics, i.e., from large diameter logs to small diameter logs; from well known wood species to lesser used species; and from superior logs quality to inferior quality. Therefore, the investigation of the physical and mechanical properties of this new characteristics wood and find out the possibilities utilization are needed.

Since year 2000 Indonesian forestry has been supplying logs about 60% from plantation forest, it was a great changed because prior to the year logs was supplied 90% from natural forest (Ministry of Forestry, 2009). About four million hectares of fast growing species has been developed with cutting cycle of 10-15 years, e.g. mangium (*Acacia mangium*), teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*), pine (*Pinus merkusii)*, sengon (*Paraserianthes falcataria),* sonokeling (*Dalbergia latifolia*) and sungkai (*Peronema canescens*) (Rohadi, 2010). Recently jabon (*Anthocephalus cadamba*) becomes populer because of fast growth, cylindric stem, few knots, light color and density about 0.43 (Anonymous, 2010).

Wood from plantation forest generally has a lot of juvenile wood and the wood is inferior in physical-mechanical properties and durability comparing to mature wood. However, houses in Indonesia which are mostly built using mature wood are not spared from termite attacks. In 1995 the economic loss of various buildings due to termite attack was about USD 200 mil (Rakhmawati 1995) and in 2000 it was USD 200–300 mil (Yoshimura and Tsunoda 2005). Thus, in future, when wood from plantation forest replaces natural wood, it is assumed that the loss will increase if the juvenile wood is not preserved prior to use for building materials.

On the other hand, Massijaya et al. (2010) mentioned that small diameter logs from fast growing species is prospectable for bio-composite products, such as plywood, particleboard, fiberboard, cementboard, glulam, laminated veneer lumber and other products, and these products could fulfill standard for physical and mechanical properties, but it was not mentioned for durability characteristics. It can be suggested that the durability of bio-composite products is similar to its solid wood, for this reason the resistance of bio-composite product especially particleboard made from fast growing species to subterranean termite should be recognized.

Particleboard is a bio-composites product which has more possibilities to use the small diameter and inferior quality logs. In addition, according to the previous study concerning market assessment, particleboard is potential for future market growth for bio-composites products.

The objective of this study is to find out the physical-mechanical properties and resistance to subterranean termite attack of of particleboard made from small diameter log from natural and plantation forests.

II. LITERATURE REVIEW

A. Particleboard

Particleboard is a generic term for a panel manufactured from lignocellulosic materials, primarily in the form of discrete pieces or particles, as distinguished from fibers, combined with a synthetic resin or other suitable binder and bonded together under heat and pressure in a hot press, and to which other materials may have been added during manufacture to improve certain properties (Maloney 1993). Simply put, particleboard is produced by hammermilling the material into small particles, spray application of adhesive to the particles, and consolidating a loose mat of the particle into a panel product with heat and pressure. All particleboards are currently made using a dry process, where air is used to randomize and distribute the particle prior to pressing.

Particleboards are often made in three layers. The faces of the boards are made up of the fines from the communition, while the core is made of the coarse material. Producing a panel this way gives better material utilization and the smooth face present a better surface for overlaying or veneering. Particleboards find use as furniture cores, where they are often overlaid with other materials for decorative purposes. Thick particleboard can be used in flooring system and as underlayment. Thin panels can be used as paneling substrate. Most particleboard applications are interior, and so they are usually bonded with urea formaldehyde (UF), although some use of phenol formaldehyde (PF) and melamine formaldehyde (MF) exists for applications requiring more durability. The various steps involved in particleboard manufacturing are included below.

A.1. Particle Preparation

There are two basic particle types: hammermill-type particles and flake-type particles. Hammermill particles are often roughly granular or cubic in shape, and thus have no significant length-to-width ratio. Particle size and geometry are great importance in board manufacturing. Particle with good slenderness ratio provide products with high bending strength and stiffness. It is of particular importance in the conventional particleboard product. Some plants, because of the wood species of the planer shavings being used, find it difficult to obtained fiber or long, thin particles for use as face material.

The most common type of machines used to produce flake-type particles are the cylinder type and the rotating disc type. The cylinder type has knives mounted either on the exterior of the cylinder similar to a planer or on the interior of a hollow cylinder. For the rotating disc type, the knives are mounted on the face of the disc at various angles. The knife angle and spacing influence the nature of the flake obtained.

The furnish is handled as a single entity to a homogeneous board processing line. For layered board, the furnish can be handled as a single entity until mat forming, where it is separated into coarse and fine-fraction size. However, it is usually simpler to handle the face and core material separately throughout the process.

A.2. Drying

The moisture content of particle is critical during hot pressing operation. The moisture content of the material depends on whether resin is to be added dry or in the form of a solution or emulsion. The moisture content of materials leaving the dryer is usually in the range of 4-8%. The main method used in drying particles include rotary, disc, and suspension drying.

A.3. Resin and Wax Addition

Frequently used resin for particleboards include UF, PF, and MF. The type and amount of resin used for particleboard depend on the type of products desired. Based on the weight of dry resin solid and oven-dry weight of the particles, resin content is usually in the range of 4-15%. Resins are usually introduced in water solutions containing about 50-60% solids. Besides resin, paraffin wax emulsion is added to improve moisture resistance. The amount of wax ranges from 0.3-2.0% based on the oven-dry weight of the particles.

Other specialized additives, such as fire retardants, need separate provision for their addition. They may be added in the resin-wood blender or elsewhere in the process line.

A.4. Mat Forming

Mat forming can be accomplished in a batch mode or by continuous formation. The batch system employs a caul or tray on which a deckle frame is placed. Mat forming is induced either by the back and forth movement of the tray or the back and forth movement of the hopper feeder. After formation, the mat is usually pre-pressed prior to hot-pressing. For three layers board, the two outer layers consist of particles differing in geometry from those of the core. The resin content of the outer layers is usually higher, about 8-15%, with the core having a resin content of about 4-8%.

In continuous mat forming systems, the particles are distributed in one or several layers on traveling cauls or on a moving belt. Mat thickness is controlled volumetrically. Like batch forming, the formed mats are usually pre-pressed, commonly with a single opening platen press. Pre-pressing produces the mat height and helps to consolidate the mat for pressing.

A.5. Hot-Pressing

After pre-pressing, the mats are then rough trimmed to length and width. The trimmed mats proceed to the hot press, which can be either a multi-opening, single-opening, stack, or continuous type. Hot-pressing temperatures are usually in the range of 100-140^{o}C. Urea-based resins are usually cured between 100-130^{o}C. Pressure depends on the number of factors, but is usually in the range of 14-35 kg/cm^2. Upon entering the hot press, the mat usually have moisture content of 10-15% but are reduced to about 5-12% during pressing.

Alternatively, some particleboards are made by the extrusion process. In this system, formation and pressing occur in one operation. The particles are forced into a long, heated die by means of reciprocating pistons. The board is extruded between the platens. The particles are oriented in a plane perpendicular to the plane of the board, resulting in properties which differ from those obtained with flat-pressing.

A.6. Finishing

After pressing, the board is trimmed to bring the board to the desired length and widths, and to square the edges. Trim losses usually amount to 0.5-8.0%, depending on the size of the board, the process employed, and the control exercised. After trimming, the boards are sanded or planed prior to packaging and shipping. The sander smooths the surfaces and removes any soft materials from the faces as well as surface blemishes caused by scratches or other blemishes on the caul plates or press platen. An exception to sanding may be found with products such as waferboard where surface smoothness is not a primary requisite or with hardboard products that have tight, hard surfaces created during the hot-pressing operation.

The particleboard may also be veneered or overlaid with other materials to provide better surface and improve strength properties. In such products, further finishing with lacquer or paint coatings may be done, or some fire-resistant chemicals may be applied.

B. Fast Growing Species

In Indonesia, the plantation forest in Perum Perhutani has been conducting since more than one hundreed years, and plantation forest in other Production Forest has been discussed since 1984 with topic of Timber Estate, Today Planting Tomorrow Harvesting. The plantation has been doing since 1990s, and nowaday the plantation forest (excluding Perum Perhutani) reaches about 4 million hectares spreadout in whole country.

The trees species are mostly fast growing species, becuase the natural forest can not supply the logs demand anymore. The cutting cycle of the plantaion forest ranges between 5-15 years, depending on demand in the market. The logs diameter ranges 20-40 cm and contains a lot of juvenile wood.

The woods species are mangium (*Acacia mangium*), sengon (*Paraserianthes falcataria*), gmelina (*Gmelina arborea*), mahogany (*Swietenia macrophylla*), mindi (*Azedarachta indica*), sungkai (*Peronema canescens*), Tarisi (*Albizzia* *lebbeck*), Jabon (*Anthocephalus cadamba*), Pinus (*Pinus merkusii*) and other species. These woods are processed for fiber production, particleboard, plywood, timber and other purposes.

III. PHYSICAL-MECHANICAL PROPERTIES

A. Materials

The materials used in this study were small diameter logs from natural forest and plantation forest, namely: Sengon (*Paraserienthes falcataria*), Cempaka (*Elmerillia sp*), Manglid (*Manglietia glauca*), Jabon (*Anthocephalus cadamba*), Sungkai (*Peronema canescens*), Mangium (*Acacia mangium*), Tarisi (*Albizzia lebbeck*), Kempas, Pinus (*Pinus merkusii*). The first three species were used for particleboard with density of 0.50 g/cm^3, the second three species for density of 0.70 g/cm^3, and the last three species for density of 0.85 g/cm^3.

Urea Formaldehyde was used as a binder with resin content 12%, and paraffin was added to improved the water resistant of the board.

B. Methods

The particleboard with a targeted density of 0.4; 0.6; 0.8; and 0.9 g/cm^3 were manufactured by using 12% of UF as a binder, and 2% wax as an additive. The hand formed mats of 30x30x1 cm were pre-pressed in order to reduce the thickness of mats that will fit into the press. After pre-pressing, the mats proceed to the hot-press at 130^{o}C for about 10 minutes.

The physical and mechanical properties of board were evaluated in accordance to the Japanese Standard JIS 5908-2003 for particleboard.

C. Results and Discussion

C.1. Density

Density is an important indicator of a composite's performance. It virtually affects all properties of the materials. The density of the specimen is determined using the full thickness of the composite, and it is based on the oven dry weight of the specimen. The density is calculated as follow:

$$Density = \frac{W\ (kg)}{V\ (m^3)}$$

Where:

- W = Oven dry weight (kg)
- V = Volume (m3)

The average density of particleboards resulted in this study are shown in Figure 1.

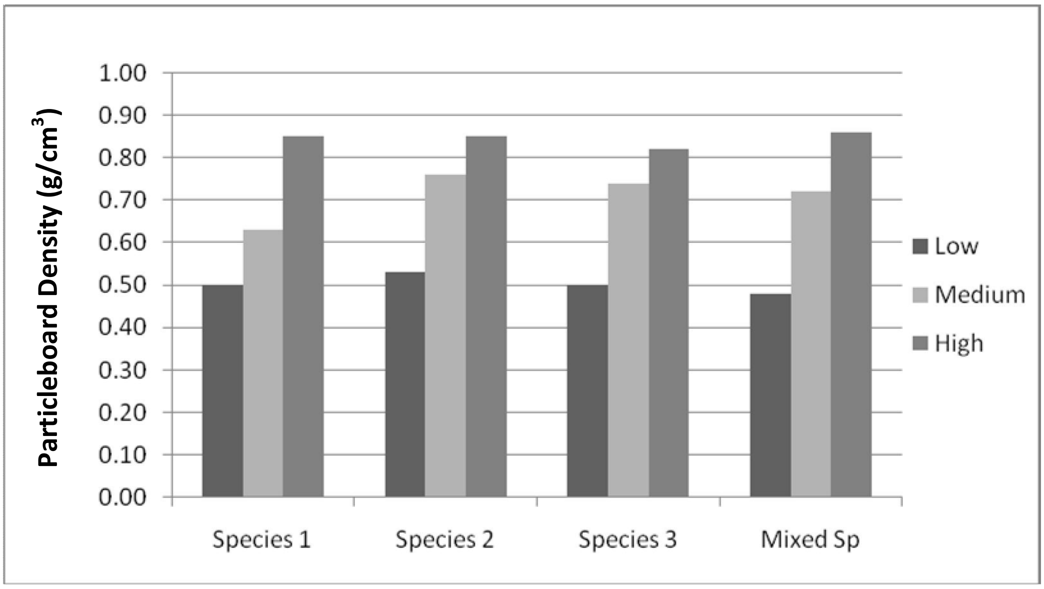


Figure 1. The average density of the particleboards

The average density of the low density particleboards was 0.50 $\pm$ 0.04 g/cm^3 ranged from 0.46-0.58 g/cm^3, the medium density particleboard was 0.73 $\pm$ 0.13 g/cm^3 ranged from 0.50-0.88 g/cm^3, and the high density particleboard was 0.85 $\pm$ 0.03 g/cm^3 ranged from 0.80-0.89

g/cm^3. According to analysis of variance there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density. Mostly wood species did not affect particleboard density, except for cempaka can not reach a target density. It can be suggesgted that every wood can be made for particleboard and it is recommended with low to medium wood density, and the compression ratio reach about 1.3 to 3.

C.2. Moisture Content

The amount of water in wood or a wood products is usually termed the moisture content (MC). MC is defined as the weight of the water expressed as a percentage of the moisture-free or oven-dry wood weight. MC is calculated as follow:

$$MC = 100\left(\frac{W1 - W2}{W2}\right)$$

Where:

MC = Moisture Content (%)

W1 = initial weight

W2 = final weight (oven dry)

The average moisture content of the boards resulted in this study are shown in Figure 2.

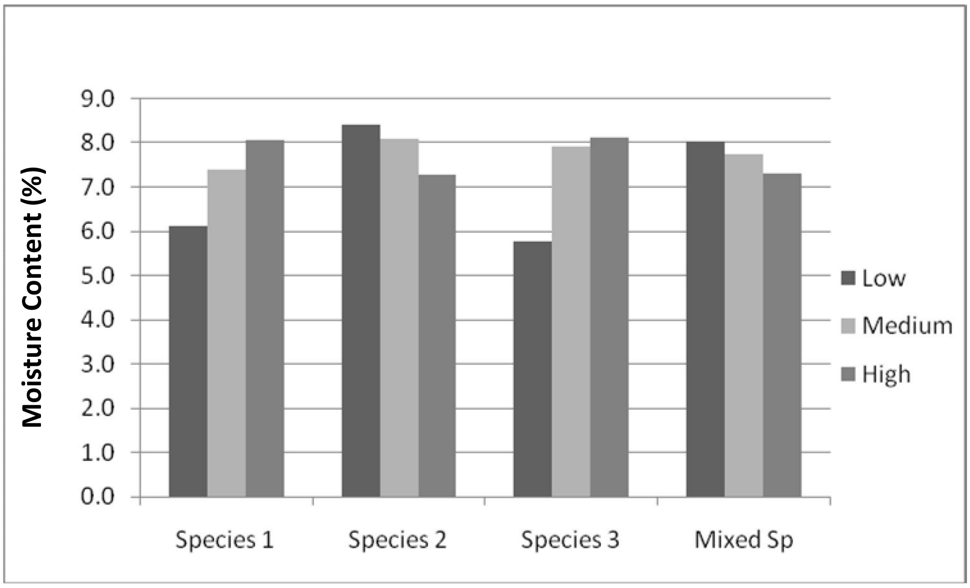


Figure 2. Average moisture content of the boards

The average moisture content of low density particleboards was 7.03 ± 1.36 % ranged from 5.00-9.13%, the medium density particleboard was 7.78 ± 0.41% ranged from 7.29-8.55%, and the high density particleboard was 7.68 ± 1.08% ranged from 7.29-8.55%. The moisture content for all densitie prticleboards were still matched to the standard of JIS and SNI.

According to analysis of variance wood species did not affect moisture content of the board, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density on moisture content. All factors namely wood species, particleboard density, and interaction bteween both factors did not affect the moisture content of particleboard, and it can be suggested that every wood can be made for particleboard.

C.3. Thickness Swelling

Thickness swelling is an indicator for dimensional stability of the board, and especially for particleboard thickness swelling is very important for physical properties quality. The average value of thickness swelling is shown at Figure 4.

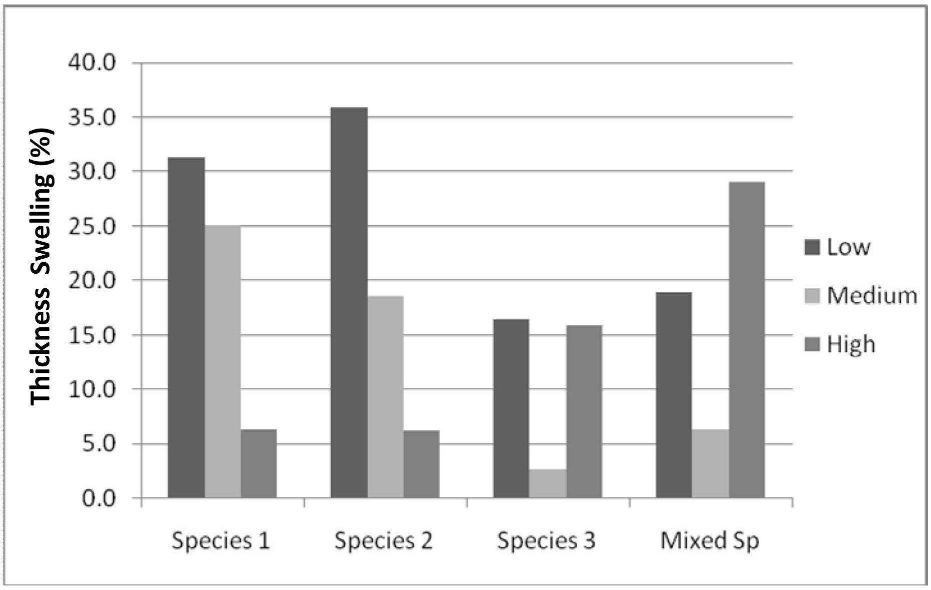


Figure 3. Average Thickness Swelling of the boards

The average thickness swelling of low density particleboards was 25.6 ± 9.8 % ranged from 6.7 - 39.5%, the medium density particleboard was 13.2 ± 13.5% ranged from 1.24-42.7%, and the high density particleboard was 14.4 ± 12.0% ranged from 2.9-36.5%. According to analysis of variance wood species did not affect thickness swelling of the board, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density. Wood species did not affect thickness swelling of the boards, it can be suggested that every wood can be made for particleboard, but the thickness swelling of low density board was still high but the others were smaller, and it had to pay attention to reduce it. All thickness swellings of the baords were still higher than standard requirement, and it had to be reduced with additional paraffin or other parameters.

C.4. Water Absorption

Water absorption is one parameter indicated particleboard physical properties, and water absorption is high related to thickness swelling properties, i.e. higher water absorption will impact to higher thickness swelling of the board. The average value of water absorption is shown at Figure 4.

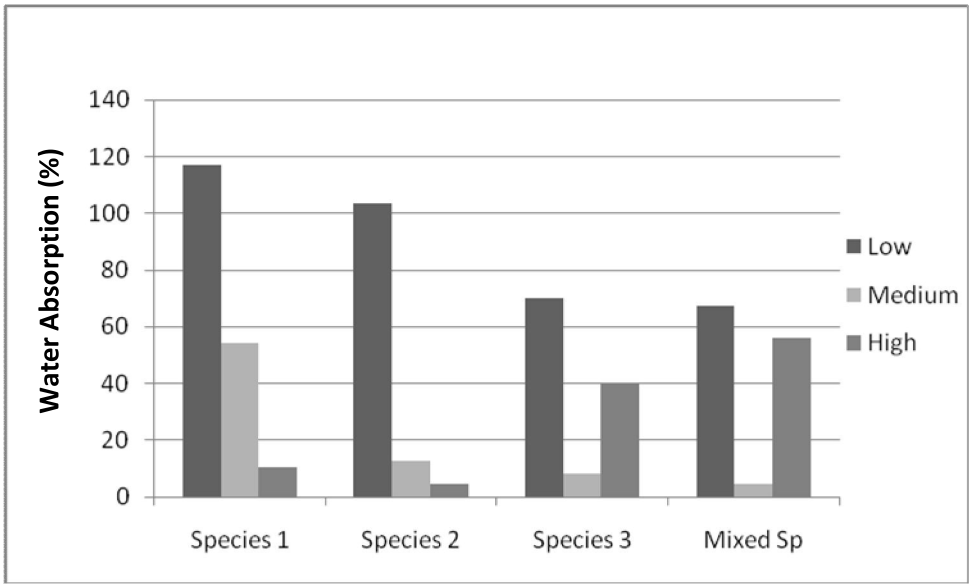


Figure 4. Average Water Absorption of the boards

The average water absorption of low density particleboards was 89.5 ± 32.3 % ranged from 21.8 - 135.8%, the medium density particleboard was 19.9 ± 27.3% ranged from 2.02-100.7%, and the high density particleboard was 27.8 ± 29.8% ranged from 3.2-88.9%. According to analysis of variance wood species did not affect water absorption, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density. Wood species did not affect water absorption of the boards, it can be suggested that every wood can be made for particleboard, but the water absorption of low density board was still high but the others were smaller, and it had to pay attention to reduce it.

C.5. Modulus of Rupture (MOR)

Modulus of rupture (MOR) is one parameter indicated particleboard mechanical properties, this properties will indicated how much load can be supported, and it can be classified refers to JIS. The average value of MOR is shown at Figure 5.

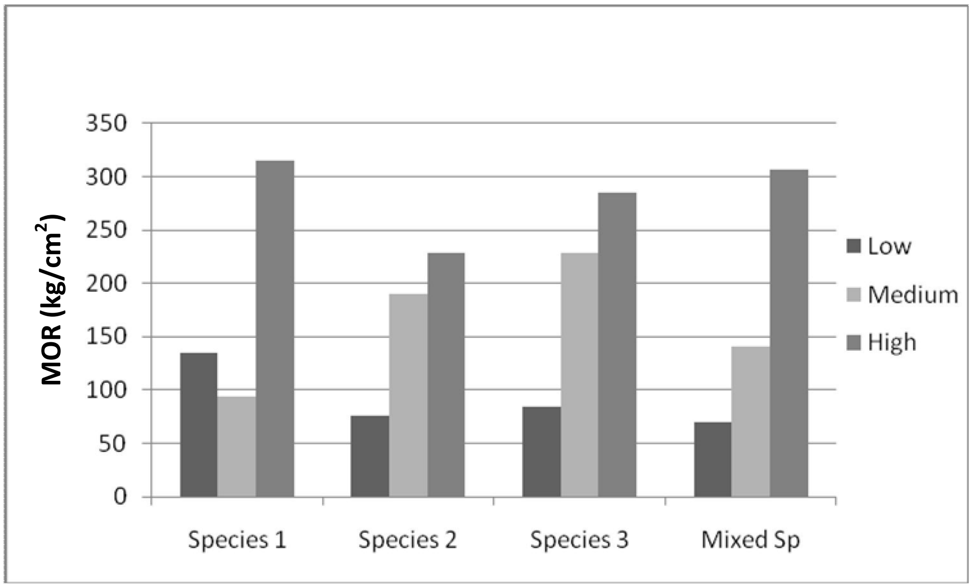


Figure 5. Average Modulus of Rupture of the boards

The average MOR of low density particleboards was 91.3 $\pm$ 41.5 kg/cm^2 ranged from 28.2 - 165.8 kg/cm^2, the medium density particleboard was 163.0 $\pm$ 70.8 kg/cm^2 ranged from 74.1-286.8 kg/cm^2, and the high density particleboard was 283.8 $\pm$ 69.0 kg/cm^2 ranged from 186.8-403.8 kg/cm^2. According to analysis of variance wood species and interaction between wood species and particleboard density did not affect MOR, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density.

Wood species did not affect MOR of the boards, it can be suggested that every wood can be made for particleboard, but the MOR of low density board and medium density board were still lower than the standard especially for minimum value, for average values were satisfied, but for high density board, the board can fulfill Type 18 of JIS and Type 200 of SNI. For low and medium densities of particleboards, it must be an effort to increase MOR, so it can fulfill the standards for lower grades.

For sengon and manglid wood species, both species can fulfill SNI and JIS standard because the minimum MOR values were higher than requirements. Sengon particleboard fulfilled for type 130 of SNI and

Type 13 of JIS standards, and manglid particleboard fulfilled for type 80 of SNI and Type 8 of JIS standards.

C.6. Modulus of Elasticity (MOE)

Modulus of elasticity (MOE) is one parameter indicated particleboard mechanical properties, this properties will indicated how much load can be supported and the board is still perform under plasticity limit. The average value of MOE is shown at Figure 6.

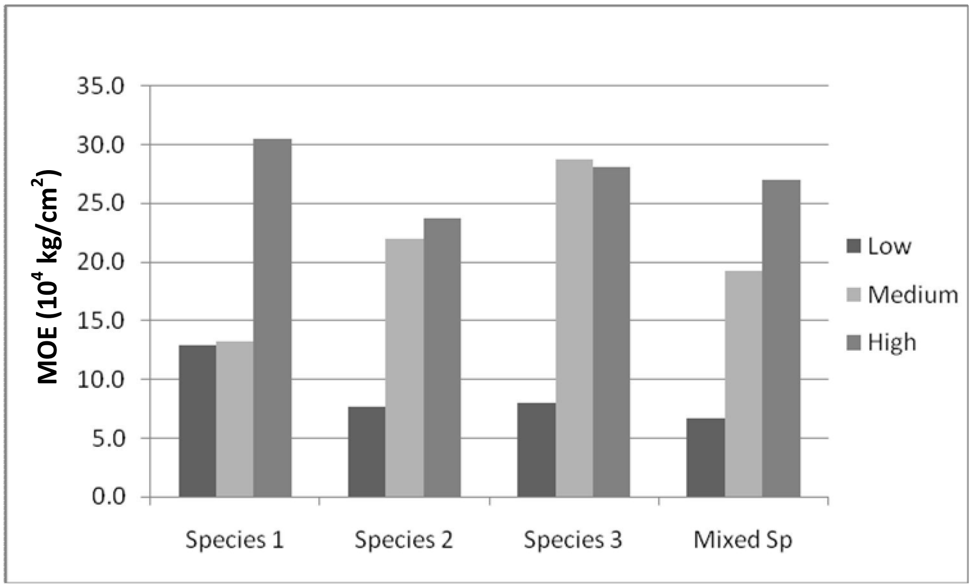


Figure 6. Average Modulus of Elasticity of the boards

The average MOE of low density particleboards was 8,801 + 3,816 kg/cm2 ranged from 3,014 – 15,786 kg/cm2, the medium density particleboard was 20,784 + 7,552 kg/cm2 ranged from 10,031-33,609 kg/cm^2, and the high density particleboard was 27,343 $\pm$ 8,352 kg/cm^2 ranged from 17,687-48,636 kg/cm^2. According to analysis of variance wood species and interaction between wood species and particleboard density did not affect MOE, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density. Wood species did not affect MOE of the boards, it can be suggested that every wood can be made for particleboard, but the MOE of low density board was still lower than the standard and could not fulfill it, but for medium density the average MOE can fulfill Type 150 of SNI and Type 8 of JIS, and high density board could fulfill Type 13 of JIS and Type 150 of SNI. For low and medium densities of particle boards, it must be an effort to increase MOE, so it can fulfill the standards for lower grades.

C.7. Internal Bond (IB)

Internal bond (IB) is one parameter indicated particleboard mechanical properties, and the average value of IB is shown at Figure 7.

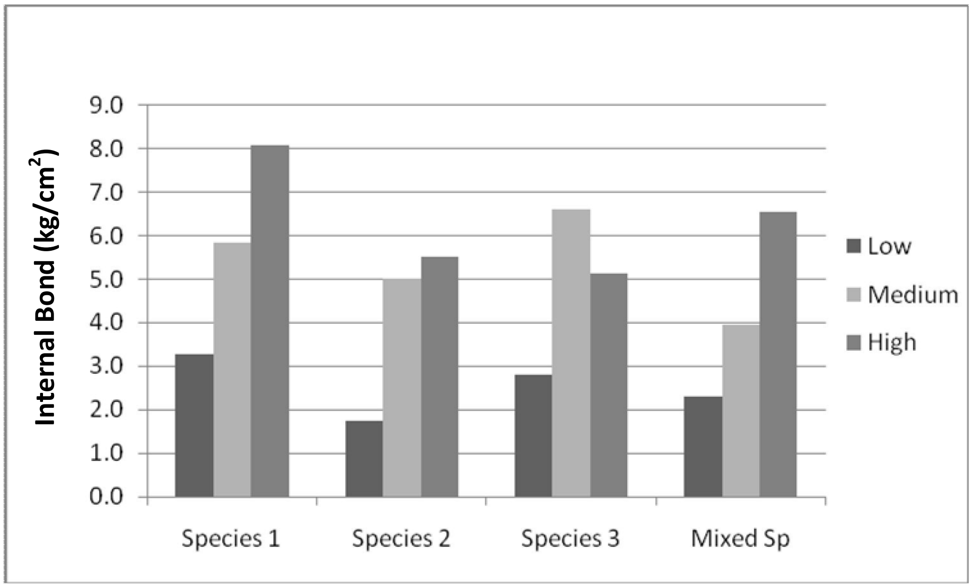


Figure 7. Average Internal Bond of the boards

The average IB of low density particleboards was 2.54 $\pm$ 0.78 kg/cm^2 ranged from 1.23 – 4.25 kg/cm^2, the medium density particleboard was 5.36 $\pm$ 2.03 kg/cm^2 ranged from 1.85-8.06 kg/cm^2, and the high density particleboard was 6.31 $\pm$ 2.03 kg/cm^2 ranged from 2.57-8.68 kg/cm^2. According to analysis of variance wood species and interaction between wood species and particleboard density did not affect IB, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density.

Wood species did not affect IB of the boards, it can be suggested that every wood can be made for particleboard, but the IB of low density board was still lower than the other boards, but it could fulfill the Type 180 of SNI and Type 18 of JIS, and for medium and high densities of boards the average IB could fulfill Type 200 of SNI and Type 18 of JIS. For each species and mixture species could also fulfill the standards, sengon fulfilled Type 200 of SNI and Type 18 of JIS, cempaka fulfilled Type 100 of SNI and Type 8 of JIS, and manglid and mixtured species fulfilled Type 100 of SNI and Type 8 of JIS.

C.8. Screw Holding Strength

Screw holding strength is one parameter indicated particleboard mechanical properties, and the average value of screw holding is shown at Figure 8.

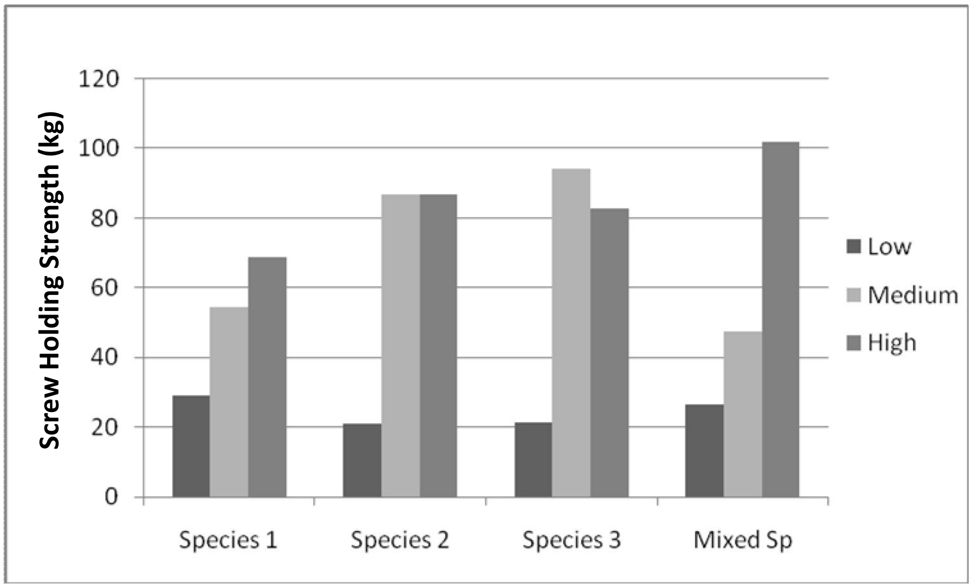


Figure 8. Average Screw Holding Strength of the boards

The average screw holding strength of low density particleboards was 24.5 + 7.2 kg/cm2 ranged from 14.5 – 39.7 kg/cm2, the medium density particleboard was 70.6 + 22.6 kg/cm2 ranged from 41.8-111.3 kg/cm2, and the high density particleboard was 85.1 + 18.5 kg/cm2 ranged from 57.4-112.5 kg/cm2. According to analysis of variance wood species and interaction between wood species and particleboard density did not affect screw holding strength, and there are no significantly different between partcleboard made from single wood species and mixture of wood species in the same particleboard density. Wood species did not affect screw holding strength of the boards, it can be suggested that every wood can be made for particle board, but the screw holding strength of low density board was still much lower than the standard and could not fulfill it, but for medium and high densities boards the average screw holding strength could fulfill Type 200 of SNI and Type 18 of JIS. For low density particleboard, it must be an effort to increase screw holding strength, so it can fulfill the standard for lower grade.

IV. SUBTERRANEAN TERMITE TEST

A. Materials

Three small diameter logs were used for manufacturing of particleboards, i.e. jabon (*Anthocephalus cadamba*), sungkai (*Peronema canescens*), mangium (*Acacia mangium*), and equal mixed of the three species was also used. Density targets of the boards were 0.60 g/cm^3 and 0.80 g/cm^3 using urea formaldehyde as a binder with resin content 12%, and 2% paraffin was added to improved the water resistant. The hand formed particle mats were hot-pressed at 130^{o}C temperature, 25 kg/cm^2 pressure for 10 minutes, and the board size was 30 cm x 30 cm x 1 cm in length, width and thicknes respectively.

B. Subterranean termite test

Wood sample was put in and touched to a jam pot containing 200 g of sand (7% moisture content under water holding capacity) and 200 healthy and active worker of subterranean termites (*Coptotermes curvignathus* Holmgren). The jam pots were put in the dark room for four weeks, and each week the bottles were weight and if moisture content of the sand reduced 2% or more, water was added to reach moisture content standard. At the end of the test, particleboard weight loss was determined regarding to SNI 01.7207–2006 (Indonesian National Standard, 2006), and feeding rate was also calculated.

C. Data Analysis

Factorial 2 by 4 in completely randomized design was used to analyze the data, the first factor was board density namely medium density particleboard (0.60 g/cm^3) and high density particleboard (0.80 g/cm^3), and the second factor was wood species namely jabon, sungkai, mangium, and equal mixed of the three species.

D. Results and discussion

D.1. Weight Loss

Weight loss percentage for each wood species and particleboard density is shown in Table 1, analysis of variance is shown in Table 2. From Table 1 it was seen that higher wood density had lower wood mass loss percentage, and could be interpretated that higher wood density had higher resistant to *Coptotermes curvignathus* termite attack, and this result was similar to Arango *et al*. (2006) who mentioned based on the six hardwood species indicate a significant inverse association between percentage mass loss and specific gravity or with other term higher specific gravity wood has more resistant to *Reticulitermes flavipes* termite. Furthermore it can be seen that particleboard resistant to termite attack was aligned to its composed wood or in other term more resistant wood producing more resistant particleboard to termite attack.

Tabel 1. Weight loss (%) for each wood species and particleboard density

Particleboard	Jabon	Sungkai	Mangium	Mixed
Medium Density	6.9	4.5	4.1	6.2
High Density	5.1	4.3	3.6	5.4
Solid Wood	8.4	3.5	2.3	-
Wood Density	0.41	0.46	0.60	

Tabel 2. Analysis of variance for weight loss and feeding rate

Factor	Weight Loss		Feeding Rate	
	F value	Sign level	F value	Sign level
Board density	3.50	0.08	1.57	0.23
Wood species	5.62	0.01	3.41	0.04
Interaction	0.65	0.59	0.02	0.99

According to analysis of variance at Table 2, particleboard density and interaction of both factors did not affect particleboard mass loss, but wood species did at 1% significant level. Board composed from higher density wood had lower mass loss, in this research the most resistant board was composed from magium (wood density 0.60 g/cm^3) followed by sungkai (wood density 0.46 g/cm^3), mixed species, and jabon (wood density 0.41 g/cm^3).

D.2. Feeding Rate

Feeding rate (µg/termite/day) for each wood species and density of particleboard is shown in Table 3, analysis of variance is shown in Table 2. From Table 3 it was seen that higher wood density had lower termite feeding rate, this fact was aligned with board mass loss, and it could be interpretated that higher wood density had higher resistant to subterranean termite attack.

Tabel 3. Feeding rate (µg/termite/day) for each wood species and particleboard density

Particleboard	Jabon	Sungkai	Mangium	Mixed
Medium Density	83.8	60.6	53.5	90.2
High Density	92.3	73.6	67.0	100.7
Solid Wood	89.5	34.5	29.3	-

According to analysis of variance at Table 2, particleboard density and interaction of both factors did not affect termite feeding rate, but wood species did at 4% significant level. Board composed from higher density wood had termite feeding rate, in this research the lowest feeding rate was composed from magium followed by sungkai, jabon, and mixed species.

V. CONCLUSION

Regarding to this study it could be concluded as follow:

a. Wood species which used in this experiment could be utilized for particleboard and these species did not much affect particleboard properties, single species and mixture species are not different regarding to physical and mechanical particleboard properties.
b. Low particleboard density was still lower performance in terms of physical and mechanical properties, but medium and high densities of the boards indicated satisfied performance for physical and mechanical properties.
c. Higher wood density had higher resistant to termite attack.
d. Particleboard resistant to termite attack was aligned to its composed wood or in other term more resistant wood species producing more resistant particleboard to termite attack.
e. Wood species affected board mass loss and termite feeding rate, board composed from higher density wood had lower mass loss and termite feeding rate as well, or in other term board composed from higher density wood had higher resistant to subterranean termite attack.
f. Board density and interaction of board density and wood species did not affect board mass loss and termite feeding rate.

AKNOWLEDGEMENT

We thank Suhasman, Esi Fajriani, Inggit Tutirin, Nia Widiastuti, and Reza Ramadhan, for helping us conducting the research. Additionally we gratefully aknowledge the time participants dedicated to this study.

REFERENCES

Anonymous. 2010. Dilarang Tebang Jabon (*Prohibited Cut Jabon*). Trubus 488, July 2010/XLI, p. 20-21. (In Indonesian).

Arango RA, Green F, Hintz K, Lebow PK & Mill er RB. 2006. Natural durability of tropical and native woods against termite damage by Reticulitermes flavipes (Kollar). International Biodeterioration and Biodegradation 57: 146–150.

Indonesian National Standard. 2006. Wood and wood products resistance test to wood destroying organism (SNI 01.7207–2006). Indonesian National Standard Bureau, Jakarta.

Maloney T M. 1993. Modern Particleboard and Dry-Process Fiberboard Manufacturing, Miller Freeman Inc, San Francisco.

Massijaya M Y, Y S Hadi, B Tambunan, N Hadjib and D Hermawan. 2010. Address technical gaps in producing bio-composite products: Identify milling issues. Collaborative works: Bogor Agricultural University Indonesia, International Tropical Timber Organization Japan, and Common Fund for Commodities Netherland.

Ministry of Forestry. 2009. Statistik 2008. Directorate of Natural Forest Development, Directorate General Forest Products. Ministry of Forestry, Jakarta, Indonesia.

Rakhmawati D. 1995. Perkiraan kerugian ekonomi akibat serangan rayap pada bangunan perumahan di Indonesia. Faculty of Forestry, Bogor. (In Indonesian).

Rohadi D. 2010. Peran hutan rakyat dalam strategi pengembangan bahan baku kayu pertukangan: Pembelajaran dari kasus tanaman jati rakyat di Kabupaten Gunungkidul dan tanaman jabon rakyat di Kabupaten Tanah Laut. Seminar Nasional Inovasi Teknologi Pengolahan Jati Cepat Tumbuh dan Kayu Pertukangan Lainnya. Bogor, Indonesia, 25 November 2010.

Yoshimura T & Tsunoda K. 2005. Termite problems and management in Pacific-Rim Asian region. Pp. 316−317 in IAWPS 2005 International Symposium on Wood Science and Technology. Volume I. 27−30 November 2005, Yokohama.

PART E

MEDIUM DENSITY FIBERBOARD

MEDIUM DENSITY FIBERBOARD (MDF)

By :

Dede Hermawan, Yusuf Sudo Hadi, and Muh. Yusram Massijaya

I. INTRODUCTION

Changing in wood supply from natural forest to plantation forest affect the wood characteristics, i.e., from large diameter logs to small diameter logs; from well known wood species to lesser used species; and from superior logs quality to inferior quality. Therefore, the investigation of the physical and mechanical properties of this new characteristics wood and find out the possibilities utilization are needed.

Medium Density Fiberboard (MDF) is the bio-composites products which have more possibilities to use the small diameter and inferior logs. In addition, according to the previous study concerning market assessment, MDF is the potential for future market growth for bio-composites products.

The objective of this study is to find out the fundamental properties of MDF made from small diameter log from natural forest and plantation forest.

II. MEDIUM DENSITY FIBERBOARD (MDF)

Medium Density Fiberboard (MDF) is a dry formed panel product manufactured from lignocellulosic fibers combined with a synthetic resin or suitable binder (Rowell 2005, Bowyer 2003). The variety of raw material types can be used for MDF. Wood residue such as planer shavings, sawdust, and plywood trim are regularly used, but the input should include at least 25 percent pulp chip to produce the desired quality of furnish (Maloney 1993). Other non-wood materials such as bagasse and kenaf can also make excellent MDF. The panels are compressed to a density of about 0.40 to 0.80 g/cm^3 in a hot press by a process in which substantially the entire interfiber bond is created by the added binder. Other materials may have been added during manufacture to improve certain properties.

MDF is a wood based composite. The primary constituent is a softwood that has been broken down into fibers which are far smaller entities than those used in particleboard. A wide variety of softwood species will constitute a suitable base for MDF production. Other materials successfully used have been waste paper and randomly collected waste wood. Mixing wood and other non-wood materials such as fibers of glass, steel, and carbon have all resulted in successful MDF type products being produced.

III. MANUFACTURING PROCESS

A. Debarking

Once the MDF plant has obtained suitable logs, the first process is debarking (Tsoumis 1991). The logs could be used with the bark, as could any fibrous material, but for optimalization of the final product the bark is removed to:

- decrease equipment damaging
- allow faster drainage of water during mat forming
- decrease organic waste load by 10-15%
- stabilize pH levels (reduces corrosion of tools)

The most popular debarker used in MDF production is a ring debarker, though rosser head and drum debarker can be used.

In some manufacturing plants the debarking process is not important as the plant obtains chips rather than logs. The chip can come from the waste of another operation or from logs chipped in the forest.

A cambio ring debarker can operate at feeds of up to one ton per minute, the logs being typically 2 to 2.5 m in length. The tool heads held in place pneumatically or by springs, rotate about the logs and rip off nearly all the bark, and do little damage to the log. The waste bark can be sold or used for power on-site stations.

B. Chipping

Though some plants accept chips directly from other operations, Logs and other raw materials such as plywood and furniture trims or sawmill cut-off block are initially reduce to chips (Bowyer 2003). Chipping is typically done at the MDF plant. The chips are similar to those used for particleboard or pulp, and are stored out-of-doors or in silos (Tsoumis 1991). A disc chipper, containing anything from four to sixteen blades, is used. The blades are arranged radially on a plate and the spinning plate is faced perpendicularly to the log feed. Following features govern the chip size

- the feed speed of the logs
- the radial speed of the knife plate
- the protrusion distance of the knives
- the angle of the knives

The chips are then screened and those that are oversized may be re-chipped, and those that are undersized used as fuel. Stockpiles of several hundred tones of chips are maintained. There may be a blending of chips from different sources or timber species to enhance certain properties. The chips are washed, and a magnet or other scanner may be passed over to detect impurities.

C. Pulping

MDF takes much of its characteristics from the fact that it uses wood cells, rather than particles. Pulping is mechanical. The main method is the thermomechanical process (Tsoumis 1991). This can be done by a Masonite Gun Process, atmospheric or pressured disk refiner. The defibrator pressurised disk refinement being that primarily used in MDF manufacture. The chips are compacted after using a screw feeder into small plugs which are heated for 30 to 120 seconds to soften the wood, then it is fed into the defibrator. The defibrator consists of two counterwise rotating plates each with radial grooves that get smaller as they get closer to the circumference. The plug is fed into the centre and gets broken down as the centrifugal forces push it toward the outside of the plates where the grooves are finer. The feeding devices at the entrance and exit to the defibrator maintain suitably high pressure and temperature (about 150 degree Celsius).

D. The Blow-line

After defibration fibers enter the blow-line. The blow-line is initially only 40 mm in diameter with the fibers passing through at high velocity. Wax, used to improve the moisture resistance of the finished board, and resin are added in the blow-line while the fiber are still wet, as dry fibers would form bundles, due to hydro bonding, and material consistency would be lost. The blow-line now expands to 1500 mm in diameter and fibers are dried by heating coils warming the blow-line to about 290^{o}C. The air-fiber ratio is about 32 kg/m^3 with air speed of 150 m/min though the air is still humid and the resin does not yet cure. The agitation of fiber in the blow-line helps disperse resin consistently. The fiber may be stored in bins for an unspecified length of time but the board making process is usually continuous from here on. The moisture content of the fibers is 12%, and thus is considered a dry process.

E. Pressing

Compressed boards are subjected to either wet or dry processing. In both cases, the pressure is hot and applied by pressing that usually have many openings, and platens heated by steam, water or oil (Tsoumis 1991). The mat can either be laterally cut to size as it leaves the pendistor or it can be cut half way through its run by a synchronized flying cut off saw. The density profile of the panel is critical to achieving satisfactory strength properties. Concentrating mass and hence load bearing ability at the bottom and top of the board means that inertial properties are maximized and the greatest strength can be obtained for minimal weight. This is achieved by the press (daylight press) acting at impacted pressure initially and then slower pressure application.

The pressure may reach to 3.5 MPa and be heated to 190-210 degree Celsius. Thicker boards may require up to 7.5 MPa and additional steam or radio frequency heating.

Pressing can be divided into platen (of which there are single opening and multi-opening types) and continuous types. Multi-opening presses are dominant in the industry at present. Continuous presses are being installed world-wide even for the process of thick panel manufacture.

F. Finishing

After pressing boards are cooled in a star dryer and final trimmed and sanded. They are given a few days storage to allow complete curing of resins. The boards are commonly given a coloured melamine laminate (e.g. High Pressure Laminates HPL), though natural wood veneers and raw MDF are common.

IV. MATERIALS AND METHODS

A. Materials

The small diameter logs from plantation forest, namely: Rubber wood (*Hevea brasiliensis*), and Mangium (*Acacia mangium*) were used as raw material of MDF. The UF was used as a binder.

B. Methods

The dry process of MDF with a targeted density of 0.7 g/cm^3 was manufactured by using 8% and 12% of UF. The hand formed mats of 30x30x0.25 cm and 30x30x0.5 cm were pre-pressed and subsequently hot-pressed at 140^{o}C for 10 minutes, and the pressure applied was 30 kg/cm^2.

The physical and mechanical properties of board were evaluated in accordance to the Japanese Standard JIS 5905-2003 for MDF.

C. Results

The properties of fiberboard depend mainly on its density. Resin content and manufacturing modifications are also important (Tsoumis 1991). Important properties which were evaluated in this study are moisture content, thickness swelling, modulus of rupture, modulus of elasticity, and internal bond.

C.1. Moisture Content

The physical and mechanical properties, resistance to biological deterioration, and dimensional stability of any wood-based product are all affected by the amount of water present (Bowyer 2003). The amount of water in such product is usually termed the moisture content (MC). MC is defined as the weight of the water expressed as a percentage of the moisture free or oven-dry wood weight. Determination of MC during manufacture and subsequent handling to verify conformance standards is generally accomplished by the oven-dry method. The average MC of the MDFs are shown in Figure 1.

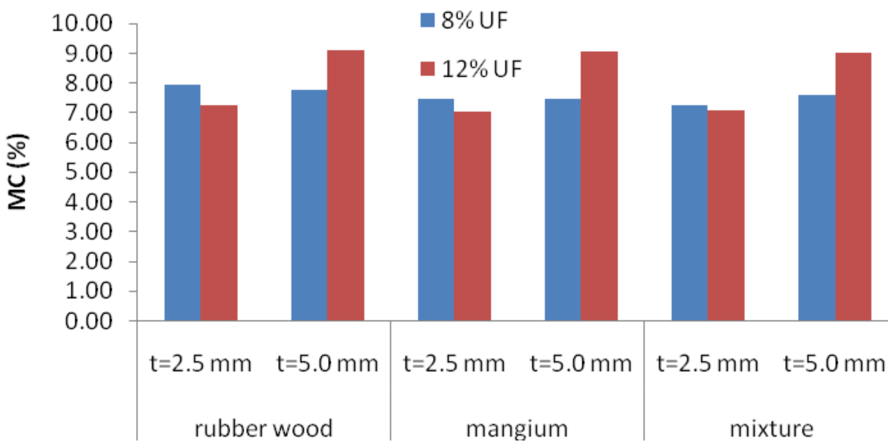


Figure 1. The average moisture content of MDFs

The average value of moisture content was in range between 7.08 – 9.10 %, fulfilling the JIS A 5905 : 2003 standard which require water content of 5 – 13%. The lowest moisture content of 7.08 % was obtained using mixture wood, 12% UF and 2.5 mm thickness. The highest water content (9.10 %) was obtained using rubber wood and 12 % UF.

C.2. Thickness Swelling

As wood dries below the fiber saturation point, that is, loses bound water, it shrinks. Conversely, as water enter to the cell wall structure, the wood swell. This dimensional change is completely reversible process. In wood panel products such as fiber board, however, the process is often not completely reversible, partly because of the compression that wood fibers undergo during the manufacturing process. The average values of the thickness swelling of MDFs are shown in Figure 2.

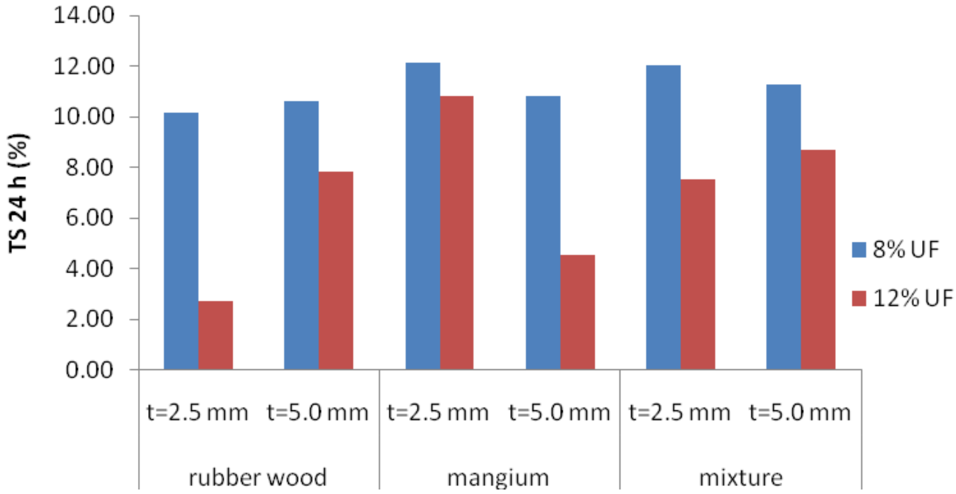


Figure 2. The average thickness swelling of MDFs

In general, the thickness swelling of 8 % UF boards was highest than of 12 % UF boards. The average value of 12 % boards was in between 2.7 – 10.8 %, while for 8 % UF board was 10.2 – 12.2 %. All the MDFs resulted were fulfilling the JIS Standard 5905-2003, and statistically there are not differences between species used. The average thickness swelling resulted in this study was lower than other studies. In commercial MDF (0.60-0.75 g/cm^3) of variable origin, an increase of relative humidity from 30 to 90% resulted in a 0.19-0.28% increase of length and a 4.3-15.0% in thickness swelling (Bennet 1969 *in* Tsoumis

(1991). The dimensional stability of most lumber products corresponds closely to unrestrained value for wood. Forest products produced from fiber, such as MDF, have unique dimensional behaviors under moisture change. These differences result from three basic causes; (1) the degree of restraint to swelling; (2) the degree of compression or crushing that the wood elements; and (3) the effect that adhesive and other additives have on the ability of the wood element to respond dimensionally to moisture change. Synthetic resin adhesive and wax are the most common additives. The wax is intended to provide resistance to liquid water pick-up. Synthetic resin can, however, alter the recovery of the crushed fiber; the greater the amount of adhesive used to manufacture product, the less the thickness swelling response to moisture pick-up. Furthermore, Tsoumis (1991) explained that in all types of fiberboard, and because of a preferred orientation of fiber length in the direction of production, shrinkage and swelling along the length of panels is similar than thickness shrinkage and swelling.

C.3. Modulus of Rupture

Modulus of Rupture (MOR) has become a common measurement of composite board bending strength. MOR is the main mechanical properties of fiberboard (Tsoumis 1991), and it is the ultimate bending stress of a material in flexure or bending (Bowyer 2003). The average MOR value of MDFs are shown in Figure 3.

The average MOR of 8 % UF boards were 22.3 – 40.0 kg/cm^2, while for 12 % UF boards were in range of 27.1 – 45.0 kg/cm^2. Statistically no differences between species and adhesive used, also the same trend resulted for different thickness of MDF. The average MOR value of MDF resulted in this study was lower than that of JIS 5905-2003 standard. Research has shown that the properties are affected by such factors as board density, kind of furnish (fine fiber, fiber bundles), pulp yield and refining, the addition and kind of resin, manufacturing variables (Tsoumis 1991). The imperfection of the fine and coarse fibers mixing are expected cause the lowering of MOR values. Board made of only fine fibers or fiber bundles are generally brittle; flexibility can be improved by mixing fine fibers with coarse fibers or fiber bundles (Maloney 1993). Similar effect was achieved by increasing the proportion of resin (Steinmetz 1973 *in* Tsoumis 1991). This study revealed that temperature of 140^{o}C of hot press had not significant effect to improve the MOR of board. Another study conducted showed that temperature at pressure up to 190^{o}C had a favorable effect on bending strength (Tsoumis 1991).

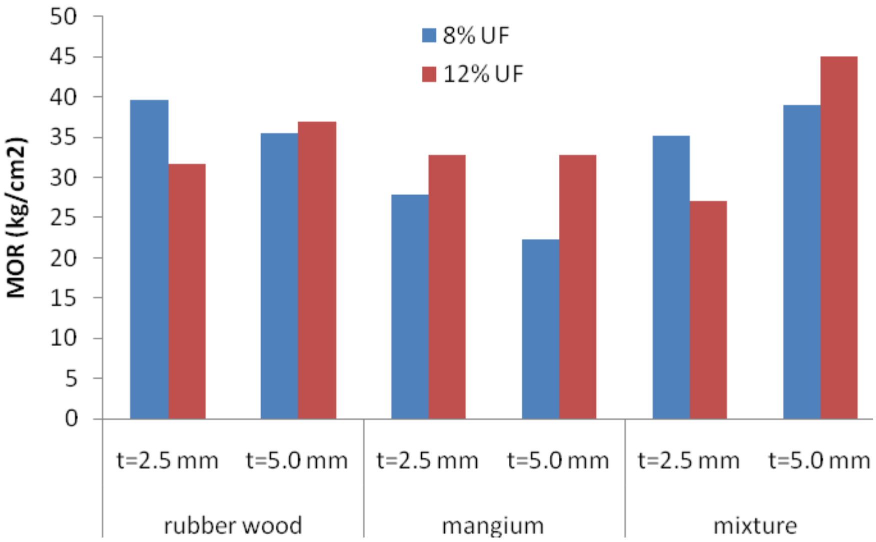


Figure 3. The Modulus of Rupture (MOR) of MDFs

C.4. Modulus of Elasticity

Modulus of Elasticity (MOE) tests the specimen's ability to resist bending. This property is determined from the slope of the straight-line portion of the load-deflection curve (Bowyer 2003). The grater the stress required to produce a given strain level, the greater the resistance to deformation and the higher the MOE of the material. The average MOE value of MDFs are shown in Figure 4.

The average MOE of 8 % UF board were 14880 – 25620 kg/cm^2, and in the range of 12230 – 30360 kg/cm^2 for the 12 % UF boards. The lowest average MOE value of 12230 kg/cm^2 was resulted by using rubber wood with 12 % UF and 2.5 mm thickness. The MDF of mixture wood was achieved the maximum MOE of 30360 kg/cm^2 by using 12 % UF and 5.0 mm of thickness. The MDF resulted in this study was achieved the value of JIS 5905-2003 required, except for the MDF of 2.5 mm thickness of rubber wood and mangium.

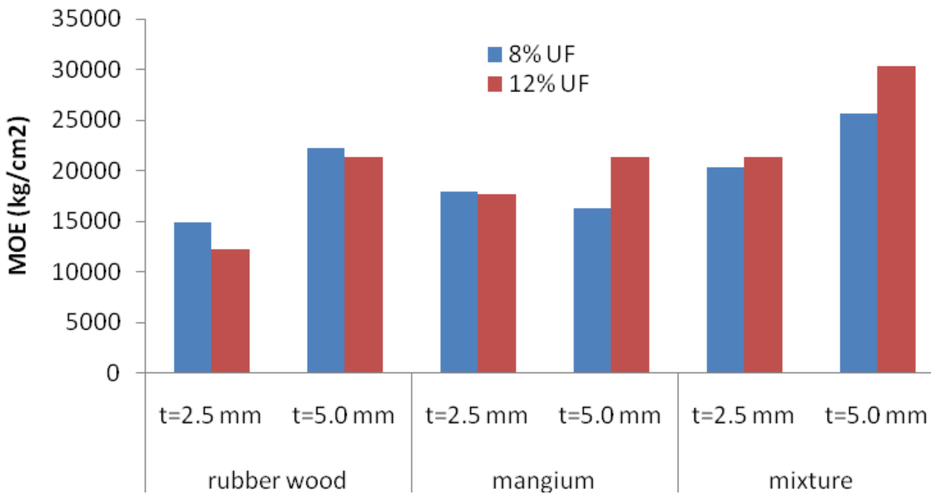


Figure 4. Modulus of Elasticity of MDFs

C.5. Internal Bond

Internal bond (IB) strength is the tensile strength measured perpendicular to the face of the specimen. Tensile strength perpendicular-to-face is a measure of the resistance of a material to be pulled apart in the direction perpendicular to its surface. A 50 mm square specimen is bonded with an adhesive to steel loading block of the same dimensions. The average IB value of MDF resulted in this study are shown in Figure 5.

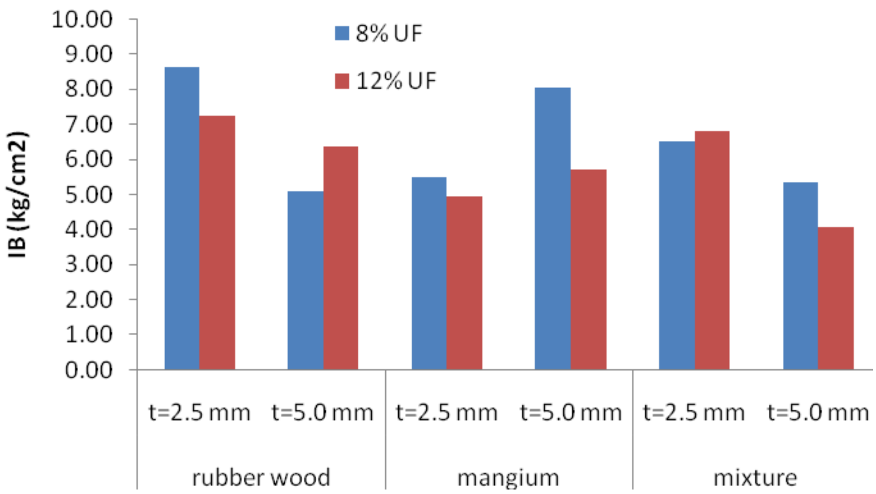


Figure 5. The Internal Bond Strength of MDFs

The average IB value of 8 % UF boards were 5.1 – 8.6 kg/cm^2, while for the 12 % UF boards were in range of 4.1 – 7.3 kg/cm^2. The IB strength of rubber wood was highest than of mangium and mixture wood, where the maximum IB of rubber wood was 8.6 kg/cm^2. All MDFs resulted were exceed the IB strength required by the JIS 5905-2003 standard.

V. CONCLUSION

The excellent physical properties of MDF made from rubber wood, acacia mangium, and mixture of both species were shown. The thickness swelling of 12.2% was the highest value, and it was lower than that of previous study conducted. All the MDFs resulted were lower thickness swelling values than that of JIS Standard 5905-2003, and statistically there were not differences between species being used.

The modulus of rupture of MDF resulted was lower than JIS Standard 5905-2003 required. There were not significant effect of resin added and species used on MOR. However, the MOE value was highest than that of JIS standard, and the species used had a significant effect on MOE of MDF resulted, where the mixture of rubber wood with acacia mangium resulted in a highest MOE value.

AKNOWLEDGEMENT

We thank Isti Sekartining Rahayu, Deded Sarip Nawawi, Yulianto Benhur Siringoringo, Galang Swadaya, Ema Ratri Kartika Juwalita, Wastu, Arvita Erizal, for helping us conducting the research. Additionally we gratefully aknowledge the time participants dedicated to this study.

REFERENCE

1. Bowyer JL, R Shmulsky, and JG Haygreen. 2003. Forest Products and Wood Science An Introduction. Iowa State Press. USA.

2. Maloney TM. 1993. Modern Particleboard & Dry Process Fiberboard manufacturing. Miller Freeman Inc. San Francisco.

3. Rowell RM. 2005. Handbook of Wood Chemistry and Wood Composites. Taylor and Francis. London.

4. Rowell RM, RA Young, and JK Rowell. 1997. Paper and Composites from Agro-Based Resources. Lewis Publisher. London.

5. Tsoumis G. 1991. Science and Technology of Wood. Van Nostrand Reinhold. NY.


CFC
INSTITUT PERTANIAN
BOGOR
ITTO