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PROJECT COMPLETION REPORT

CFC/ITTO/62-PD40/00 Reev. 4(I)

UTILIZATION OF SMALL DIAMETER LOGS FROM SUSTAINABLE SOURCE FOR BIO-COMPOSITE PRODUCTS

Faculty of Forestry
Bogor Agricultural University
Bogor, Indonesia

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PROJECT CFC/ITTO-62-PD 40/00 REV. 4(I): UTILIZATION OF SMALL DIAMETER LOGS FROM SUSTAINABLE SOURCES FOR BIO-COMPOSITE PRODUCTS

Host Government : Republic of Indonesia

Executing Agency : Faculty of Forestry, Bogor Agricultural University (IPB)

Period :

01 December 2007 – 30 November 2010
(with 13 months extension from 01 December 2010 to 15 December 2011)

Faculty of Forestry
Bogor Agricultural University
Bogor, Indonesia
2011

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PREFACE

This Completion report of CFC/ITTO/62-PD 40/00 Rev. 4 (I) Utilization of Small Diameter Logs From Sustainable Source for Bio-Composite Products was prepared with reference to the format provided in Annex D of the ITTO manual for Project Monitoring, Review and Evaluation, ITTO, May 1999.

The project was funded by Common Fund for Commodities (CFC) and International Tropical Timber Organization (ITTO) for a forty nine-month project entitled "Utilization of Small Diameter Logs From Sustainable Source for Bio-Composite Products" (of CFC/ITTO/62-PD 40/00 Rev. 4 (I)) starting from December 1, 2007 to 15 December 2011.

The Project was executed by Bogor Agriculrural University (IPB) - Indonesia in collaboration with Forest Products Research Centre Ministry of Forestry (FPRC MoF) – Indonesia, Universiti Putra Malaysia (UPM), Forest Product Research and Development Institute (FPRDI) – Philippines, Forest Research Institute (FRI) – Papua New Guinea. This CFC/ITTO Project has two national partners, namely PT. Sumalindo Lestari Jaya and PT. Bumi Sari Kusuma.

The overall achievement of this forty-month project was very significant and remarkable to the bio-composite industries. This was indicated by the number of companies which actively involved to support the execution of the projects. The remarkable contribution comes from PT. Sumalindo Lestari Jaya, PT. Sari Bumi Kusuma, PT. Andatu Plywood Industry, PT. Sumber Graha Sejahtera, PT. Majora inkas, PT. Paparti Pertama, PT. Masari Dwisepakat Fiber, PT. Kutai Timber Indonesia, PT. Erna Djuliawati, and PT. Wijaya Tri Utama.

On behalf of the Project Executing Agency, I would like to acknowledge all the assistance and guidance received from CFC and ITTO. Without its financial support, this project would have not been implemented and successfully completed. Special thanks go to Mr. Ramon Carrillo (Forest Industry Project Manager, ITTO) and Ms. Yukiko Tomihisa (CFC Project Assistant Manager) for their excellent assistance and support during the implementation of the project. Appreciation and thanks too, to the project collaborating agencies: FPRC MoF – Indonesia, UPM – Malaysia, FPRDI – Philippines, and FRI – Papua New Guinea. To the companies supported the project and the members of the Project Steering , we would like to express our sincere thanks and appreciation for their support,

guidance and invaluable inputs and constructive criticism. Colleagues in IPB and FORDA are gratefully acknowledged for their comments, inputs, and support during the execution of the project activities.

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

Bogor, March 2012
Project Coordinator,

Prof. Yusuf Sudo Hadi

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EXECUTIVE SUMMARY

The project has collected and made available comprehensive information on small diameter logs (SDL) and their potential utilization in value added products for the bio-composite products. The small diameter logs could be produced from plantation and natural forests. The specific objectives of this project are the following:

a. To asses market needs of biocomposite products made from SDL from the tropical rain forest.
b. Determine the wood properties and utilization technology of SDL and transfer this technology for manufacturing of value added bio-composite products.

The research was focused on the present and future markets of bio-composite products, the physical and mechanical properties of SDL as raw material of biocomposite products, and fundamental properties of bio-composite products such as Plywood, Laminated Veneer Lumber (LVL), Glued Laminated Timber or Lumber (Glulam), Particleboard and Medium Density Fiberboard (MDF). Outcome of the research were implemented to the mills for optimal products and they could be sold in the global market with fulfilled the standard requirements.

The review market data and examine trends to understand what bio-Composite products are sold today and where are they sold, were the first focused of this study. The market and trend review provide an analysis of production, export, import, consumption, trade and prices for each wood-composite products: plywood, veneer sheets, particleboard and fiberboard; in World, ITTO countries, Indonesia, Malaysia, and Papua New Guinea.

Veneer sheet production during the period of 2002-2006 by ITTO country member was more than 15 million m^3 and produced by Malaysia, Brazil, Indonesia, Ghana, India, the Philippines, and Côte d'Ivoire. Major tropical veneer sheet importers were The Republic of Korea, Taiwan, French, China and Italy. For plywood production in the same period was more than 84 million m^3 produced by Indonesia, Malaysia, Brazil and India. Major tropical plywood importers were Japan, United States of America, The Republic of Korea, Taiwan, China, and, a few Western European countries. Particleboard production was about 19 million m^3 and produced by Brazil, Thailand, Malaysia, and Indonesia. For fiberboard production in the same period was about 24 million m^3 produced by Brazil, Malaysia, Thailand, Indonesia, Venezuela and India.

Based on current world's demand and its trend, shares of Indonesia's bio composite product imports of total bio composite product imports in each major country destination as reported by importer countries and considering the principal policies and market forces that are likely to affect the global and regional markets, both plywood and medium density fibreboard made from small diameter log would be plausible to be developed for international market (i.e. Japan, China, the Republic of Korea, Taiwan, Saudi Arabia, and United Arab Emirates) as well as for domestic market. Meanwhile, veneer sheets and particleboard made from small diameter log would be plausible to be developed for domestic market.

The second focused of this study was to identify suitable wood species and evaluate physical and mechanical properties of small diameter logs. Research on small diameter logs of 24 species from natural forest and 14 species from plantation or community forest in Indonesia was carried out for physical, mechanical, and chemical properties regarding to biocomposite products feasibility. The results showed that low and medium densities wood were feasible for bicomposite products, and regarding to the result of market analysis, the prospectus products are plywood, laminated veneer lumaber (LVL), particleboard, medium density fiberboard (MDF), and glued laminated lumber (Glulam).

UPM Malaysia considered 9 groups of SDL have the potential as alternative raw materials for the production of bio-composite products, especially for plywood, laminated veneer lumber, oriented strand board (OSB), cement board and medium density fibreboard manufacturing. FPRDI Philippine did research on *Eucalyptus citriodora, Eucalyptus europhylla* and *Alstonia macrophylla* G. Don in terms of basic properties, and these wood species were investigated for cement board feasibility. PNG Forest Research Institute and Bogor Agricultural University did research on basic properties of 6 wood species of PNG, and several SDL species are feasible for bio-composite products (plywood, LVL, glulam, particleboard and MDF), however some of them only feasible for particleboard and MDF.

In order to produce the high quality product, several milling issues and quality control concerns for raw material were identified. Some milling issues regarding to utilize SDL for LVL and plywood are determining on wood fundamental properties, spindle less rotary machine for veneer production, low quality of produced veneer, hot press veneer drying, pay attention to veneer repair and compose, gluing technique, and pressing process. The main problem to be addressed in Glulam production using SDL is in board production, drying lumber (lamella), and gluing process. In particleboard manufacturing reported that there is no technical problem in producing high quality particleboard and MDF using SDL, however low density SDL is avoided due to the economical point of view.

Regarding to the change of logs supply in Indonesia from natural forest to plantation or community forest, monitoring system for quality and quantity of incoming raw material is very important in terms of wood species, grade, moisture content, dimensions, volume, and visual appearance of SDL for checked and documented. The important issues related to the utilization of SDL as raw materials for Bio-composite products (glulam, LVL, plywood, particleboard and MDF) are wood density, spiral and interlocked grain, knots, juvenile wood, decay, and extractive content. The SDL incoming raw material should be processed as soon as possible due to the low natural durability.

The following research was done for fundamental properties of biocomposite products manufactured from SDL. Evaluation of appropriate properties of plywood from SDL can be mentioned that the surface quality of Urea Formaldehyde bonded and Melamine Formaldehyde bonded plywoods was classified as grade 1, and all of the plywood shear strength parallel and perpendicular to the face or back veneer grain in dry and wet condition fulfilled the JAS Standard for plywood No. 232 year 2003. The average rotary veneer yield of SDL from community and plantation forest using spindle-less rotary lathe was 62 % with standard deviation of 9.9%.

Evaluation of appropriate properties of Laminated Veneer Lumber (LVL) from SDL, the moderate specific gravity wood possessed had 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 SDL of moderate specific gravity woods were suitable to be used for structural uses such as for supporting poles, frame in house, roof timbering, floor joint, and other structural uses.

Evaluation of appropriate properties of Glued Laminated Lumber (Glulam) from SDL the some Glulams were classified to the group E10-E11 based on modulus of elasticity properties, but based on the value of modulus of rupture Glulam was classified or grouped as E10-E17, and some the other had lower grade depending on wood species used. As an example Glulam made from mixed species from jabon-mangium and mangium-manii were not eligible for construction (E<E10), but Glulam made from mangium, jabon and mixed pine-mangium met the JAS (2003) can be used for wood construction and quality pertained E10 or more. The recovery of glulam manufacture from SDL plantation timber ranged from 31-53% with an average of 38%.

Evaluation of appropriate properties of particleboard from SDL could be mentioned that wood species used in the experiment could be utilized for particleboard and these species did not much affect particleboard properties, single species and mixture of species were not different regarding to physical and mechanical particleboard properties. Low density particleboard was still lower in terms of performance related to physical and mechanical properties, but medium and high density particleboards exhibited satisfied performance for physical and mechanical properties. Regarding to termite test the results showed that higher wood density had higher resistant to termite attack, and the resistance was related to its constituent wood or in other words more resistant wood species produced more resistant particleboard to termite attack.

Evaluation of appropriate properties of medium density fiberboard (MDF) from SDL could be mentioned that physical properties of MDF made from rubber wood, mangium, and mixture of both species were excellent and was matched to JIS Standard 5905-2003. The MDF modulus of rupture was lower than the JIS Standard 5905-2003 requirements, however the modulus of elasticity (MOE) value fulfilled JIS standard, and the species used had significant effect on MOE of the resulting MDF, where the mixture of rubber wood and mangium wood resulted in a highest MOE values.

The next activities were to determine equipment needs for production and manufacturing constraints, including review equipment availability, and identify source and costs for equipment. Regarding to equipment availability, all the mills have satisfied equipment required and can produce biocomposite products for export marker to varied countries destinations. In conventional plywood mill the raw material uses logs with diameter more than 40 cm, but nowadays and further future the logs supply will be dominated by SDL, in this case the mill has to provide some equipments namely spindle-less rotary lathe and hot press dryer, and also more activity in veneer repairing and veneer composing. But for the other products (not based on veneer products) the available equipment in the mills are still satisfied.

Information of source and costs for equipments of hot press dryer for veneer and spindle-less rotary lathe are mainly produced by China because the price is much cheaper compare to the equipments produced by Taiwan, Japan, Germany, Italy and other countries. As an example, hot press dryer BJG48-40-12 made in China costs USD 46,875, spindle-less rotary lathe 9' 9HL-W-3-350 consists of input conveyor costs USD 4,162, spndle-less lathe costs USD 49,210, output conveyor USD 4,995, and spindle-less rotary lathe 9' made in Taiwan costs USD 90,000. Other spindle-less rotary lathe 5' 5HL-W-3-350 made in China costs USD 22,800, and spindle-less rotary lathe 5' made in Taiwan costs USD 60,000.

Regarding to implementation of SDL for biocomposite products, work with mills to identify issues when incorporating SDL into the production process was done. Implementation of SDL for plywood mills has to pay attention that the portion of high quality plywood resulted from SDL is very low as compared to that of large diameter log (LDL), however laminated veneer lumber, glulam, medium deinsity fiberboard and particleboard industries did not report any inferior products. Some critical issues in SDL implementation compared to LDL at plywood mill are log pond needs more space for logs storage, debarking and log cutting have more activity, SDL cannot be round up in the conventional rotary lathe because the minimum diameter to be processed in conventional rotary lathe is 40 cm, and plywood produced from SDL is relatively lighter compared to those made from LDL, veneer resulted from SDL cannot be dried using conventional dryer because it tends to be wavy and the portion of narrow veneer was very high and the veneer resulted from SDL should use hot press dryer, veneer storage could be a problem because dried veneer easily attacked by mold due to the minimum extractive content, veneer resulted from SDL need repairing process with much more time and skilled human resources as compared to those of LDL veneer, the capacity of veneer jointer decreased sharply when incorporating SDL into the production process because the portion of narrow veneer was very high as compared to those of LDL.

The next process is assembling veneers to be plywood, and some attention should be intensively done at veneer arrangement or veneer composing which needs more time because so many jointing in one sheet veneer; moreover arrangement of face and back veneer should be conducted more carefully, glue spreading needs more time when incorporating SDL into the production process as compared to those of LDL because glue spreading process need two times process for avoiding veneer being overlapped and detached and for avoiding core gap, prepress should be arrange very carefully to adjust glue penetration and veneer overlap, materials requirement on the plywood industry increased sharply especially glue tread, hot melt, gummed tape, cutter and knife because the total number of jointer increased by about 300 %, other aspect is also important i.e. skill of human resources should be improved to facilitate production of high quality plywood made from SDL.

The other work was done to identify potential trade barriers trough standards for selected products and markets, to ensure compliance and to verify that appropriate test were conducted. Several standards known for bio-composite products such as plywood, LVL, glulam, particleboard and MDF. Among the international standard being used by Indonesian bio-composite industries are Japan Standard (JPIC/JAS), British Standard (BS), United States Standard (IHPA), German Standard (DIN). However, Japan Standard is the most popular used in Indonesian Bio-composite industries. Field research to the various bio-composite (plywood, LVL, glulam, particleboard and MDF) industries in

Indonesia shown that most of the bio-composite products quality which was produced from small diameter logs fulfills the international standards.

To ensure quality assurance, establish quality control procedures were conducted ensuring that products are meet with certain standard. Quality control involves the examination of a product or process for certain minimum levels of quality. The goal of a quality control is to identify products that do not meet a company's specified standards of quality. If a problem is identified, the job of a quality control team or professional may involve stopping production temporarily. Depending on the particular product, as well as the type of problem identified, production or implementation may not easy entirely.

The quality characterize of the products depends on the panel being produced. Since the plywood is produced by assembled from layers of veneer, the moisture content and shear strength is the critical quality that shoud be meet with a certain minimum levels. The surface quality of plywood, such as knot, roughness, decay, discolouration, etc. are the additional quality characterize of plywood which will drive the market penetration. In case of glulam and LVL, the bending strength and shear strength are the essential quality that should be fulfilled. The density, internal bond strength, and bending strength are the performance of particleboard and MDF that should be meet with the certain standard.

Concerning coordination with international standard bodies, Indonesian USDL team have actively involved to contribute for ISO standards improvement through the Ministry of Forestry Republic of Indonesia based on the USDL research results, experiences and their expertise in bio-composite products.

To complete the project, regional workshop has been organized and convened in Bogor Indonesia in December 2010 to facilitate the transfer of technology on SDL management and utilization for biocomposite products to regional academicians, the timber industry sectors, and related government officers. Scientists, students, researchers, related industries representatives, birocrate or decision makers, experts, related association or society, and Non-Governmental Groups from Indonesia, and some representatives from Malaysia, Philippines, and Papua New Guinea have been involved the actively. We discused all topics concerning current and future markets of bicomposite products, basic properties of some wood species from Indonesia, Malaysia, Philippine, and Papua New Guinea and the possibility for biocomposite products, biocomposite products properties from SDL utilization, and the issues to implement SDL to the mills production.

We realize that SDL especially from plantation forest will be the future logs supply, and it is possible to utilize for biocomposte products such as plywood, laminated veneer lumber, glued laminated lumber (glulam), particleboard, medium density fiberboard, and also cement board. All the boards can meet the standard requirements by regulating the factors in processing variables. Furthermore facing to global market orientation, logs from sustainable forest management is required and the products should have a document explaining timber legality assurance.

I. PROJECT IDENTIFICATION

A. CONTEXT

Forest provides a wide array of benefits to human society, which is either tangible (e.g., timber, non-wood forest products) or intangible (e.g. water and soil protection, recreation, existence value) in nature. Future role of forest in Indonesia will be the role in industrialization, promoting sustainable raw-material supply and diversifying into non-timber products, in respect to the ecological function. Therefore, the Indonesian authorities prioritize the development of sustainable forest management of tropical rain forest and timber plantation. It is stated in "GBHN" (Indonesian Development Guidelines) and UUPK No. 41 Th. 1999 (Forestry Regulation, 1999).

UUPK No. 41, 1999 describes clearly general principles of management, development and utilization of the national forest estate and natural forest resources. While, forestry policy underlines the importance of improving the knowledge on potential timber resources, the management of that potential and the planning of its utilization. Forest utilization will be described to the added value products to optimize the use of raw materials coming from sustainable sources.

Ministry of Forestry, the Republic of Indonesia, promote also the forest research development on sustainable forest management, sylviculture and wood utilization efficiency as well.

The national program on Research and Technology issued by the Indonesian National Research Council also give priority to the Environment Development Technology. Indonesia confirms its adherence to international objectives. Among them are the ITTO Target 2000, the objectives and recommendation of the United Nations Conference on the Environment and Development held in Rio de Janeiro in 1992, the Convention on International Trade in Wild Fauna and Flora Species Threatened with Extinction (CITES) and the world heritage.

Indonesia, Malaysia, the Philippines and Papua New Guinea as members of ITTO have an obligation to support the ITTO objectives towards the sustainable forest management. In other hand, Papua New Guinea exports round logs amounted to 3.0 million m^3 per annum, while the PNG Logging Code of Practice is being developed. The Forest Research Institute of Papua New Guinea is fully aware of the issues of certification and sustainability. The transfer of technology of bio-composite to the other ITTO producer countries will enhance the product diversity made of wood. It may influence to the policy of the countries**.**

This research project contribute directly and indirectly to the promotion, further processing and manufacturing of bio-composite products made of SDL to achieve higher added value of small-diameter logs such as to provide more wood supply for wood-based consumption, increasing wood industry investment, increasing of wood-based products and export income, to provide more job opportunities for the local people and regional growth income. The results of the project created more job opportunities to the community especially on plantation, logging, wood processing, marketing and distribution activities. Various bio-composite products have being produced, therefore, industry will used the raw material efficiently. Societal value to the raw material will affect the economic role of wood-based industry in Indonesia, Malaysia, Philippines, and Papua New Guinea.

The positive environmental impacts of this research is promoting the wood utilization efficiency, and to conserve the remaining natural forest. The negative impact of SDL exploitation may affect the forest structure and composition if the implementation of wood harvesting is not conducted properly.

The appropriate structural of residual stand before and after logging is shown in Figure 1.

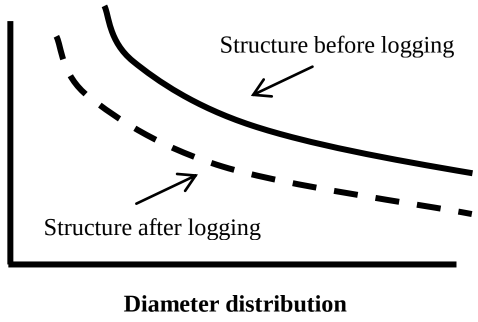


Figure 1. Forest structure condition before and after logging

B. ORIGIN AND PROBLEM

Indonesian Selective Cutting and Replanting System have been implemented in Natural Production Forest in Indonesia since 1972. Its minimum diameter cutting is 50 cm. In fact, genetically and environmentally there are some tree species that never reach the minimum diameter cutting of 50 cm. SDL of 10-49 cm represent 70 % of natural forest biomes and 90% of community forest. Technically these species could be used as raw materials for bio-composite industries and economically they are also marketable. Utilization of small-diameter logs might conserve the remaining natural forests.

In this proposed research project, bio-composite define as materials that have the commonality of being glued or bonded together. There were five types of dominant bio-composite products in the market now, namely plywood, LVL, Glulam, particleboard and MDF. The schematic problem tree of SDL utilization is shown in Figure 2.

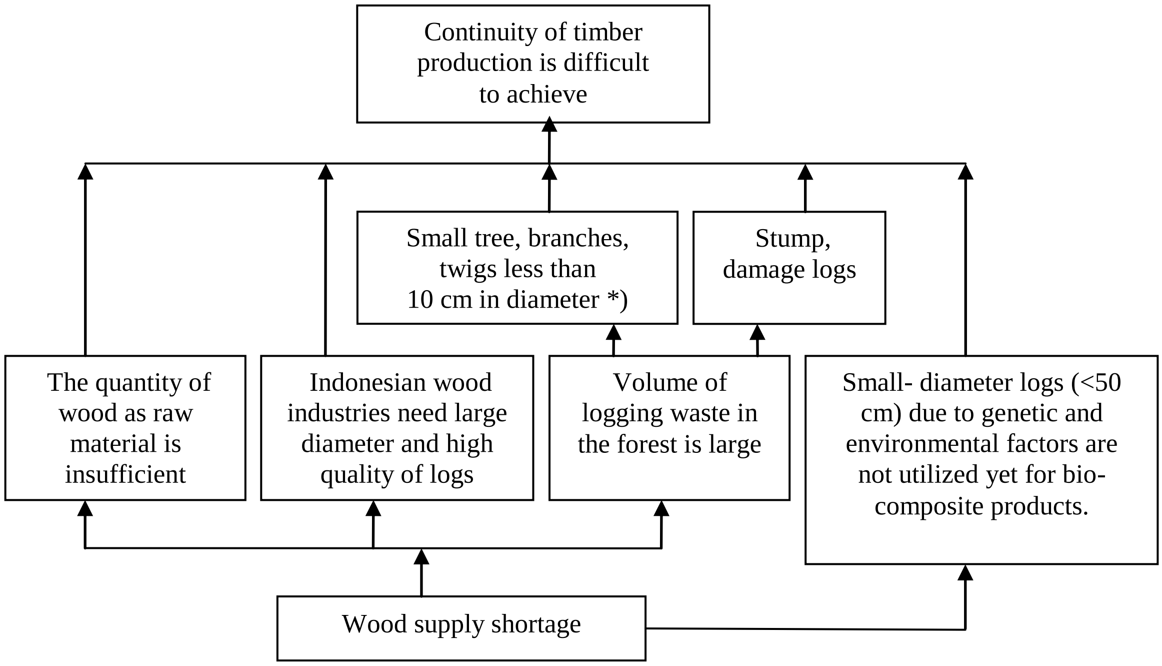


Figure 2. Problem Tree of Small-Diameter Logs (SDL) Utilization Resulted from Genetic and Environmental Factors.

Note: *) Research on utilization of small tree, branches and twigs less than 10 cm in diameter has been done by FORDA.

The Indonesian annual log production in 1998 was 21.5 million m^3, while the wood demand in the same year was 59 million m^3, so there was a huge amount of wood supply shortage namely 38.5 million m^3 (Manurung, 1999). Those logs are classified as high quality and large-diameter logs. Up to now, the bio-composite industry tends to use the high quality and large-diameter logs. While, the standing stock of those kinds of trees is declining.

In this research project, SDL is defined as tree species/log which has diameter less than 30 cm, while the bio-composite products were plywood, Laminated Veneer Lumber (LVL), Glued Laminated Timber (Glulam), particleboard and Medium Density Fiberboard (MDF).

In order to overcome the wood shortage problem, utilization of small-diameter logs is one of the important prospectus alternatives. The utilization of SDL nowadays in Indonesia become very popular, especially in plywood industry, LVL, glulam, particleboard and Medium Density Fiberboard.

2. PROJECT OBJECTIVES AND IMPLEMENTATION STRATEGY

The mission of Indonesian Forestry Development is to manage the forest in sustainable way and to minimize the logging impact; to produce raw materials for wood industry (bio-composite industry) from the sustainable sources.

At the present time, there are limited timbers species on the wood markets or traded internationally due to their unknown fundamental properties. Such condition accelerates deforestation to find out the most marketable species.

The project was executed in the state natural forest production on lowland tropical rain forest and community forest. Its supervision was carried out by the Project Steering Committee that consisted of the representatives of the Ministry of Forestry, the Directorate General of Forest Utilization, the ITTO representative, CFC representative, and the representatives of Project Executing Agency and the representatives from the forest concession holders partners (Alas Kusuma Group, and Bumi Raya Group). The Project Implementing Agency was the Faculty of Forestry, Bogor Agricultural University, Bogor, Indonesia.

The scientists supporting the project were invited to be involved in the project activities from Bogor Agricultural University Indonesia, Ministry of Forestry Indonesia, UPM Malaysia, FPRDI Philippines, and FRI Papua New Guinea.

The USDL project concern with plywood, LVL, Glulam, particleboard and MDF. Such kind of bio-composite products and technology in Indonesia, Malaysia, Philippines, and Papua New Guinea is still needed.

Project Objective

The development objective of the project is to contribute to the continuity of timber production, forest resource security, socio-benefit from sustainable sources, determination of SDL wood properties, and technology transfer of utilization of SDL for value-added bio-composite products. The specific objectives of the project are as follows:

1. To asses market needs of USDL from the tropical rain forest.

2. Determine the wood properties and utilization technology of SDL and transfer this technology for manufacturing of value – added bio-composite products.

Project Strategy

Tropical rain forest represents high tree diversity and low timber production (Freezeilah, 1998). The existing condition showed that most of Indonesian bio-composite industries, especially plywood and sawmill industries need large diameter and high quality of wood, while 70 % of biomes is dominated by SDL that is controlled by genetic and environmental factors.

At the present time, the utilization of SDL to help alleviate the growing wood shortage is not yet a reality. This situation is the results of limited information on wood processing technology and inadequate data on fundamental properties of SDL, their logging system and their silvicultural aspects. Schematic reason for selection of SDL utilization for bio-composite industry is shown in Figure 3. Detail explanation concerning problems, causes and alternative solutions is shown in Table 1.

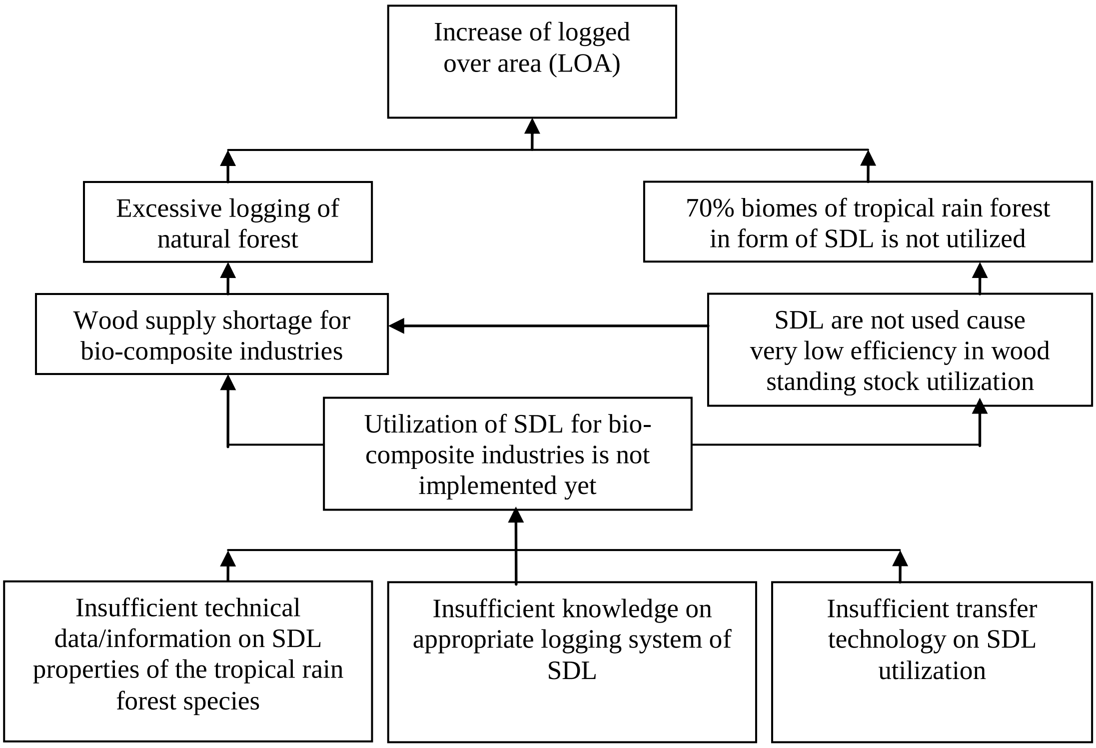


Figure 3. Reason for Selection on Small-Diameter Logs Utilization for Bio-Composite Industries.

Table 1. Clarification of Problems, Causes and Alternative Solutions

Problem	Causes	Alternative Solutions
Utilization of small-diameter logs (SDL) for bio-composite industries is not implemented yet	Insufficient data / information on SDL potency in tropical rain forest	• Assess all available information from other sources to obtain comparable and usable results from other countries with similar problems. • Evaluation and determination of tropical rain forest on their ability to produce Small Diameter Logs.*
	Insufficient knowledge on appropriate logging systems of small-diameter logs.	• Assess all available information from other sources to obtain comparable and usable results from other countries with similar problem. • Carry out field experimental test to determine the appropriate logging system for SDL.* • Evaluation and determination of appropriate logging technology / system for Small Diameter Logs.* • Hire the expert on logging system.*

Utilization of small-diameter logs (SDL) for bio-composite industries is not implemented yet	Insufficient technical data on wood properties of small - diameter logs	• Assess all information available and consultation to the other experts. • Comparable and usable results from other countries on SDL utilization. • Capacity building of Wood Technology Division to carry out research on SDL properties. • To conduct a research on the wood properties of small diameter logs.
	Insufficient transfer of technology on utilization of small - diameter logs.	• Information dissemination on utilization of bio-composite products made of SDL. • Training course/workshop on bio-composite technology. • Collaboration with other countries, which are more advance on SDL utilization technology.

Note : * it is not executed in this project due to limited budget.

Utilization of small diameter logs for bio-composite industry is not implemented yet. It is caused by three major problems, namely insufficient data / information on SDL potency in tropical rain forest, insufficient knowledge on their appropriate logging systems, insufficient technical data on their wood properties and insufficient transfer of technology on utilization of small - diameter logs.

Among the alternative solutions in Table 1, the best strategies to solve these problems would be (1) to conduct the evaluation and determination of tropical rain forest on their ability to produce small diameter logs, (2) to conduct evaluation and determination of appropriate logging technology / system for

Small Diameter Logs, (3) to conduct a research on the wood properties of small diameter logs for bio-composite products, (4) to conduct workshop on bio-composite technology, (5) to conduct the collaboration with other countries, which are more advance on SDL utilization technology.

The inventory of small diameter logs will illustrate the ability of a forest that might be possible to produce the trees that their growth never reach the minimum diameter cutting as required by the Indonesian Selective Cutting and Replanting System (50 cm). It is possible that those species have good economical value. Those small diameter logs then must be examined to determine their properties to meet the requirements of certain bio-composite products. Since the bio-composite industry needs skilled persons, the training course/workshop on bio-composite technology is a compulsory for the producer countries such as Indonesia, Malaysia, the Philippines, and Papua New Guinea.

Risks

Utilization of SDL is a relatively new idea of wood utilization efficiency and policy perspective in Indonesia, Malaysia, Philippines, and Papua New Guinea. With regard to the project results implementation, there are some risks of failure if there are lack of cooperation with the private timber sectors, governments and lack of adequate community/society support. Therefore, a firm cooperation with all stakeholders are needed to optimize the resources (scientists, equipment, facilities, and fund).

During the implementation of the project, there was a time adjustment from 3 (three) years project activities to 4 (four) years without any additional project fund. This happen because there were difficulties in collaborators communication since the collaborators come from Malaysia, Philippines and Papua New Guinea. However, during the execution of the project, utilization of SDL in all project collaborators country increased sharply, especially in Indonesia, Malaysia and Philippines. In case of Indonesia, some small scale plywood industries have been established in Java island using small diameter logs for plywood production.

3. PROJECT PERFORMANCE (PROJECT ELEMENTS PLANNED AND IMPLEMENTED)

The project outputs and activities as written in the proposal were implemented very well even though some activities have been executing behind the schedule due to the external constrain of the PEA such as difficult in communication, personal changes in collaborator staffs, and other administrative problems. The research results classified as very good and some international publications have been made by the scientists involved. All the scientific publications acknowledge ITTO and CFC as sponsor of the research.

A. Outputs

a. Specific Objective 1: To assess market needs of SDL from the tropical rain forest.

- Output 1.1: Assess market needs.

b. Specific Objective 2: Determine the wood properties and utilization technology of SDL and transfer this technology for manufacturing of value-added bio-composite products.

-Output 2.1. Address technical gaps in producing bio-composite products.

-Output 2.2. Determine equipment needs for production and manufacturing constraints.

-Output 2.3. Address production coordination issues.

-Output 2.4. Mitigate potential trade barriers.

-Output 2.5. Comply with relevant standards.

-Output 2.6. Conduct regional workshop.

B. Activities

Output 1.1. Assess market needs.

-Activity 1.1.1. Review market data and examine trends to understand what

bio-composite products are sold today and where are they sold.

Plywood production from ITTO producer countries decreased by 7.0% over the period 2002-2006. Over that period, about 84.32 million m^3 of plywood were produced which accounted for 25% of the world's production of plywood. The Asia-Pacific region provided 74.9%, the Latin America region 22.9%, and the Africa region 2.2%. The largest single producer was Indonesia, which alone accounted for 31.5% of ITTO producer countries production. Other important producers were Malaysia (28.8%), Brazil (20.3%) and India (11.3%). Major tropical plywood importers in 2006 were Japan, United States of America, The Republic of Korea, Taiwan and China. A few Western European countries were also important importers, though smaller.

Veneer sheet production from ITTO producer countries increased sharply by 33.6% during the period 2002-2006. Over this period, about 15.78 million m3 of veneer sheet were produced which accounted for one third of the world's production of veneer sheets. Of this 54.3% was provided by the Asia-Pacific region, 24.3% by the Latin America region, and 21.4% by the Africa region. Main producers were Malaysia, Brazil, Indonesia, Ghana, India, the Philippines, and Côte d'Ivoire, which together accounted for 87.2% of ITTO producer countries production. Major tropical veneer sheet importers in 2006 were The Republic of Korea, Taiwan, French, China and Italy. Japan, formerly a major tropical veneer importer, became less significant with imports continuing to decline.

Particleboard production from ITTO producer countries increased slightly by1.5% during the period 2002-2006. Over this period, about 18.96 million m3 of particleboard were produced which accounted for 3.9% of the world's production of particleboard. The Latin America region provided 69.3%, the Asia-Pacific region 29.4%, and the Africa region 1.3%. The largest single producer was Brazil, which alone accounted for 59.0% of ITTO production. Other important producers were Thailand (14.25), Malaysia (8.4%), and Indonesia (6.0%).

Over the period 2002-2006, fiberboard production from ITTO producer countries increased sharply by 39.5%. Over this period, about 24.51 million m3 of fiberboard were produced which accounted for 9.5% of the world's production of fiberboard. Of this 53.7% was provided by the Asia-Pacific region, 45.7% by the Latin America region, and 0.6% by the Africa region. The main producers were Brazil (37.0%), Malaysia (27.7%) and Thailand (14.8%), which together accounted for 79.5% of ITTO production. Other important producers were Indonesia (8.7%), Venezuela (5.6%) and India (2.5%).

In case of PNG**,** PNG has been a net exporter of wood products for many years while its domestic consumption is low. Round wood log exports have been the main export commodity, with about 90 percent of it harvested timber volume exported as logs.

In year 2000, the total volume of log harvest in PNG only reached 18,761,960 m^3. For this volume, the royalties was 18,761,960 in Kina. There was a decreased amount of volume harvested in following year. It decreased about 230,149 m^3 in volume of logs harvested in 2001 and the royalties got decreased in to 16,470,431 in Kina. But, in 2002, the volume of volume harvested increased dramatically, from 1,646,047 m^3 in 2001, to 2,140,953 m^3 in 2002. The royalties also got increased in to 21,425,672 in Kina. This means that there were an increased volume of logs harvested about 76.88 % and increased of royalties about 76,87%. In 2003, the volume of logs harvest wasn't really different with volume harvested in 2003. the royalties also wasn't show any significant change in amount although there were an decreased about 289,628 in kina. One year later, the volume of harvested increased about 676,616 m^3 (32.21%) and the royalties also grown up in to 28,347,957 in Kina (increased 25%). In 2005, the table shows increases volume of log harvested but decreases royalties in Kina. There was also a significant increased volume of logs harvest in 2006. In 2006, the volume of logs harvest reached 3,389,891 m^3 (1.19 times higher than 2005).

Year 2008, there was an decreased logs volume harvested about 20.8 %, however the royalties increased 16 %. One year later, the logs harvest didn't increased significant but the royalties could reach 45,725,183 in Kina. In 2010, the logs harvest reach 3,756,105 m^3 and the royalties 62,763,469 in Kina. The royalties is the biggest amount of royalties for last ten years.

The forest industry is considered by the Government as a major player in the economic development of the country. There are about 25 foreign-owned logging companies operating in PNG, the majority coming from Malaysia. Most of these companies are connected in the sense that they are owned by one large conglomerate, but operating under different company names. One particular company controls close to 45 percent of all logging and log export operations in the country, and is one of the five companies that together control over 80 percent of the log export market.

Over the past two decades, the number of companies operating in forest and wood-based industries has declined – from an early count of more than 40, to about 25. This decline has largely been a result of diminishing timber resources that are available to sustain these operations. Many of the operations that commenced in the 1970s and 1980s and even 1990s have been forced to close as they were not harvesting wood at a sustainable level. Some companies are now re-entering logging coupes so as to sustain their operations. Others are involved in salvage operations where the landowners have indicated an interest to convert their lands to agricultural projects.

Most of the companies in PNG are involved to a large extent in harvesting and export of round wood logs, with less than 10 percent of the annual log quota being processed on shore. The country has only one chip mill, two plywood mills, five major sawmills, and two veneer mills. Apart from these mills, a small volume of sawn timber is processed domestically into furniture.

The technology used in the timber industry is varied, but in general not sophisticated. There have been some investments in new technology, especially in downstream processing plants such as ply mills, veneer mills, and some sawmills. Much of the equipment is recycled, especially in the logging equipment used for harvesting and transportation of logs.

A few furniture-making companies have some level of sophistication in the machinery in place; however, the bulk of the companies involved in the timber industry do not employ very high technology. This is partially a result of the relative how wage structure that enables companies to operate without any real need to mechanize their operations with high technology.

Most of PNG's trade in forest products is mainly in the form of round logs for export to countries such as China, Japan, India, Vietnam, Republic of Korea, Malaysia, Philippines, and Taiwan, P. O. C.. This is allowed by exports in woodchips, sawn timber, plywood, and veneer. Small amounts of furniture have been exported. PNG has over the years also been importing forest products, mainly finished products as in household/office furniture, building materials, and other products such as laminated timber for construction. All of PNG's paper requirements are imported.

The majority of the timber harvested from PNG forest is exported. PNG logs are exported to 11 countries, all in the Asian region. More than 80 percent of log exports go to just China/Hong Kong, Korea and Japan. China is the principal market for round logs from PNG; it imported over one million cubic meters of logs from PNG in 2002 rising to 1.7 million cubic meters in 2005 – accounting for 74.6 percent of PNG's log exports. The major markets for processed and semi-finished products are Australia, New Zealand and various South Pacific countries. Veneer is predominantly exported to China and South Korea.

The forest industry has mainly been log export oriented. About two million cubic meters of tropical logs are exported annually making PNG the world's second largest exporter of tropical logs after Malaysia. In 2005, the export of forest products represented 4.7 percent or K476.3 million of the value of all exports from PNG (K10,147.5 million) making forest products the largest non-mineral export from PNG in terms of value.

In year 2005, logs export volume reached 2,305,383 m^3 and total revenue US$ 139,791,307. This number increased for next two years until year 2007 which the total volume of export reach 2,863,349 m^3 with the average price US$ 71.89 after 2007, for next two years the logs export volume decreased in to 2,066,854.145 m^3 and also the total revenue decreased in to US$ 168,240,897 in 2009. In another side, the table never shows any decreased of average price from year 2005 until 2010.

West New Britain is the largest province in logs export volume. The largest volume 920,910.138 m^3 was exported in 2007. The second largest province in logs volume is West Sepik with total export 2005 – September 2010 reached 2,166,109 m^3. The biggest exported was in 2009, which this province exported 534,352 m^3.

There are five biggest province that high in log export, there are West Sepik, East New Britain, West Sepik, Western , and Gulf. In 2011, West Sepik lead by 25% of export logs percentage. East New Britain is about 17%, West Sepik 18%, Western 12%, and Gulf 9%.

Based on the region, the dominant region in PNG log export were Island, Southern and Mamose. In year 2002, Island region only produce about 400,000 – 600,000 m^3. Compare to another region, this region only occupy the second place. In this region, log export has an increasing number every year. Increasing number of log export, makes this region overstep Southern region before 2005. The highest Log export was in 2008, about 1,200,000 m^3.

According to SGS monthly reports, PNG rainforest logs which exported were much higher compared to those of plantation logs. In the period of 2005 – 2007 there were significant increased of rainforest logs export. In 2007, the number of rainforest which had export was bigger than 2,500,000 m^3, this number is almost as huge as rainforest logs exported in 1997. In the 2008 rainforest export felt in to level 2,000,000 m^3 – 2,500,000 $m^{3.}$

The percentage of PNG log export harvested from plantation forest mostly under 10%. The high percentages were reach in 2003, 2004, and 2005 with percentage 11%, 12% and 9%, respectively. The most popular wood species harvested from plantation forest was Kamarere (*Eucalyptus deglupta* Bl.), Balsa (*Ochroma lagopus*), Klinki Pine (*Araucaria hunsteinii* K. Schum), Teak (*Tectota grandis* Linn.) and Terminalia (*Terminalia brassii* Exell).

Malas species was the PNG biggest logs which had exported in 1997. In successive was Callophyllum, Taun, Kwila, Mersawa, and Terminalia, in 1998, there were three species which almost has the same number of exports, Malas, Callophyllum, and Taun. Two years later Callophyllum was increased in export, but the other two species (Malas and Taun) was decreased. In 2004, the number of Taun which exported were increased so dramatically, the highest level of exported Taun was at 2006, which over than 350,000 m^3 and become the highest species which exported at the year.

The grade of the PNG log export mostly classified as high quality log. The highest proportion was in 2002, which the proportion was more than 12%.

Taun is the biggest species exported outside PNG. From 2008 – 2010, number of Taun exported was not more than 400,000 m^3. But in 2011, the number was increased more than 50,000 m^3.

The largest total revenue province is West New Britain, this province owned US$ 251,910,775 from 2005 until September 2010 with the biggest revenue was US$ 63,137,327 in year 2007.

The province with the highest average price are Central, East Sepik and West Sepik. Central is a province with highest average price (US$ 109.045). The highest average price per year in this province is US$ 186.580; which happened in 2005. In the 1998, the dominant market for PNG log export was Japan (55%), Korea (18%), Mainland China (10%) and Philippines (10%). There was big decreasing of Japan, Philippines, and Korea percentage import year to year. Japan still dominant until year 2000. However, the percentage getting decrease in year to year, and the lowest percentage was in 2009 (0%). In the other side, growing logs industry in China leads China become the biggest importer of PNG's logs. The highest percentage was in 2009, with 89.40%. This trend is predicted will continue in the future

In case of Philippines, there are 40 plywood producers in the country with a total daily rated capacity of 2,864 cu m as of 2008 (Table 2). Presently, however, plywood plants operate on average, at less than 80% of capacity because of difficulties in the supply of wood raw materials.

Table 2. Number of bio-composite producers and daily rated capacity.

Bio-composite products	No. of producers	Daily Rated Capacity
Plywood	40	2,864 cu m
Blockboard	6	42 cu m
Fiberboard	1	10 cu m
Particleboard	1	1000 panels
Cement bonded boards	2	50 panels per day

Source: Philippine Forestry Statistics 2008 and personal interviews

Production and Distribution

Production of major bio-composite products

Plywood is still the major bio-composite product produced in the Philippines. From 2003 to 2008, the production ranged from 2,864 to 2,809 cu m, with the highest production in 2007 which is 2,920 cu m. Fiberboard and blockboard production, on the other hand was below 100 thousand cu m and was fairly stable from 2007 to 2008 (Fig. 4). One fiberboard plant located in Taguibo, Butuan City, Mindanao has a daily rated capacity of 4,000 board feet (9.4 cu m).

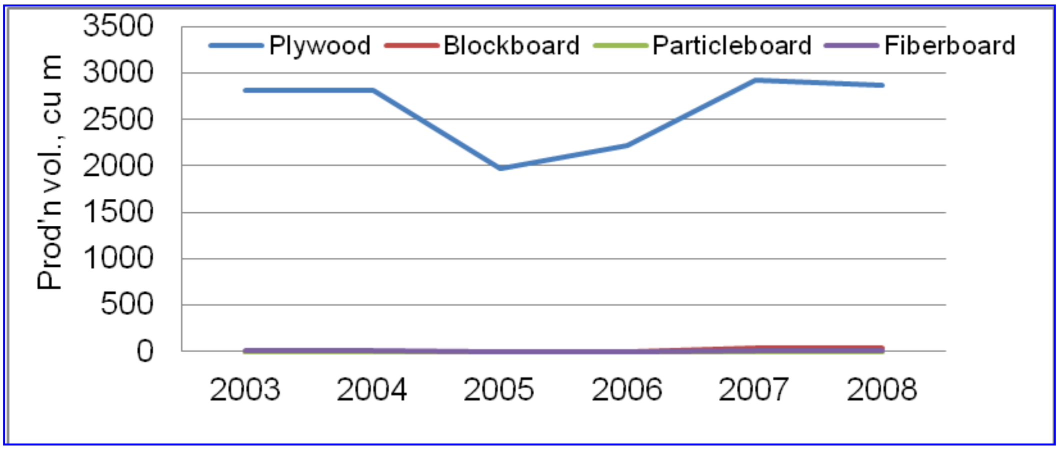


Figure 4. Production of wood-based panels, 2003-2008

Product Flow

The production and distribution chain of processed wood products in the Philippines starts at the natural or plantation forest. *Paraserianthes falcataria*, *gmelina arborea* and *shorea negrosensis* species are the more common types of local roundwood species used in bio-composites. The country also imports logs. In 2006, the country imported 65,185 cu m of roundwood, the lowest so far since 1996 when imports peaked at 877,000 cu. m.

Sawlogs are further processed into lumber in sawmills. Veneer logs may either go to veneer plants or plywood plants. Plantation thinnings go to particleboard, fiber board or wood wool cement board plants. The bulk of fiberboards used in the local market are imported by local distributors whose buyers come from the furniture and construction sector (Fig 5).

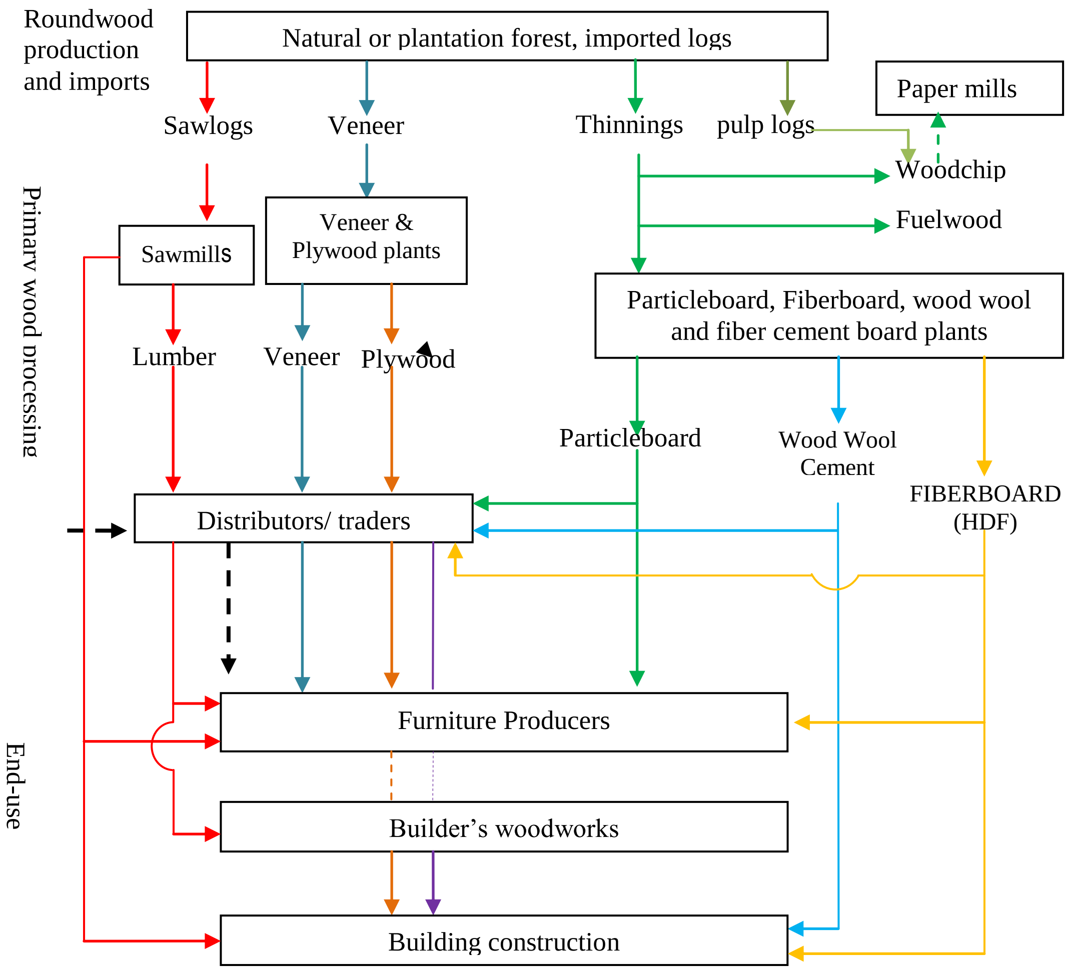


Figure 5. Production and distribution flow of bio-composites

Major end-use markets for bio-composites are the furniture and construction industries and to a smaller extent, builder's woodworks. More than 80% of the direct buyers of plywood and blockboard are traders and 31% of direct buyers are contractors. About 20% are more or less equally distributed between furniture makers and builders woodworks (Table 3).

Twenty five percent of the volume of cement bonded boards is channeled through traders; 65% are bought directly by building contractors. The lone producer of particleboard ships directly to furniture producers in Manila and Cebu, the Philippines' major furniture production center.

Table 3. Composition of direct buyers of bio-composites

Type of Buyers	Plywood and Blockboard Ave %	Particleboard Ave %	Cement bonded boards Ave %
Traders	87	20	
Furniture makers	11	80	
Contractors	31		100
Builders woodworks	10		

Production Centers

The Philippines is divided into three major island groupings—Luzon in northern Philippines, Visayas in the Central part and Mindanao in the south (Fig. 6). The only operating particleboard plant and 29 plywood producers out of the country's total of 40, are located in the Mindanao region, which is also known as the country's "timber corridor." In 2007, 286 thousand cu meters of plywood were produced in these regions, representing almost 96 % of the country's total plywood production of (Table 4).

Table 4. Plywood production by region, 2007.

Region	Total Production (cu m)	%
Philippines	**286,457**	**100.00**
Luzon	**12,585**	**4.47**
National Capital Region (NCR)	4,597	
Region 4-A	7,628	
Mindanao	**268,872**	**95.53**
Region 9	10,289	
Region 10	78,689	
Region 11	39,910	
Region 13	139,984	

Source: Philippine Forestry Statistics

LUZON
1 Fiber cement board plant
2 Agri-wood based cement bonded board plants
10 plywood plants

Major demand centers
METRO MANILA, Region III CALABARZON

VISAYAS
1 plywood plant

Major demand centers
CEBU AND BOHOL

MINDANAO
29 plywood plants
1 particleboard plant

Figure 6. Location and distribution of wood based bio-composite plants and major demand centers for wood bio-composites

In 2006, the Philippine Forestry Statistics listed ten plywood plants in Luzon and only one in the Visayas. However, since there was no recorded plywood production in the Visayas in 2006, this may imply cessation of operations.

While majority of plywood plants are located near the sources of raw materials, fiber cement boards (FCB) and wood wool cement bonded boards (WWCB) are produced in Southern Luzon nearer to the larger markets of Metro Manila and outlying provinces (Fig 3). The FCB plant uses virgin pulp that are imported from New Zealand while the WWCB plant uses *Gmelina arborea* and other materials available in the vicinity. The WWCB plant has also started using bamboo in combination with wood.

The Macro-environment of the Bio-Composites Industry in the Philippines

the Construction and Furniture Sectors

The demand for bio-composites is tied primarily to the state of activities of the construction sector and the furniture industry.

<u>Construction Industry</u>

Despite the global financial crisis, the local construction sector did not suffer major slumps in activity. There has been an increasing trend in residential and building construction for the past three years (Fig 7).

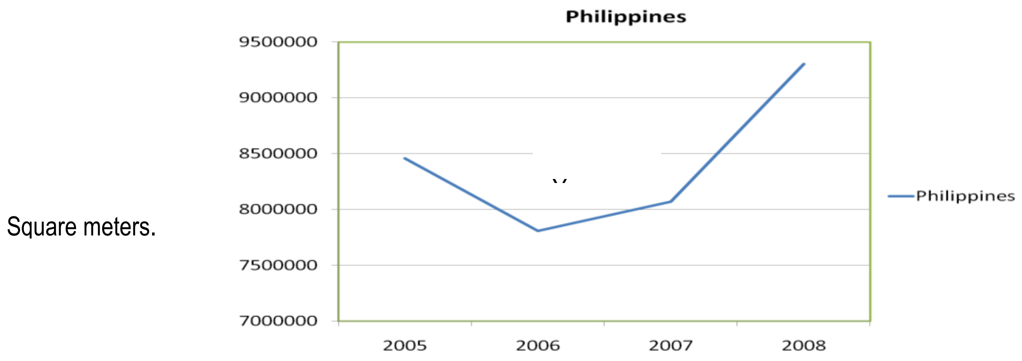


Figure 7. Total construction in square meters, 2005-2006

Comparative figures for the first quarter of 2009 and 2008 also show an increase in residential building construction which rose by 21.3 percent in the first quarter of 2009 compared to the same quarter of 2008. Similarly, non-residential building construction grew to a remarkable 42.6 percent (Fig 9).

Construction is focused on single-type residential houses, followed by residential condominiums and apartments. There has been an increase of around 180,000 sq m in total floor area for all types of buildings.

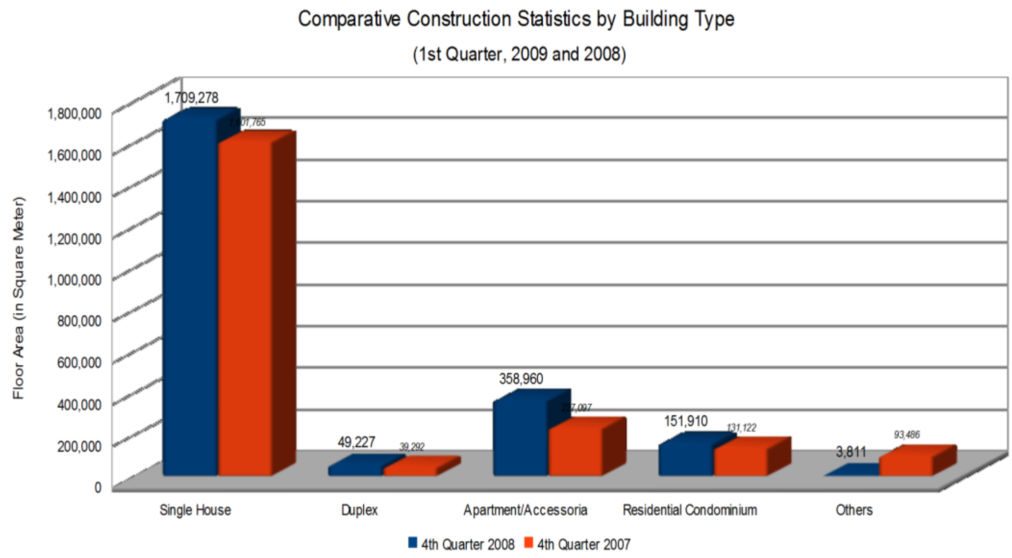


Figure 8. Comparative Construction Statics by Building Type

<u>Furniture Industry</u>

An estimated 15,000 firms comprise the local furniture industry (Department of Trade and Industry, 2005). Only 2% are considered large ventures and the remaining 98% are small and medium-sized firms.

Wood furniture, mostly in solid wood, is the most common material used in furniture exports, accounting for 59% of total Philippine furniture exports to the world.

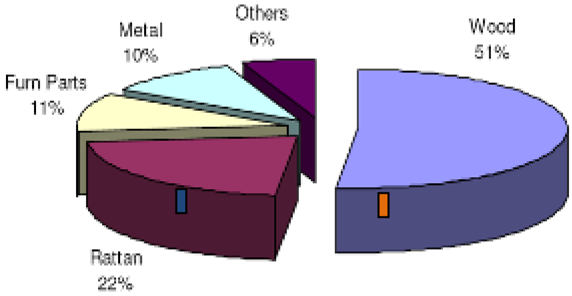


Figure 9. Most common material used in Philippine furniture export

Bio composites such as plywood, medium density fiberboard and particleboard are used for panel furniture such as office tables and cabinets, most of which go to the domestic market. Domestic furniture production fills the requirements of new residential, hotel and office buildings. Thus, demand for local furniture and the raw materials used in their manufacture is also fuelled by the construction sector.

Institutional

Major institutions that impact on the bio-composites industry are the Department of Trade and Industry (DTI), Department of Environment and Natural Resources (DENR) and trade associations such as the Philippine Wood Producers Association (PWPA).

The Bureau of Product Standards (BPS) of the Department of Trade and Industry (DTI) develops, implements and coordinates standardization activities. Of the bio-composite products in the Philippines, standards have been developed only for plywood. Thirty-three plywood plants have been granted product standards certification and can thus use the PS Mark on their products.

The BPS conducts regular and special assessment of manufacturers of plywood, ensuring that no plywood produced by Non-PS Mark License holder shall be sold to, or offered for sale by any marketing outlets. The BPS can also take action and impose fines and penalties against manufacturers, importers, traders, distributors and/or marketing outlets selling substandard plywood or plywood without PS or Import Commodity Clearance (ICC) from the BPS.

The DENR, on the other hand, may cancel a company's Wood Processing Plant Permit (WPP), deny the application for renewal of WPP, padlock the plywood mill and impose fines or penalties against non-WPP holders or violators of the PS mark. It can also cancel the Certificate of Registration for Authority to Import Wood Materials of importers of substandard plywood or plywood without ICC mark.

The PWPA works together with the DENR and BPS to ensure that plywood, whether imported or locally manufactured, conforms with the specific national standard for the protection of the consumers. The PWPA is an association of lumber, veneer and plywood producers and gives voice to the issues currently faced by the wood processing industry.

Policies that impact on the raw material sources of bio-composite plants are shaped by the DENR. Supply of wood raw materials have been affected by policies on "the non-renewal of timber leases and licenses; the prohibition of cutting from old-growth forests (through NIPAS Act or RA 7586 & DAO 02, 1992), the cancellation or suspension of timber concession activities in secondary; and the on and off policy of banning timber" (Carandang, 2005).

Technological

New technologies and processes have given rise to alternative materials and products that directly compete with the more "traditional" wood bio-composites. Fiber cement board is seen as a direct competitor by plywood producers.

On the other hand, most plywood plants were established in the 70s and some are still operating on vintage equipment. Despite these, the industry has managed to adapt and survive. Most advanced technologies for bio-composites in general, is externally acquired from the more developed nations which have developed newer technologies on bio-composites, particularly on adhesives and the use of different fiber-base resources in combination with other materials.

Environmental

One of the big issues faced by the bio-based composites industry is on the nature of adhesives used, particularly on the volatiles they release when used in bio-composites products. Most local firms have yet to shift to non-formaldehyde based adhesives, partly because of cost considerations and partly, because the local market in general, is not as particular and demanding.

Trading of Bio-Composites Industry in the Philippines

In 2008, The Philippines has imported Particleboard (included here are oriented strand board and wafer board) from many countries as shown in Table 5. For items 1.1 and 1.2, the bulk of importation came from Thailand and Malaysia which are 1,381,282 and 11,308,771, respectively. The bulk of surface-covered with melamine impregnated paper came from Thailand which is 1,345, 252 in gross kilograms. Total importation in 2008 was 34,480,251 gross kilogram. The value was USD 12,276, 278 FOB or USD 13, 568, 192 CIF.

Table 5. Particleboard Imports: 2008

Commodity/Country of Origin	Quantity, Gross Kilogram
1. Oriented strand board and wafer board of wood	
1.1 Unworked or not further worked than sanded	
China, People's Republic of	7,876
Hongkong	1,436
Japan (excludes Okinawa)	802,890
Malaysia	608,025
Singapore	6,025
Thailand	1,381,282
1.2 Other	
China, People's Republic of	1,151,394
Germany	19,285
Hongkong	30,539
Japan (excludes Okinawa)	1,261,960
Korea, Rep of (South)	1,810
Malaysia	11,308,771
New Zealand (excludes Western Samoa)	29,900
Singapore	133,684
Thailand	4,771,285
2. Other Wood	
2.1 Unworked or not further worked than sanded	
Japan (excludes Okinawa)	218,970

2.2 Surface-covered with melamine impregnated paper	
Austria	50,000
China, People's Republic of	89,243
Hongkong	69,260
Malaysia	241,429
Thailand	1,345,252
2.3 Surface covered with decorative laminates of plastics	
Austria	25,000
China, People's Republic of	18,000
Thailand	25,072

Source: National Statistics Office

The Philippines has imported fiberboard from several countries totaling to 34, 336, 228 in net kilogram with a value of USD 12,534,875 (FOB) (Table 6). Importation of fiberboard varied with densities such as 0.80 g/cm^3, 0.50 g/cm^3 but not exceeding 0.80g/cm^3 and 0.35 g/cm^3 but not exceeding 0.50 g/cm^3 The bulk of importations with density exceeding 0.80 g/cm3 came from Thailand, China (Peoples Republic) and Malaysia with quantities of 1,191,299; 1,179,665; and 1,100,572 in net kilogram, respectively. Few quantities of this kind were also imported from Australia, Chile, Taiwan, India, Japan, Singapore and USA.

For fiberboard of wood or other ligneous materials of a density exceeding 0.50 g/cm^3 but not exceeding 0.80g/cm^3 that are not mechanically worked or surface covered, the bulk of importations came from Malaysia (6,488,516), China, People's Republic of (2,082,926) and Thailand (1,845,776). On the other hand, item 2.3 which is considered as other, the top three country of origins were from Thailand (3,597,355), Malaysia (2,972,017) and People's Republic of China (2,933,193).

There were also initial data gathered that the Philippines exported particleboard and fiberboard in 2008. For particleboard with surface covered with decorative laminates of plastics, it has exported a quantity of 1,499 in gross kilogram to Egypt Arab Republic. These particleboard with laminates of plastics are believed as re-exportation although there is a plant in the Philippines that does the lamination of imported particleboard. The Philippines has also exported fiberboard to Japan with a quantity of 2,945 in net kilogram.

For fiberboard of wood or other ligneous materials of a density exceeding 0.35 g/cm^3 but not exceeding 0.50 g/cm^3, the countries of origins were Australia, Malaysia, People's Republic of China, Germany and Norway with a total quantity of 479,614.

Table 7 shows that veneer and other wood; plywood and other plywood and veneered panels; fiberboard as well as particleboard are among the top imports of the forest based products. Importation of particleboard has the lowest percent share compared to others while importation of fiberboard was almost consistent at 2% share from 2001 to 2006. On the other hand, Table 8 shows that export of plywood, veneer and fiberboard was much lower compared to other forest based products.

Table 6. Fiberboard Imports: 2008

Commodity/Country of Origin	Quantity, Net Kilogram
1. Fiberboard of wood or other ligneous materials of a density exceeding 0.80 g/cm^3	
1.1 Not mechanically worked or surface covered	
China, People's Republic of	128,000
Malaysia	410,711
Thailand	61,563
1.2 Other	
Australia	62,300

Chile	25,989
China, People's Republic of	1,179,665
Hongkong	38,189
India	1,670
Indonesia	190,296
Japan	48,020
Malaysia	1,100,572
New Zealand	640,969
Singapore	15,061
Taiwan (Republic of China)	682
Thailand	1,191,299
USA	35,726
2. Fiberboard of wood or other ligneous materials of a density exceeding 0.50 g/cm^3 but not exceeding 0.80g/cm^3	
2.1. Not mechanically worked or surface covered	
Australia	59,280
China, People's Republic of	2,082,926
Hongkong	16,813
Indonesia	485,229
Italy	336,760
Malaysia	6,488,516
New Zealand	1,772,482
Sarawak	184,788
Singapore	54,641
Thailand	1,845,776
USA	105,700
2.2 Wooden beading and mouldings	
Chile	24,362
China, People's Republic of	4,657
Malaysia	23,845

2.3 Other	
Australia	25,500
Austria	34,282
Chile	67,322
China, People's Republic of	2,933,193
Hongkong	105,205
Indonesia	1,821,773
Korea, Republic of (South)	32,840
Malaysia	2,972,017
New Zealand	581,144
Singapore	55,816
Thailand	3,597,355
USA	29,022
3. Fiberboard of wood or other ligneous materials of a density exceeding 0.35 g/cm^3 but not exceeding 0.50 g/cm^3	
3.1 Not mechanically worked or surface covered	
Australia	9,266
Malaysia	48,240
3.2 Other	
Australia	24,864
China, People's Republic of	189,754
Germany	196,875
Norway	10,615
4. Fiberboard of wood or other ligneous materials	
4.1 Not mechanically worked or surface covered	
Indonesia	325,996
Malaysia	253,093

Source: National Statistics Office

Table 7. Top Forest-Based Products Imports, 2001 – 2007

Product \ Year	2001	2002	2003	2004	2005	2006	2007
	% Share to Total						
Paper and Paperboard and Articles of Paper & Paperboard	56.37	55.91	63.04	60.66	57.29	62.48	69.16
Lumber	13.35	16.41	17.06	12.95	15.71	12.15	9.29
Pulp and Waste Paper	12.52	11.22	1.11	10.29	7.61	7.87	7.19
Log	6.92	6.42	5.36	2.62	3.18	2.51	2.45
Veneer and Other Wood, worked not exceeding 6mm, n.e.s	4.49	3.13	3.95	2.41	2.39	1.47	0.97
Forest-based Furniture	2.51	0.76	1.01	2.85	2.82	3.23	2.84
Fiberboard	2.03	2.72	2.05	2.87	2.43	2.27	1.52
Wood Manufactured Articles, n.e.s.	0.85	0.97	1.53	0.93	1.05	1.07	1.15
Plywood and Other Plywood and Veneered Panels	0.66	2.23	4.60	4.19	7.36	6.49	4.25
Wood continuously shaped along any of its edges or faces	0.29	0.24	--	--	--	--	--
Particleboard	--	--	0.29	0.24	0.16	--	1.18
Wood chips and particles	--	--	--	--	--	0.48	--

Source: Philippine Forestry Statistics 2001 - 2007

Table 8. Top Forest-Based Products Exports, 2001 – 2007

Year / Product	2001	2002	2003	2004	2005	2006	2007	
	% Share to total							
Forest-based Furniture	42.03	46.04	33.00	43.19	40.26	18.80	14.66	
Wood Manufactured Articles, n.e.s	23.72	22.88	---	22.94	23.15	59.39	64.57	
Paper and Paperboard and Articles of Paper & Paperboard	18.91	14.75	19.27	14.78	18.31	12.50	11.97	
Pulp and Waste Paper	6.05	6.47	1.21	7.69	8.84	4.86	4.16	
Selected Non-timber Manufactured Articles	3.94	3.99	4.93	3.83	2.67	1.15	1.10	
Lumber	3.19	2.09	3.28	1.83	1.43	1.20	1.20	
Wood Charcoal	1.06	1.03	---	1.40	1.31	---	0.72	
Plywood and Other Plywood Veneered Panels	0.63	1.99	1.53	3.32	2.99	0.87	1.24	
Veneer and Other Wood Worked not	0.32	0.63	0.65	0.61	0.62	0.37	0.32	

exceeding 6 mm n.e.s								
Non-timber Forest Products	0.15	0.13	0.22	--	--	0.05	0.06	
Fiberboard			0.44	0.41	0.42	0.05		

Source: Philippine Forestry Statistics 2001 - 2007

-Activity 1.1.2. **Determine where the potential for future market growth for bio-composite products exists.**

I. Potential future market of Indonesia wood composite products

1.1. Plywood

MOF (2007) reported over the period 2002-2006, in order of importance, major country destinations of Indonesia's plywood exports were Japan, United States, China, the Republic of Korea, Taiwan, Saudi Arabia, United Arab Emirates, United Kingdom, and Belgium, which together accounted for 83% of Indonesia's plywood exports (Table 5). In Japan, China, the Republic of Korea, and United Arab Emirates, plywood import from Indonesia's was around 27%-33% of their total plywood imports (Table 6). In Saudi Arabia, it was almost 60% of its total plywood imports.

Although China has been the largest plywood producer in the world since 2003 as well as a net exporter (Table 1), its plywood import was still large, ranging from 1.7 to 2.0 millions m3 per year. Meanwhile, even though, consumption in United States of America, Japan, and United Kingdom grew slightly and even decreased in the Republic of Korea (-10%), but these countries were net and major world importers, which together accounted for 54% of world's plywood imports. Hence, It is obvious these five countries would still be the future market for Indonesia's plywood exports.

1.2. Veneer sheets

MOF (2007) reported over the period 2002-2006, in order of importance, major country destinations of Indonesia's veneer sheets exports were Japan, United States, China, the Republic of Korea, Taiwan, Germany, Saudi Arabia, Italy, and United Kingdom, which together accounted for 84% of Indonesia's veneer sheets exports (Table 5). However, In United States, the Republic of Korea, and Italy, veneer sheets import from Indonesia's was much less than 1% of their total veneer sheets imports (Table 6). In Germany and United Kingdom it was around 1% of their total veneer sheets imports. Meanwhile, in Japan, China and Saudi Arabia, it ranged from 5.1% to 6.8% of their total veneer sheets imports.

The fact that most veneer sheets production were consumed domestically over the period 2002-2006 and considered that veneer sheets export price were more than double of plywood export price, then, if Indonesia would domestically process veneer sheets, it should produce high added value forest products. Otherwise, selling veneer sheets is more profitable than to process it first into plywood and then sold it.

MOF (2007) reported over the period 2002-2006, in order of importance, major country destinations of Indonesia's particleboard exports were the Republic of Korea, Taiwan, Viet Nam, Hongkong, China, and Malaysia, which together accounted for 97% of Indonesia's particleboard exports (Table 5). However, in the Republic of Korea, Viet Nam, China, and Malaysia, particleboard import from Indonesia's was only ranged from 2.3% to 6.9% of their total particleboard imports.

Although during that period Indonesia's particleboard exports to those countries were declining, China and Republic of Korea imports of particleboard were still large, ranging from 0.7 to 1.1 millions m3 per year (Appendix 3). Similar to that veneer sheets product, most particleboard were consumed domestically over the period 2002-2006. Coupled with particleboard import that was almost triple over that period, particleboard production should be intended for domestic consumption.

MOF (2007) reported over the period 2002-2006, in order of importance, major country destinations of Indonesia's fiberboard exports were China, Saudi Arabia, Republic of Korea, Taiwan, Syria Arab Republic, Egypt, United Arab Emirates, Viet Nam, Philippines, and Hongkong, which together accounted for 89.5% of Indonesia's fiberboard exports. In China, the Republic of Korea, and Saudi Arabia, fiberboard import from Indonesia's was around 9.1%-11.5% of their total fiberboard imports. For the rest countries, it ranged from 3.3% to 6.1% of its total fiberboard imports.

China and the Republic of Korea would still be potentially become major country destinations of Indonesia's fiberboard exports in the future since they are world's major consumers and net importers of fiberboard with imports ranging from 1.7 to 2.6 millions m^3 per year for China and from 0.3 to 0.8 millions m^3 per year for the Republic of Korea.

Wood and Bio-Composite Products in PNG

Domestic processing of woods expected to increase when the PNG Government policy on domestic processing in forestry is endorsed and implemented by the Government and the private sector. Consumption, especially of sawn timber and other furniture products from wood, is expected to grow steadily and could increase markedly as the economy has been to improve, with the building industry expected to boom.

Consequently, it is expected that exports of round wood will decrease and there will be an increase in the export of processed products such as sawn timber, plywood, wood chips, and furniture, including carbon. These are the main processed products that have been exported up to now. There is now foreseeable expansion to other finished products such as pulp and paper, or fiber board.

In terms of wood-based industries the outlook for 2020 is that many of the timber harvesting companies in the country will not be able to sustain themselves in terms of wood supply and hence will be forced to close. This is specifically for those that operate in small concession areas and depend entirely on the natural forests. Companies that have established their own plantations will sustain themselves in terms of wood supply.

Trend of Technological Changes in Wood Processing And Bio-Composite Products in PNG

Technological changes are taking place every day that impact on forests and forestry. Wood processing machinery for downstream processing of wood has to be imported or even developed in the country and geared, not only for processing for export markets, but for domestic markets as well. Many of the current sawmills in the country are using older machinery, and they will need to look ahead and refit so that recovery is higher with less wastage.

Since January 2010, PNG government policy has dictated that all newly approved forest projects must contain a strong element of downstream processing. Producers already generate sawn timber, veneer sheets, plywood and processed, but these sectors will receive much greater emphasis. The most new probable bio-composite products will be produced by PNG in the near future are Laminated Veneer Lumber (LVL), Glued Laminated Lumber (Glulam), and particleboard, while fiberboard such as Medium Density Fiberboard will be the second phase of PNG forest industries development.

All the forest industries must start to consider importing new technology, not only to improve the quality of their products so as to fetch better prices, but to address issues of pollution and PNG's contribution to climate change and global warming.

Bio-Composites Demand and Supply In Philippines

Plywood

Plywood is still the most common type of bio-composite used. On the average, about 66% of bio-composites used in construction projects of contractor-respondents is plywood, which is used as ceilings and interior walls.

Domestic demand for plywood is met by local production and augmented by imports. It is noted that export remarkably increased from 2006 to 2008 while import decreased from 2006 to 2007 (Fig. 10). Based on these figures, 89% to 98% of total supply went to the domestic market (Table 9).

Table 9. Production, trade and consumption of plywood.

PLYWOOD, cubic meters							
Year	Prodn.	Imports	Supply	Exports	%	Available for Domestic Use	%
2001	292,294	8,242	300,536	6,834	2	293,702	98
2002	350,353	24,847	375,200	21,909	6	353,291	94
2003	350,891	48,557	399,442	16,637	4	382,811	96
2004	385,570	42,045	427,615	47,731	11	379,884	89
2005	314,182	78,005	392,187	40,015	10	352,172	90
2006	316,922	75,135	392,057	19,952	5	372,105	95
2007	281,457	58,517	339,974	37,000	11	302,974	89
2008	*	*	*	39,000		*	

Source: Philippine Forestry Statistics

Note: Data for 2008 are not yet available except for export

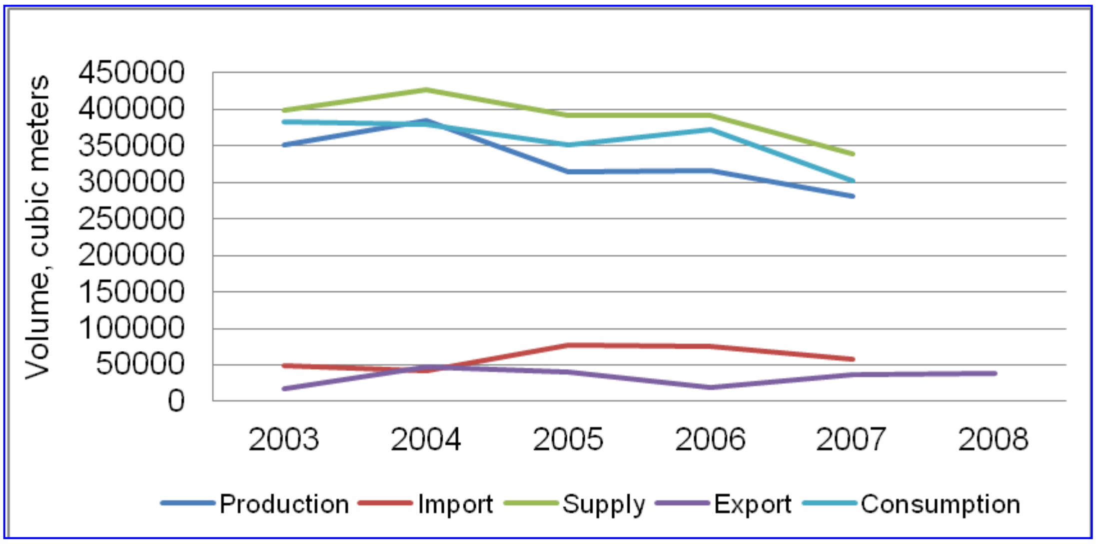


Figure 10. Plywood production, trading and consumpsion

Fiberboard

Compared to plywood, local production of fibreboard is minimal falling on or around 50 thousand cu m per year (Table 2). Locally produced fibreboards, also called "*lawanit,*" are high density fibreboards (HDF). In construction, they are used as ceilings and interior walls.

The Philippines does not produce medium-density fibreboards (MDF). Demand for MDF and HDF boards and final products are filled in by imports.

Imports of fiberboard were highest in 2004 but re-exports showed an increasing trend from 2004 to 2006. Domestic consumption, however, decreased from 48 million kg. in 2002 to 30 million kg. in 2006.

Table 10 Production, trade and consumption of fiberboards

FIBERBOARD					
Year	Production '000 metric tons	Imports '000 net kg	Supply '000 net kg	Exports '000 net kg	Domestic Consumption '000 net kg*
2001	5	44,292	44,292	28	44,269
2002	4	48,478	48,478	113	48,369
2003	7	29,315	29,322	5,367	23,955
2004	not available			9,798	*
2005	8	47,937	47,945	10,226	37,719
2006	5	47,981	47,866	1,795	46,191
2007	6	39,546	39,552	558	38,994
2008	**	34,336	**	**	**

Source: Philippine Forestry Statistics

Note: *Data for 2004 is not available except for export

**Data for 2008 are not yet available

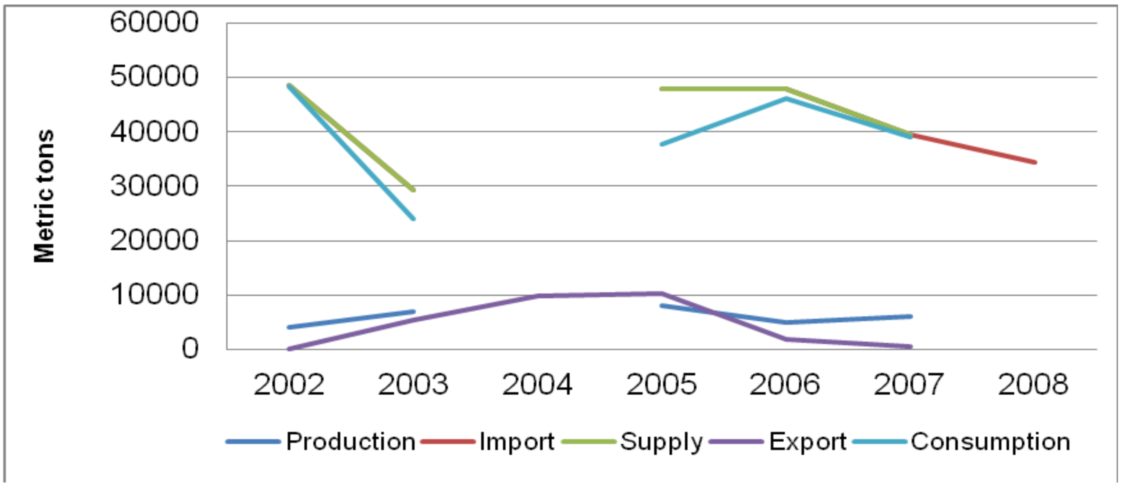


Figure 11. Fiberboard production, trading and consumpsion

Particleboards

The Philippines has three particleboard plants but as of 2009, only one is operating. The plant can produce 1,000 high density particleboards per day but on average produces only 650 panels a day. It uses tops and branches of *gmelina arborea* as raw material and prides itself in using formaldehyde-free glue in their products. In its early operations, the plant used sugarcane bagasse as raw material but due to the poor quality of sugarcane bagasse that adversely affected the finished product, the company opted to use *gmelina arborea*.

Their boards are shipped direct to furniture makers in Cebu and Manila. Twenty percent of their market is in Cebu, 70% in Manila and 10% goes to the local market in the plant's hometown in Ozamiz. Because the plant is operating below capacity, the country still imports a sizeable quantity of particleboards (Table 11). Imports increased from around 3 million net kg in 2001 to 31 million net kg in 2007. Only less than 2 percent is exported. Although no data are available at the Philippine Forestry Statistics in 2008, actual visit and interview shows that there is a production at the Particleboard Plant in Ozamiz City. The production output may be too small compared to import thus the output of 650 panels per day is insignificant.

One particleboard commercial plant that has stopped operating in 1999 is in the process of reconditioning the machineries/equipment in order to produce boards using coconut coir fiber as raw material.

Table 11 Production, trade and consumption of particleboard.

PARTICLEBOARD, in '000 gross kg					
Year	Production	Imports	Supply	Exports	Domestic Consumption
2001	No data	2,948	2,948	-	4
2002	n.d.	3,674	3,674	-	3,674
2003	n.d.	7,162	7,162	-	7,162
2004	n.d.	6,173	6,173	-	6,173
2005	n.d.	4,249	4,249	175	4,074
2006	n.d.	8,478	8,478	140	8,338
2007	n.d.	31,412	31,412	6	31,406
2008	n.d.	34,480			

Source: Philippine Forestry Statistics and National Statistics Office

Cement Bonded Bio-composites

Other bio-composites in the market are agri-based cement bonded (CBB) boards and fiber cement boards (FCB). There are only two agri-based cement board plants in the country and one large fiber cement board plant. One CBB plant specifically wood wool cement board is owned and managed by an architect. Instead of using only *gmelina arborea* as raw material, it also uses other wood that are available in their vicinity such as fruit trees that do not bear fruit anymore. To save on production cost, waste bamboo fibers from furniture makers are mixed with wood wool. WWCBs produced are used in the housing and construction projects of the manufacturer. The other CBB plant uses abaca fiber wastes as raw material since the location is noted as abaca producing region of the Philippines. The finished products do not reach the market because these are used in their housing projects.

Fiber cement (fiber reinforced cement composite) was originally developed by James Hardie in 1980. One of the main ingredients of fiber cement products is cellulose fibers from wood or non-wood sources which are added to reinforce the cement composite. Also, small amounts of chemical additives are utilized to help the process, or provide products with particular characteristics (Golbabaie, M 2006). There is only one producer of fiber-cement board in the country which is traded under the brand Hardiflex. This uses imported virgin pulp fiber.

A new company has started with the commercial production of fiber cement sheets (Solidflex Brand) and fibers cement roofing (Mightyflex Brand) in 2009. Product thickness range from 4 – 15 mm with densities ranging from 0.95 – 1.05 g/cm^3.

Bio-composites in Construction

Bio-composite products have found increasing applications in housing construction compared to other industrial applications (Table 12). Plywood is still the most common type of bio-composite used by building contractors. All respondents have used plywood and fiber cement boards in their projects, while 50% and 25% have used particleboard and blockboard, respectively, in their projects. These were used as ceilings and interior walls; but only fiber cement boards were used as exterior walls.

Table 12. Uses of bio-composites in construction

Product	Application
Plywood	Ceilings, interior walls
Fiber-cement board	Ceilings, interior and exterior walls
Blockboard	Interior walls
High density fiberboard	Ceilings, interior walls
Particleboard	Ceilings
Cement-bonded board	Ceilings, interior walls

In terms of the product mix, an average of 66% of the bio-composites used in their construction projects is plywood. However, fiber cement boards, which were introduced in the country ten years ago have eaten into the market share of the more “traditional” panel products. An average 23% of bio-composites used by the respondents is fiber cement boards (Table 13.).

Table 13. Extent of use of bio-composites.

Product	Average % Share Used in Projects
Plywood	66
Fiber-cement board	23
Blockboard	15
High density fiberboard	13
Particleboard	7
Cement-bonded board	2

Table 14.Attributes considered in choosing type of bio-composite used.

Attribute	Importance 1=most important
Suitability	1.6
Durability	1.8
Quality	2.5
Availability	4.0
Specification	4.6
Price	4.8
Appearance	5.6

Suitability to the structure being built, durability of the material and quality seems to be the most important attributes considered by the respondents when choosing the type of bio-composite material to use (Table 14). One implication here is the importance of durability as an attribute. Taken in conjunction with the findings that fiber cement boards have eaten into the share of plywood, this again reflects the perception that wood is not as durable as say, cement. Price is also a less important consideration than durability or suitability to specific use.

Growth and Resource Sustainability

Bio-composites will always be acceptable materials for construction and furniture. However, new bio-composite products that substitute directly with another bio-composite, affect how market shares are re-aligned. The introduction of fiber-cement boards for instance has cut into the market share of plywood, although it is still the most popular bio-composite material used in construction. On the other hand fiber cement boards and fiberboards have different applications. Thus, market share of fiberboards basically remain unaffected by fiber cement boards.

The growth of the bio-composites industry will depend on the growth of industries dependent on it and on the introduction of new products, technologies and new applications. Fiber-cement board, introduced ten years ago, is the latest bio-composite to be introduced in the market and has managed to carve a niche in the construction sector. Eighty nine percent of plywood producers and users believe that usage rate for this product will increase significantly in the next three years (Table 15). This reflects the perception that fiber cement boards are a threat to the plywood market. On the other hand, only 54 percent of the respondents are optimistic that there will be a significant increase in demand for plywood; 31 percent believe that demand will remain basically unchanged. There has also been a surge in the use of fiberboards, as seen in the increase of fiberboard imports. About 80 percent of the respondents think that in the next three years, fiber board usage will increase.

Of the bio-composites in the country, plywood is perhaps the most challenged in terms of raw material sustainability. Unlike new composite products which use smaller elements, plywood production still relies on whole timber. Although these are sourced from plantations rather than from natural forests, very few (30%) bio-composite producers think that there are enough raw materials to sustain production (Table 16. In contrast, 70% of the respondents think otherwise --there will not be enough raw materials to sustain production.

Table 15 Respondents' perceived trend in demand for bio-composites

Product	% of Respondents				
	Increase		Decrease		No change
	Sig.	Not Sig	Sig	Not sig	
Plywood	53.8	7.7	-	7.7	30.8
Fiber cement board	88.9	-	-	-	11.1
Blockboard	42.8	28.6	-	-	28.6
Particleboard	33.3	22.2	11.1	11.1	22.2
MDF	50.0	33.3	-	-	16.7
HDF	14.3	14.3	14.3		57.1

Reasons given by both sides are conflicting. Those who believe that there will be enough resources consider *falcata* as fast-growing and sustainable and thus see no reason why difficulties in supply should occur. On the other hand, most producers believe that replanting efforts fall short of expectations because of lack of government support. These conflicting perceptions actually point to geographical differences in the supply of raw materials. Those who don't find it difficult to source raw materials are actually located in a region where replanting efforts are relatively strong and their proximity to plantations make it easy for them to acquire raw materials. Apparently, there is no timber surplus to meet the requirements of plywood producers located farther away.

Table 16. Perceptions on raw material sustainability

YES, there will be enough raw materials to sustain operations within the next five years	**NO, there will NOT be enough raw materials to sustain operations within the next five years**
30%	70%
• **"Falcata is a sustainable plantation species"** • **"Replanting of falcata is continuous"**	• "no reforestation; no government support" • "Yearly consumption exceeds replanting" • "Most local farmers do not want to replant due to the many restrictions (*regulations*) imposed…in cutting their own trees" • "less attention given to replanting"

Supply difficulties limit production. One respondent operates for only three days a week due to lack of veneer logs. Often, they have to buy veneer from veneer plants located

4.4. Output 2.1. Address technical gaps in producing bio-composite products.

-Activity 2.1.1. Identify suitable wood species and evaluate physical and *mechanical properties.*

This activity focused on examining the wood properties of species identified as possible source of SDL, based on findings from output 1 and local species of each collaborators (UPM, FPRDI, IPB, and FRI-PNG). Species known to have a wide range of properties that make them unsuitable for manufacturing bio-composite products will be excluded from further investigation. Species currently used in production (plantation thinning) will be a primary focus. Species from natural forests will be subjected to mechanical or physical test as necessary to determine their suitable for use in composite products.

A. Fundamental Properties of Selected Indonesian SDL Species

1. Physical and Mechanical Properties

Information concerning physical and mechanical properties of small diameter logs is very important to know the feasibility of wood species for bio-composite products such as plywood, LVL, glulam, particleboard and MDF. The average values of physical and mechanical wood properties can be seen in **Table 17, 18 and 19**.

Table 17. Physical and mechanical properties of SDL from plantation and community forest

No.	Wood Species	MC	Sg	Static bending (kg/cm^2)			Compression // (kg/cm^2)	Hardness(kg/cm^2)		Strength class*
				MPL	MOE x1000	MOR		End	Side	
1.	Sengon	107.69	0.25	262	33	465	215	160	112	IV-V
	Paraserianthes falcataria (L) Nielsen	12.54	0.28	316	45	526	283	222	119	
2.	Kayu afrika	55.70	0.39	301	62	467	326	289	245	III
	Maesopsis eminii Engl.	16.10	0.41	394	66	533	341	345	267	
3.	Tisuk	65.30	0.34	372	52	489	287	302	205	III-IV
	Hibiscus macrophyllus	14.92	0.43	426	72	615	345	209	199	
4.	Suren	55,65	0.37	286	38	343	216	215	157	III-V
	Toona sureni Merr.	17,18	0.47	305	87	532	292	218	264	
5.	Ekaliptus	110.30	0.37	304	44	458	281	315	316	IV (V-II)
	Eucalyptus deglupta Bl.	14.00	0.47	359	36	537	280	315	316	
6.	Sengon buto	121,35	0.41	348	45	439	263	243	156	III
	Enterolobium cyclocarpum	13,49	0.49	376	45	427	302	328	216	
7.	Mindi	45.54	0.44	354	29	470	264	255	210	III-II
	Melia azedarach	14.62	0.53	327	27	444	332	255	210	
8.	Kiseseh	36.50	0.45	404	116	743	411	391	327	II-III
	Cinnamomum purrectum	13.77	0.56	637	112	886	609	450	384	
9.	Mangium	68.16	0.50	381	65	544	314	296	296	II-III
	Acacia mangium Willd.	16.79	0.60	424	123	605	321	232	279	
10.	Mahoni	48,32	0.51	353	49	482	297	365	274	II-III
	Swietenia macrophylla King	13.40	0.57	373	557	76	376	392	392	
11.	Rubberwood	75.08	0.56	537	63	680	326	376	312	II-III
	Hevea brasiliensis	11.46	0.66	587	60	733	382	567	346	
12.	Puspa	58.80	0.57	386	164	629	399	508	523	II
	Schima wallichii (DC.) Korth.	17.30	0.61	512	178	776	402	588	500	
13.	Gmelina	143.75	0.58	159	31	260	158	145	218	III
	Gmelina arborea	12.01	0.57	317	97	590	300	272	237	
14.	Pinus	64.35	0.59	293	58	335	199	250	183	III
	Pinus merkusii	14.64	0.73	312	53	484	311	311	208	

Remarks: MC= Moisture Content; Sg= Specific gravity; MPL= Modulus at proportional limit; MOE= Modulus of Elasticity; MOR= Modulus of Rupture; C//= Maximum crushing strength;
* = After Oey (1990)

In **Table 17**, it is clear that the moisture content of the fresh SDL from plantation and community forest ranged from 36.50 - 143.75%, average 75.56%, equilibrium moisture content range from 11.46-17.30% with average 14.30%. SDL specific gravity range from 0.28-0.73 with average 0.52. Based on SDL specific gravity, Hevea, puspa, gmelina and pine classified as médium specific grafity wood, and the others classified as low specific grafity wood. Most of the small diameter logs from plantation and community forest classified as low specific grafity Wood. This is because most of the SDL harvested not more than 10 years (young tres). Spesific grafity of young trees in general is lower compared to those of old trees. (Haygreen, 2003).

Based on specific grafity, static bending properties, maximum crushing strength parallel to the grain and hardness, only puspa and hevea classified as strength class II, mindi, kiseseh, mahoni and mangium classified as strength class II-III, while mangium, afrika, sengon buto, melina and pine classified as strength class III and the other wood species (sengon and tisuk) classified as strength class IV (IV-V). Based on the above fact shows that SDL from plantation and community forest (puspa, karet, mindi, kiseseh, mahoni and mangium) can be used for light construction. However, most of the SDL are suitable for composite products raw materials such as plywood, LVL, Glulam, particleboard and MDF.

Table 18. Average physical and mechanical properties of SDL from natural forest

No.	Wood species	MC,%	Sg	Static bending,kg/cm^2			C//, kg/cm^2	Hardness,kg/cm^2		Strength class*
				MPL	MOE (x1000)	MOR		End	Side	
1.	Benuang	153.81	0.22	61	15	51	62	52	16	V
	Octomeles sumatrana Miq.	16.13	0.26	99	22	153	65	31	64	
2.	Segulang	94.50	0.31	95	24	98	69	105	29	V
	Evodia sp.	15.31	0.38	158	30	223	116	166	219	
3.	Merkubung	97.58	0.33	143	41	93	95	109	32	IV-V
	Macaranga gigantean	17.48	0.41	142	27	213	124	73	118	
4.	Jabon	94.23	0.33	89	25	72	88	108	31	IV-V
	Anthocephalus cadamba	16.02	0.41	107	15	185	112	105	128	
5.	Sungkai	93.87	0.37	284	61	121	124	172	75	IV-III
	Peronema canescens	16.82	0.46	182	30	255	131	126	177	
6.	Pisang-pisang	76.26	0.48	340	84	151	148	186	76	IV
	Mezzetia parvifolia Becc.	14.00	0.58	211	45	326	178	135	191	

7.	Cempening	57.36	0.62	194	46	165	166	295	126	III-IV
	Querqus sp.	16.86	0.75	240	51	386	185	254	309	
8.	Kelampai	57.59	0.64	242	60	215	218	273	131	II-IV
	Elaterospermum tapos Bl.	15.27	0.78	274	57	447	206	280	320	
9.	Belatik	56.93	0.63	200	45	178	183	276	124	II-III
	Cococeras Sumatrana J.J.S.	12.00	0.79	225	57	421	194	218	248	
10.	Sampe	54.20	0.66	236	64	216	196	324	144	II-III
	Microsas henrici	16.55	0.81	283	66	437	225	330	328	
11.	Ubar	56.49	0.69	265	65	230	216	243	114	III-II
	Eugenia sp.	16.99	0.85	327	67	525	243	286	307	
12.	Ketikal	47.66	0.79	227	68	209	191	298	146	III-II
	Ochanostachys amentacea Mast.	16.39	0.98	274	65	468	189	288	356	
13.	Terentang	64.70	0.28	241	105	303	149	154	83	IV
	Campnosperma spp.	16.00	0.26	263	98	313	181	147	105	
14.	Meranti merah	33.00	0.27	145	62	309	180	136	50	II-IV
	Shorea leprosula Dyer	14.00	0.32	179	66	359	236	130	64	
15.	Macaranga (2)	48.08	0.21	272	64	410	271	275	132	III
	Macaranga hypoleuca (Bl.) Muell. Arg	13.36	0.34	396	85	592	317	349	167	
16.	Tengkawang	51.50	0.38	518	95	543	235	580	183	III-IV
	Shorea gysbertsiana Burck.	14.70	0.39	302	89	569	324	314	201	
17.	Bayur	35.60	0.33	226	37.7	413	195	189	180	II-III
	Pterospermum spp.	13.50	0.39	294	50.2	489	251	163	119	
18.	Jelutung	76.30	0.32	209	55	361	233	176	120	III-V
	Dyera costulata Hook. f.	15.50	0.40	233	59	366	177	128	79	
19.	Petai hutan	104.95	0.33	145	64	282	345	227	128	IV
	Parkia sp.	14.72	0.41	204	64	318	207	473	83	
20.	Meranti putih	43.60	0.42	279	99	509	256	212	190	II-IV
	S. javanica K. et V	15.00	0.42	367	98	587	323	263	232	
21.	Cempaka	75.55	0.37	370	76	599	288	320	272	III
	Elmerillia sp.	15.83	0.44	467	81	624	493	390	245	
22.	Terap putih	58.20	0.40	235	37	393	218	236	394	III-V
	Artocarpus spp.	12.60	0.43	344	48	498	263	267	303	
23.	Medang	38.72	0.49	339	84	486	260	243	210	II-V
	Alseodaphne cratoxylon Kosterm.	15.62	0.50	488	93	578	290.8	230	189	
24.	Pulai	42.10	0.38	234	65	361	182	208	131	IV-V
	Alstonia sp.	14.90	0.55	354	90	526	321	330	203	

Remarks: MC= Moisture Content; Sg= Specific gravity; MPL= Modulud at proportionallimit; MOE= Modulus of Elasticity; MOR= Modulus of Rupture; C// = Maximum crushing strength;
* = After Oey (1990)

Table 18 shows the moisture content of fresh SDL from natural forest ranged from 33.00-153.81%, average 67.20%. Equilibrium moisture content ranged from 12.00-17.48% with average 15.23%. Wet density range from 0.21-0.79 gram/cm^3 , average 0.43 gram/cm^3. Air dried density range from 0.26-0.98 gram/cm^3 , average 0.51 gram/cm^3. Based on wood specific grafity classification, benuang, segulang, merkubung, jabon, sungkai and pisang – pisang classified as light wood. The other SDL species such as cempening, kelampai classified as medium wood and the others classified as weight wood.

Several SDL such as cempening, kelampai, belatik, sampe, ubar and ketikal are feasible for wood construction utilization (strength class II, II-III), the other species classified as strength class IV which is feasible for light construction. Benuang and segulang which is classified as strength class V can be used for bio-composite products which is not require strength prerequites.

Several SDL from natural forest classified as strength class II-III can be used for construction such as red meranti, macaranga, white meranti, cempaka, kelampai, belatik, sampe, ubar and ketikal. The other SDL species can be used for light construction, handicraft and raw material for composite products.

2. Wood Color

Wood color is not related to the mechanical strength. However is very important due to its effect to the buyer preferences. For instance, in one country the popular bio-composite products color is yellow light on the other countries the brown color is more popular, especially for plywood, glulam and LVL. In case of particleboard and MDF, the color is not so important due to the laminating treatment when used as a final products. The wood color of the small diameter log is very wide it lies from light yellow to the dark brown. Description of the sample color can be seen in the figures below.

Benuang (Octomeles sumatrana Miq.)

Segulang (*Evodia* sp.)

Merkubung (Macaranga gigantean)

Jabon (Anthocephalus cadamba)

Sungkai (*Peronema canescens)*

Pisang-pisang (*Mezzetia parvifolia* Becc.)


Cempening (*Querqus* sp.)


Kelampai (*Elaterospermum tapos* Bl.)


Belatik (*Cococeras Sumatrana* J.J.S.*)*


Sampe *(Microsas henrici)*


Ubar (*Eugenia* sp.)

Ketikal (*Ochanostachys amentacea* Mast.)

Terentang *(Campnosperma* spp.)

Meranti merah *(Shorea leprosula* Dyer)

Macaranga (2) (*Macaranga hypoleuca* (Bl.) Muell. Arg)

Tengkawang *(Shorea gysbertsiana* Burck.)

Bayur *(Pterospermum* spp.*)*

Jelutung *(Dyera costulata* Hook. f.)

Petai hutan *(Parkia* sp.)

Meranti putih *(S. javanica* K. et V)

Cempaka *(Elmerillia* sp.)

Terap putih *(Artocarpus* spp.)

Medang *(Alseodaphne cratoxylon* Kosterm.*)*

Pulai *(Alstonia* sp.)

Figure 12. The wood color of the small diameter log

In Malaysia, the following species have been short-listed as potential alternative raw materials for the production of bio-composite products.

- Rubberwood (*Hevea brasiliensis*): latex clone, latex timber clone, and timber latex clone.
- New rubberwood species: *H. spruceana, H. pauciflora, H. benthamiana, H. guianensis*
- *Acacia mangium*

- *Acacia auriculiformis*
- Acacia hybrid *(A. auriculiformis* + *A. mangium*)
- Sentang (*Azadirachta excelsa*)
- Sesenduk (*Endospermum malaccense*)
- Mahang (*Macarangga gigantea*)
- Oil palm (*Elaeis guineensis*)

2.2.1 Rubberwood (*Hevea brasiliensis*)

Rubberwood tree (Fig 13) is known to have many local names. In Malaysia, this particular species is well known as 'kayu getah', rubberwood, and 'para rubber'. It is also known as rubberwood in Brunei and India. In Indonesia, the famous local names are 'kayu getah', 'kayu karet' and 'getah para'. People in Thailand refer to it as 'katoh' and 'yang phara', while in Myanmar, it is known as 'kyetpaung'. In Vietnam, rubberwood is better known as 'cao su'.

Fig. 13: 4-year old high density rubber plantation in Simalajau, Sarawak**.**

Fig. 14: The surface of rubberwood sawn timber that is suitable for many applications.

Rubberwood is classified as a light hardwood with air dry density ranging from 560 - 650 kg/m^3 (see Table 19). Its texture is moderately coarse but even, with straight to shallowly interlocked grains (Fig. 14). It is classified as a non-durable species and very susceptible to attacks by fungi and insects. Bio-deterioration starts almost immediately after the trees are felled. Blue stain fungi penetrate the ends of logs within a week of felling and the infection is found to be more severe during the raining season.

Rubber wood is fibrous material with fibre length of 1214 µm, fibre diameter of 23.5 µm and cell wall thickness of 6.37 µm. The timber seasons fairly rapidly with bowing and springing as the main defects. Rubber wood shrinkage is rather low. The air dry shrinkage in tangential and radial directions was 2.51% and 1.61%, respectively (Table 19). Boards of 13-mm thickness take 2.5 months to air dry, and this takes around 3.5 months for 38-mm thick boards. Kiln Schedule D is recommended to dry rubberwood. A 25-mm thick board can be dried in approximately 6 days. According to Hong and Sim (1994), bowing, springing and end-splitting are the main defects during kiln drying.

Rubberwood is very amenable to preservatives and relatively easy to treat. Treatment, however, must be carried out almost immediately after sawing. Resistance against bio-deterioration can be enhanced by a subsequent kiln-drying of the boards. It is moderately easy to slightly difficult to saw and easy to cross cut, although latex may tend to clog up the saw teeth. Meanwhile, timber planes easily with a smooth finish. The nailing property is rated as good, and the logs are generally free from defects. Due to the presence of tension wood in most rubber wood, woolly surface may be present, particularly on the quarter-sawn material.

The timber falls into Strength Group C or SG5 (MS 544: Part 2:2001). Its modulus of elasticity (MOE) is almost similar to many light hardwood species, with a mean value of 9,240 N/mm^2, a modulus of rupture (MOR) mean value of 66 N/mm^2, a compression parallel to grain mean value of 32 N/mm^2, a compression perpendicular to grain mean value of 4.7 N/mm^2 and a shear strength of 11 N/mm^2 (Hong & Sim. 1994).

Both rubber logs and sawn rubber wood are extremely susceptible to staining fungi as well as insect attacks. Thus, if there is any delay (which should not be more than 2-3 days) in their conversion or processing, chemical preservatives containing a fungicide and an insecticide could be applied by spraying or end coating the logs for temporary protection. Another temporary protection can be done by dipping the boards in a mixture of fungicide and insecticide. For a long term protection, however, treatment processes such as the conventional Bethell process can be done using borax compound.

Rubberwood is normally used for manufacturing furniture, flooring, interior finishing, panelling, mouldings, plywood, charcoal manufacture, wooden pallets, staircase, ornamental items, door components, joinery, cabinet making, etc. It is also used as a core material for block boards and has been chipped for pulp and paper manufacturing and as the main source of fibre material for the production of medium density fibre board (MDF) (Hong & Sim, 1994).

Table 19. Properties of Some Rubberwood Species

Properties	**Species**				
	H. brasiliensis (LC)	New Rubberwood (9 yrs)			
		H. spruc.	*H. pauci.*	*H. guai.*	*H. bentha.*
Anatomy: [1]					
Fiber length (L), µm	1214	1158	1189	1145	1200
Fiber diameter (D), µm	23.5	23.7	24.3	24.9	23.6
Cell wall thickness (W), µm	6.37	6.51	6.08	6.17	6.13
Physical: [2]					
Density, kg/m^3	560-650	590	500	650	610
Air-dry Shrinkage (T), %	2.51	2.89	3.32	2.91	2.57
Total Shrinkage (T), %	n.a	n.a	n.a	n.a	n.a
Air-dry Shrinkage(R), %	1.61	1.53	1.73	1.49	1.66
Total Shrinkage (R), %	n.a	n.a	n.a	n.a	n.a
Mechanical: [3]					
Modulus of Rupture (MOR), N/mm^2	66	64.56	71.42	75.99	78.72
Modulus of Elasticity (MOE), N/mm^2	9240	8027	7234	8085	8051
Compression // to grain, N/mm^2	32	38.49	31.93	38.87	41.4
Shear, N/mm^2	11	14.88	9.52	16.56	17.81
Hardness (Janka), kN	4.35	n.a	n.a	n.a	n.a

Source: [1)] Izani (2006); [2)] Lee *et al.* (1982; [3)] Wong (2002).
Note: n.a is not available

2.2.2 New Rubberwood Species

Other than *H. brasiliensis,* there are several new Hevea wood species which have been introduced in Malaysia. These include *H. spruceana, H. pauciflora, H. guianensis* and *H. benthamiana.* The properties of these species of woods are shown in Table 2.1. The results show that most of the anatomical, physical and mechanical properties of new Hevea species possess almost similar properties to the established *H. brasiliensis*.

The density of the new rubberwood species falls in the range of 500 - 650 kg/m^3, whereby the highest value was recorded for *H. guianensis* and the lowest for *H. pauciflora*. The fibre length was in the range of 1145 - 1200 µm, and this was 23.6 - 24.9 µm for fibre diameter and 6.08 - 6.51 µm for the cell wall thickness (Izani, 2006).

The timber falls into Strength Group C or SG5. The MOE was indicated in the range of 7234 - 8085 N/mm^2, with *H. guianensis* recorded the highest value and *H. pauciflora* recorded the lowest. Meanwhile, the MOR fell in the range of 65.56 - 78.72 N/mm^2. *H. benthamiana* was found to have the highest value, while *H. pauciflora the lowest.* The shear values ranged from 9.52 - 17.81 N/mm^2, with *H. benthamiana* having the highest value and *H. pauciflora the lowest* (Wong, 2002).

2.2.3 *Acacia mangium*

Acacia mangium has many vernacular names (Fig. 15). In English, it is popularly known as ‘black wattle’, ‘brown salwood’, ‘hickory wattle’, ‘mangium’, and ‘Sabah salwood’. In the Philippines, the Filipino call acacia as ‘maber’, and in Indonesia, the acacia wood is known as ‘mangga hutan’, ‘nak’, and ‘tongke hutan’. In Malaysia, the tree is known as ‘mangium’, and this is called ‘kra thin tepa’ and ‘krathin-thepha’ in Thailand.

Fig. 15 : 4-year old *A. mangium* plantation in Tawau, Sabah.

Fig. 16: Tangential surface of *A. mangium* sawn timber.

The sapwood is cream coloured, while the heartwood is dark brown-yellowish or pale brown with a pinkish tinge, and is not sharply demarcated from the sapwood (Fig. 16). *A. mangium* wood has interlocked grains with medium lustre, and the texture is moderately fine and uniform. The average fibre length, fibre diameter, and fibre wall thickness of *A. mangium* are 928 µm 12.4 µm and 2.44 µm, respectively. As depicted in Table 20, the average density of *A. mangium* is 590 kg/m^3 at 12% moisture content (Leong, 2002; Wong, 2002; Hamami *et al.*, 1998b).

A. mangium wood dries at a moderate speed, with slight drying defects, such as end cracks or small lateral cracks. Air dry shrinkage from FSP to 12% MC is 1.99% in tangential direction and 1.3% in radial.

It is crucial to note that *A. mangium* is classified as Class 3 in its natural durability. The wood is moderately resistant to decay when it is fully exposed to the weather, clear of the ground and well-drained in free air circulation. The wood of *A. mangium* is normally not recommended for in-ground use as this wood is resistant to preservative treatments. The wood is moderately hard (rated at 3 on a 6-class scale) in relation to indentation and easy to work on using hand tools. *A. mangium* wood can be satisfactorily bonded using normal wood glue (Awang & Taylor, 1993).

The timber is categorized in Strength Group C. The average MOE and MOR values for *A. mangium* are 9529 N/mm² and 62.76 N/mm², respectively. The compression parallel to the grain and shear strength values of this species are 42.86 N/mm² 15.06 N/mm², respectively, and are comparable with other acacia (Azrina, 2002; Haifah, 2002; Izani, 2006).

A. mangium wood is relatively easy to work and machine. It turns well and gives a smooth finish. The wood can be planed, shaped, bored and turned, with excellent surface finish. In particular, sanding process is relatively easy and gives a smooth surface as well. The timber takes stain well with little requirement for filler. The timber can be laminated well and it is very popular for the production of garden furniture.

The fibre and the pulp are readily bleached to high brightness levels and they are also excellent for paper making. The neutral sulphite semi-chemical pulping of *A. mangium* gives yields up to 61-75%. Currently, it is grown primarily for the source of pulp and paper in Sabah, Sumatra and Vietnam. *A. mangium* wood also makes excellent particleboards. *A. mangium* timber is an important source of wattle timber. The wood is used for construction, boat building, furniture and cabinet making, and veneers. It makes attractive furniture and cabinets, mouldings, as well as door and window components. On the contrary, it is unsuitable for lumber because it contains knots and flutes, has a high incidence of rot and is subject to termite attack. It has high tannin contents (18-39%), justifying commercial exploitation of tannins. *A. mangium* sawdust provides a good quality substrate for the lucrative production of shiitake mushrooms (Awang & Taylor, 1993).

Table 20: Properties of Acacia and Sentang Species

Properties	Species			
	A. mangium (20 yrs)	A. auriculiformis (20 yrs)	A. hybrid (20 yrs) a)	Az. excelsa (10 yrs) b)
Anatomy:[1)]				
Fiber length (L), µm	927	953	991	975
Fiber diameter (D), µm	12.4	17.41	14.73	16.8
Cell wall thickness (W), µm	2.44	2.59	3.77	2.83
Physical:[2)]				
Density, kg/m³	590	810	560	501
Air-dry Shrinkage (T), %	1.99	4.47*	n.a	2.71

Total Shrinkage (T), %	n.a	n.a	5.3	6.31
Air-dry Shrinkage (R), %	1.27	3.32*	n.a	1.80
Total Shrinkage (R), %	n.a	2.71*[)]	2.9	3.92
Total (Vol.), %	n.a	n.a	9.1	n.a
Mechanical: [4)]				
Modulus of Rupture (MOR), N/mm^2	62.76	97.1	94.01	83.3
Modulus of Elasticity (MOE), N/mm^2	9529	8886	9075	8667
Compression // to grain, N/mm^2	42.86	40.76	46.5	44.8
Shear, N/mm^2	15.06	13.32	10.89	13.7
Hardness (Janka), kN	1.75	n.a	n.a	2.94

Sources: [1)] Azrina (2002); Haifah (2002); Izani (2006); [2)] Leong (2002); Wong (2002); Hamami *et al.* (1998b, 1999); [3a)] Bernard (2007); [3b)] Nordahlia (2008)

Note: n.a. is not available

2.2.4 *Acacia auriculiformis*

This species is known for its different vernacular names, such as 'akash mono' in Bengali, 'wattle' and 'coast wattle' (Australian), 'black wattle', 'ear leaf acacia', 'ear pod black wattle' (Darwin), and 'ear pod wattle' (English). In Japan, this particular species is popularly referred to as Japanese acacia, 'northern black wattle', 'Papua wattle', 'tan wattle', and 'wattle'. In Indonesia, this wood is popularly known as 'akasai', 'akasia', 'kasia', and 'ki hia'. People in Malaysia always call it 'akasia kuning', 'kasia', while in Thailand, it is known as 'krathin-narong'.

The natural stands of *A. auriculiformis* are found in Australia, South Western Papua New Guinea and Indonesia. It is widely planted in tropical Asia, with extensive plantings in China and India. In Peninsular Malaysia, it has also become naturalized. It is planted to a lesser extent in Africa and South America. It is a native species in Australia, Indonesia, Papua New Guinea, and exotic in Cambodia, Cameroon, China, Democratic Republic of Congo, India, Japan, Kenya, Malawi, Malaysia, Nigeria, Philippines, Tanzania, Thailand, Uganda, Zanzibar, Zimbabwe (Corner, 1997).

A. auriculiformis is an evergreen tree that grows to a height of 15-30 m, with a trunk up to 12 m long and 50 cm in diameter. It has dense foliage with an open, spreading crown. The trunk is crooked and the bark is vertically fissured (Fig. 17 and Fig. 18).

Fig. 17: 4-year old stand of *A. auriculiformis* in Tawau, Sabah.

Fig. 18: Small diameter logs harvested from a village in Sabah.

Young trees respond to coppicing much better than old trees, but the trees do not sprout vigorously. Nevertheless, the best results are obtained if the stump is cut at a height of 0.6-1 m above the ground. Under favourable conditions, trees may reach a height of 15 m in 5 years and produce an annual wood increment of 15-20 m^3/ha over 10-12 years. An increment in the height of 2-4 m per year in the first few years is common even on soils of low fertility. On relatively fertile Javanese soils receiving 2000 mm annual rainfall, a mean annual increment of 15-20 m^3/ha is obtainable, but the increment is reduced to merely 8-12 m^3/ha on less fertile or highly eroded sites. Thus, a recommended rotation is 4-5 years for fuel wood, 8-10 years for pulp, and 12-15 years for timber (Corner, 1997).

A. auriculiformis generally possesses properties that are superior than that of *A. mangium*. Haifah (2002) and Wong (2002) have shown that *A. auriculiformis* exhibits more superior traits both in its anatomical and strength properties. The average fibre length, fibre diameter and fibre wall thickness of *A. auriculiformis* are 953 µm, 17.41 µm, and 2.59 µm, respectively. Meanwhile, the average density of *A. auriculiformis* is 810 kg/m^3 at 12% moisture content (Table 2.2).

A. auriculiformis wood dries at a moderate speed, with slight drying defects, such as end crack or small lateral cracks. Air dry shrinkage from FSP to 12% MC is 4.47% in tangential direction and 3.32% in radial. The average MOE and MOR values for *A. auriculiformis* are 8886 N/mm^2 and 97.1 N/mm^2, respectively, and it also commands higher strength values compared to *A. mangium*. As shown in Table 2.2, the compression parallel to the grain and shear strength values of this particular species are 40.76 N/mm^2 and 13.32 N/mm^2, respectively, and comparable with other acacia (Leong, 2002; Wong, 2002). *A. auriculiformis*, with its dense wood and high energy (calorific value of 4500-4900 kcal/kg), serves as a major source of firewood. It also provides very good charcoal that glows well with little smoke and does not spark.

This species is extensively used for paper pulp. Plantation-grown trees have been found to be promising for the production of unbleached kraft pulp and high-quality, neutral, sulphite semi-chemical pulp. To date, large-scale plantations have already been established for the production of pulp, such as the one in Kerala, India.

The sapwood is yellow; the heartwood light brown to dark red, with straight grained and reasonably durable. This wood has fine grain, and is often attractively figured and finishes well. In fact, it is excellent for turnery articles, toys, carom coins, chessmen and handicrafts. The species is also used for furniture, joinery, tool handles, and construction.

The bark of *A. auriculiformis* contains sufficient tannin (13-25%) for commercial exploitation and also 6-14% of a natural dye suitable for the soga-batik industry. In India, the bark is collected locally for use as a tanning material. A natural dye, which is used in the batik textile industry in Indonesia, is also extracted from the bark of this particular species.

Damages by pests and diseases are minor. In Indonesia, its growth rate has been impaired by rust fungus known as *Uromyces digitatus*. In India, root rot caused by a fungus (*Ganoderma lucidum*) has been reported. A beetle (*Sinoxylon spp*.) can girdle young stems and branches, and cause them to break. The insect is of concern because the tree will develop multiple leaders if the main stem is damaged and the length of the bole will also be reduced.

2.2.5 Acacia Hybrid

A. mangium x A. auriculiformis hybrids often occur spontaneously in places where both parental species have been introduced in the same vicinity (Fig.

19 and Fig. 20). Tham (1976) documented that *A. mangium* and *A. auriculiformis* could cross pollinate naturally and produce a hybrid that grows much faster than that of its parent trees. The morphological traits of these hybrids (e.g. flower colour, pod aspect, leaf shape and size, bark aspect and colour, and wood density) are generally intermediate between those of the *A. mangium* and *A. auriculiformis* pure parent species. Generally, hybrid *Acacia* is long and straight, with that a clear bole and light branching.

Fig. 19: 2-year old acacia hybrid (*A. mangium x A. auriculiformis*) stand.

Fig. 20: A 5-year old acacia hybrid plantation in Ulu Kukut, Sabah.

Although planted to a far lesser extent as compared to *A. mangium*, the *A. mangium x A. auriculiformis* hybrid has a promising potential for plantation use since it has been shown to be more vigorous and adaptable than both its parental species (Fig. 20). In addition, this particular hybrid has a higher wood density and cellulose content compared to *A. mangium* and seems to be less prone to heart-rot disease, which may affect a high proportion of logs at the end of the plantation cycle in *A. mangium* (Wong *et al.*, 1996; Le Dinh Kha, 2001).

The hybrid *Acacia* also shows more resistance to heart-rot disease that occurs in *A. mangium.* It was observed that the species grows vigorously to resist heart-rot disease in the forest plantations (Banik & Nurul Islam, 1996). As a result, it has become a major industrial plantation species in Malaysia, Thailand and Indonesia. Fast growing tree species are particularly important to meet the demands of wood and furniture industries, pulp and paper mills (Kijkar, 1992). The hybrid tree possesses many characteristics of its parent species (Gani *et al.*, 2001). Most of the reports state that the hybrid *Acacia* is more productive than either of the parent species on different site types in Vietnam, Malaysia, and Thailand.

2.2.6 Mahang *(Macarangga* spp.)

Macarangga spp. is a small tree which can grow up to 25 m tall and 30 cm dbh (Fig. 21). This is an early successional tree species that grows mainly in swamps and can be collected up to 100 m in altitude. It comprises some 250 species, whereby about 30 appear in the tropical Africa and Madagascar, the rest in the tropical Asia (from India to Indo-China, China, Taiwan, and the Ryukyu Island), throughout the Malesian region, northern Australia and the Pacific, east to Fiji. The main centre of its diversity is found within the Malesia, where some 160 species grow with an exceptionally high number of endemic species in Borneo and New Guinea (Sosef *et al.*, 1998).

Fig. 22: Texture and colour of Mahang wood.

Fig. 21: Mahang trees

Macarangga spp. is a light weight hardwood, with a density ranging from 270 to 500 kg/m³ at 15% MC (Table 21). Meanwhile, heartwood is pale yellow-brown to pale brown or grey-brown; sometimes, it is with a pinkish tinge, and not clearly differentiated from the sapwood. As illustrated in Figure 2.5b, the grain is straight or slightly interlocked with a texture that is moderately fine to moderately coarse and even planed surfaces lustrous. Growth rings are sometimes apparent, with vessels that are in moderately small to medium sizes, solitary and in radial multiples of 2-4(-6), tyloses few; moderately abundant parenchyma, apotracheal in narrow bands which are visible with a hand lens, occasionally tends to diffuse-in-aggregates, with very fine rays, is visible with a hand lens, and without ripple marks. It is a fibrous material, with a length of 1660 µm, a width of 51.5 µm and a cell wall thickness of 4.9 µm. Shrinkage is moderate, with a total shrinkage of 7.0% and 3.0% in the tangential and radial directions, respectively. Although the wood is non-durable and liable to sap-stain and insect attack, it is moderately resistant and susceptible to *Lyctus*. However, it is permeable to pressure treatment.

The wood is somewhat fibrous, soft to moderately and fairly weak, and easy to work on. In static bending, the MOR is between 42-50 N/mm^2, and this is between 4940-6728 N/mm^2 for MOE. Its compression parallel to the grain is 19-27 N/mm^2, a shear of 5.7-6.6 N/mm^2 and a hardness of 1.03 kN. The Mahang wood is classified under Strength Group D.

The Mahang wood is traditionally used for temporary construction, especially for parts of native houses that are not in contact with the ground. It is also suitable for light framing, interior trim, moulding, shingles, packing cases, and outriggers for canoes, especially for match splints. In the Philippines, this wood is a favourite material for wooden shoes. *Macarangga* produces high-quality pulps and particleboards, cement-bonded boards and wood-wool boards. It is also suitable for the production of plywood, and known for good fuel wood.

Table 21. Properties of Sesenduk, Mahang, and Oil Palm

Properties	**Species**				
	Endospermum malaccense [a)]	*Macaranga gigantea* [b)]	*Elaeis guineensis* (OPT) [c,d)]		
			Outer	Midlle	Center
Anatomy:					
Fiber length (L), µm	1940	1660	1050	1314	1583
Fiber diameter (D), µm	53.5	51.5	26.83	32.45	29.72
Cell wall thickness (W), µm	5.2	4.9	6.99	7.81	7.18
Physical:					

Density, kg/m^3	390	270-500	362	254	196
Air-dry Shrinkage (T), %	1.3*)	n.a	n.a	n.a	n.a
Total Shrinkage (T), %	5.45	7	n.a	n.a	n.a
Air-dry Shrinkage (R), %	1.2*)	n.a	n.a	n.a	n.a
Total Shrinkage (R), %	2.71	3	n.a	n.a	n.a
Total Shrinkage (Vol.),%	n.a	n.a	22.6	50,1	67.8
Mechanical:					
Modulus of Rupture (MOR), N/mm^2	69.31	42-50	29.54	12.90	6.69
Modulus of Elasticity (MOE), N/mm^2	9999	4940-6728	299.95	114.21	62.80
Compression // to grain, N/mm^2	29.27	19-27	14.57	5.33	4.06
Shear, N/mm^2	9.96	5.7-6.6	3.2	1.0	1.0
Hardness (Janka), kN	1.18	1.03	1.0-11.8	0.67-5.3	0.3-4.8

Sources: [a] Mahadi (1998); [b] Anas (2004); [c] Bakar *et al.* (2000); [d] Bakansing and Hamami (2005)
*) MTC-ERM (2008).
Note: n.a. is not available

2.2.7 Sesenduk (*Endospermum* spp.)

Fig. 23: Sesenduk tree.

Fig. 24: Texture and colour of Sesenduk wood.

Sesenduk belongs to the family of *Euphorbiaceae* which comprises 13 species that are widely distributed from Assam (India), throughout the mainland of South-East Asia and China towards the Malesian archipelago, including Peninsular Malaysia, Sumatra, Borneo Island, the Philippines, northern Sulawesi, Moluccas and New Guinea, and to further east towards Fiji and to the south of northern Queensland. Almost all its species occur within the Malesian area. The 3 most widespread ones are *E. diadenum, E. moluccanum, and E. peltatum.* There is only one species, i.e. *E. diadenum,* found in Peninsular Malaysia (Figure 23), while *E. peltatum* is found in Sabah and Sarawak (Sosef *et al.*, 1998).

Sesenduk is a light hardwood with a density of 270-500 kg/m^3 at 12% moisture content (Table 23). The sapwood is not differentiated from the heartwood, which is bright yellow when fresh, often with a green tinge and darkens to light brown upon exposure (Fig. 24). The grain is straight, interlocked or wavy, with a texture that is moderately coarse to coarse, but even. The surface is lustrous, but lack a figure. Slight checking may occur during drying, with a total shrinkage of 5.45% in the tangential direction and 2.71% in the radial direction. Nonetheless, timber is not durable and very susceptible to blue stain, termites, pinhole borer and marine borer attacks, and when sawn to longhorn beetle attack. It has good peeling properties and produces quality veneers without any pre-treatment, as well as good gluing, painting, screwing and nailing properties. Sesenduk has long fibres (1940 μm), with diameter of 53.5 μm and a cell wall thickness of 5.2 μm.

The timber falls into Strength Group D, with a static bending MOR of 69.31 N/mm^2 and an MOR of 9999 N/mm^2. The compression parallel to grain is 29.27 N/mm^2 and the shear of 9.96 N/mm^2. The hardness is 1.18 kN.

The Sesenduk timber can be used for a variety of purposes, where lightweight, comparatively soft and light-coloured hardwood is required for match boxes and splints, chopsticks, popsicle sticks, medical sticks (spatula), ice-cream spoons, toothpicks, carvings and handicrafts. The wood is non-durable when used in contact with ground; hence, all the applications should be under cover. It is also suitable for pattern making, drawing boards, pencil slats, blockboard trays, furniture parts, picture frames, plywood chests, packing cases and crates, and buoys and floats. In addition, the wood can also be fabricated into laminated wood for panelling and moulding. The fibres are suitable for pulp, paper, and fibre-board productions.

2.2.8 Sentang (*Azadirachta excelsa)*

Azadirachta excelsa is a large deciduous tree that grows up to 50 m in height, with bole up to 125 cm in diameter, and without buttresses. In Malaysia, however, this particular species has been selected as potential species for forest plantation due to its fast growth and good timber. It has also been documented at fifteen years old, whereby it can grow up to 35 cm DBH (Fig. 25) and is suitable as a raw material in the furniture and wood composite industries. The wood has a feature of smooth bark surface that becomes fissured and shaggily flaky in old trees. *A. excelsa* is native to the Malaysian Peninsular, Sumatra, Borneo, Indonesia and the Philippines. The family comprises 50 genera with about 575 species.

Fig. 25: Sentang tree.

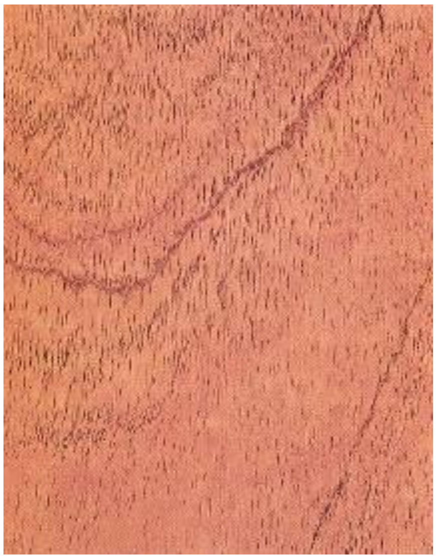


Fig. 26: The texture and colour of Sentang wood.

The timber is moderately hard and heavy, and has a mean density of 501 kg/m^3 at air dry MC (Table 23). Sapwood and heartwood of this timber have distinct colours, with the latter being darker. Meanwhile, the texture of the timber is slightly coarse and uneven, and these are due to its tendency to have a ring-porous structure (Fig. 26). The anatomical structure shows that the vessels are diffused, solitary or multiple, round to oval shaped, and filled with dark-coloured dry extractive deposit in the heartwood. Parenchyma is apotracheal and paratracheal, and the tangential section shows multiseriate rays which are mostly 2-3 cells wide. Heterocellular rays were observed in the radial section in both types of wood. The timber is non-durable to moderately durable. Its fibre is relatively short, with a length of 975 µm, a diameter of 16.8 µm, and a cell wall thickness of 2.83 µm. Shrinkage is relatively low with the total shrinkage in tangential direction of 6.31% and in the radial direction of 3.92%.

The timber falls into Strength Group C with 83.3 N/mm^2 (MOR) and 8667 N/mm^2 (MOE). The compression parallel to the grain is 44.8 N/mm^2, with a shear of 13.7 N/mm^2 and the hardness is 2.94 kN. The wood is generally easy to work on, and has a good finish. The boring properties are rated as good, whereas planing and shaping are moderately good.

The timber has been used for construction work (joinery, interior finishing and flooring) and for furniture. The log can produce moderate to high quality veneers. It has also been used for high class joinery work, furniture, interior finishing, panelling, mouldings, partitioning, plywood, flooring and ornamental items.

2.2.9 Oil Palm *(Elaeis guineensis* Jacq.*)*

Oil palm was introduced into Malaysia in the late 1800s. However, extensive cultivation was not carried out until the 1960's. Today, the total areas under oil palm cultivation in Malaysia are well over 3 million hectares, and about 80% of which are in Peninsular Malaysia. Matured oil palms are usually felled after the age of 25 years (Fig. 27), and this is either due to their decreasing yields or because they have grown too tall, causing harvesting very difficult to carry out. The oil palm stems are normally disposed off by leaving them to rot or burning them in the field. However, freshly felled stems, with their high moisture contents, cannot be easily burnt in the field. Moreover, leaving the stems in the field without further processing will physically hinder the process of planting new crops as the stern can take about five years to completely decompose.

Fig. 27: Mature oil palm trees ready for replanting

The common name for the palm is *Elaeis guineensis,* i.e. the Palmae family. It occurs naturally in the tropical rain forests of West Africa, stretching from Senegal to Angola and extending further along the Congo River. The oil palm was first introduced into Malaysia in 1870 through the Botanic Garden, Singapore. Nonetheless, the interest in the commercial exploitation of oil palm started only in the 1900s. Today, Malaysia is one of the major exporters of palm oil in the world.

The oil palm, being a monocotyledon, has marked structural differences from our commercial timbers. The most remarkable features of woody monocotyledons are that most of them achieve their stature without secondary thickening. Thus, unlike the wood of most other tree species, which is mostly secondary xylem, the wood of oil palm consists of primary vascular bundles that are embedded in parenchymatous tissue (Fig. 28). There is usually a very hard peripheral rind surrounding the soft central region. The wood of palm is not homogenous. Anatomically, the hard peripheral zone composes of a narrow layer of parenchyma and congested vascular bundles that give rise to a sclerotic zone, which forms the main mechanical support to the palm stem. The central zone consists of larger and widely scattered vascular bundles that are embedded in the thin-walled parenchymatous tissue. Each vascular bundle consists of a fibrous sheath, phloem cells, xylem, and parenchyma cells, and is surrounded by spherical, druse-like silica bodies. The xylem is always sheathed with parenchyma cells and usually consists of one or two wide vessels. Fibre is relatively long with a length of 1050-1583 µm in an increasing order from the inner core to the peripheral layer, a diameter of 26.83-32.45 µm and a cell wall thickness of 6.99-7.81 µm.

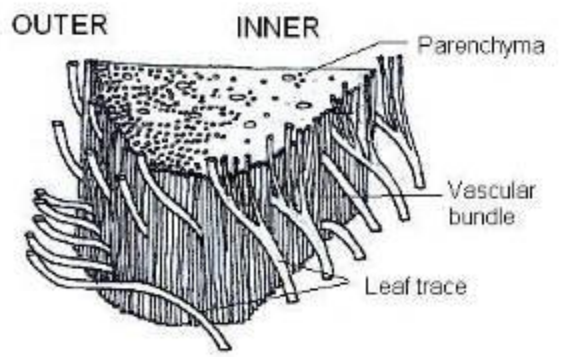


Fig. 28: The structure of oil palm wood showing congested vascular bundles at the outer and parenchyma at the inner.

Oil palm has a great variation of density values at different parts of the stem. Its density is low in the centre of the stem, but gradually increases toward the bark. The average density values range from 196-362 kg/m^3 air dry (Table 2.3). The timber is very susceptible to fungal and insect attacks due to the presence of high sugar and starch contents. The stem is rather difficult to process, particularly at the region near the bark, due to the presence of silica in the cells. Chong *et al*. (2010) have reported poor machining properties (see Fig. 29). The lumber of oil palm trunk is difficult to dry and suffers from various drying defects, including raised grain, warping and collapse. The total volumetric shrinkages recorded for oil palm wood were 22.6% at the outer layer, 50.1% at the middle, and 67.8% at the inner core.

Fig. 29: Oil palm wood showing bad planing and boring properties

The high density variation within the oil palm stem has a significant effect on its strength properties. Based on a joint study conducted by University of Malaya and FRIM, the MOE, MOR and compressive strength along the grain were found to be linearly correlated to the density. Table 2.3 shows the basic strength properties of oil palm wood which were tested at the outer, middle and central layers. The MOR was found in the range of 6.69-29.54 N/mm^2, and this was 62.8-229.95 N/mm^2 for MOE, with the compression parallel to the grain between 4.06-14.57 N/mm^2 and a hardness of 0.3-11.8 kN.

Oil palm wood has a potential to be used for various applications, as enjoyed by the popular coconut wood in the Philippines. With proper treatment, oil palm wood could be used for various light construction applications. It can be also used as a core material for the production of block boards and plywood, which in turn, can be used as framing materials for the manufacture of upholstery furniture (Fig. 30). Some selected materials from the stem may also be used to manufacture furniture. In particular, veneers that are obtained from the stem are used for manufacturing formed plywood for furniture components.

Fig. 30: Oil palm veneers are used for plywood (left) and LVL (right) productions

Beside the uses mentioned above, other possible usage of oil palm stem is in the form of composite panel products, such as particleboard, wood-cement board, gypsum-bonded particleboard and medium density fibreboard (MDF) (Chew *et al.*, 1991). Research has also indicated that the kraft pulp from oil palm stems can be used as a reinforcing material for cellulose fibre reinforced cement boards (CFRC) (Abraham, 1998). Other uses investigated include the briquetting of oil palm stem, with empty fruit bunches and pressed fruit fibres into solid fuel pellets. Apparently, the calorific value of the fuel pellets produced is very similar to that of most tropical hardwoods (i.e. about 17.8 MJ/kg). Under controlled conditions, it is also possible to convert oil palm stem into fermentable sugars to produce alcohol fuels through enzymatic activity (Hoi *et al.*, 1991).

A research carried out at the Forest Research Institute of Malaysia (FRIM) has indicated that oil palm trunks may also be exploited commercially for various purposes, such as for manufacturing composite panel products like medium density fibreboard (MDF), block board, laminated veneer lumber (LVL), mineral-bonded particleboard and plywood. Other uses suggested include furniture and paper making. The latest research by Bakar *et al*. (2008) revealed that if properly treated, oil palm wood could be used for high grade furniture and construction materials. Both the treated and untreated oil palm woods are shown in Fig. 2.14 below.

Fig. 31: Treated (left) and untreated (right) oil palm wood

To give a brief processing overview of the species, regardless of the product made, the basic processing characteristics of the selected species discussed in the previous chapter are reviewed in this section. These are for basic information of the respective species before discussing their processing characteristics for wood composites. Most of the data used here were derived from the secondary data (see sub-section 2.2).

a. Rubberwood (*Hevea brasiliensis*)

- Moderately easy to slightly difficult to resaw and easy to cross cut although latex may tend to clog up the saw teeth.
- The timber planes easily and the finishing is smooth. Due to the presence of tension wood in most rubberwood, woolly surface may be present, particularly on the quarter-sawn material and this can be overcome by optimizing cutter tools angle and by using appropriate applications of sanding sealer and finished coatings for the semi-finished products.
- The timber seasons fairly rapidly with bowing and springing as the main defects. However, kiln drying with Kiln Schedule D is recommended. 25 mm thick boards can be dried in approximately 6 days. Among the main defects are bowing, springing and end-splitting.
- Shrinkage is rather low. Radial shrinkage averages 0.8%, while tangential shrinkage averages 1.9%.

- Very amenable to preservatives. Therefore, preservation treatment must be carried out almost immediately after the boards emerge from the saw.
- Rubberwood is extremely susceptible to staining fungi as well as insects attack. Thus, if there is any delay (not more than 2-3 days) in conversion or processing, chemical preservatives containing a fungicide and an insecticide could be applied by spraying or end coating the logs for temporary protection.

b. Acacia species (*Acacia mangium* and *Acacia* hybrid)

- Wood can be dried at a moderate speed, and slight drying defects could take place, such as cracking at the ends or small lateral cracks;
- Relatively easy to work and machine. Timber has been reported to plane, shape, bore, mortise and turn with excellent surface finish.
- Moderately hard (rated 3 on a 6-class scale) in relation to indentation and ease of working with hand tools.
- Gluing can be satisfactorily bonded using standard procedures.
- It polishes and paints well.
- Trial production of furniture for commercial production has found that planing, turning and spindle moulding are easy with little tearing.
- Sanding is easy and smooth surface can be achieved.

c. Mahang (*Macarangga gigantea*)

- Grain is straight or slightly interlocked.
- Texture is moderately fine to moderately coarse and even; planed surfaces lustrous
- Shrinkage is moderate and in seasoning, and the wood is liable to sap-stain and is subject to insect attack. The wood is soft to moderately and fairly weak.
- Easy to work but somewhat fibrous.

- Non-durable and permeable to pressure treatment.

d. Sentang (*Azadirachta excelsa*)

- The timber seasons fairly rapidly, with only slight twisting and end-checking as the main sources of degrade. 13 mm thick boards take approximately 2 months to air dry, while 38 mm thick boards take around 4 months.
- Shrinkage is very low with both radial and tangential shrinkage averaging at 0.5%.
- Sentang wood is generally easy to work. The boring properties are rated as good, whereas planing and shaping are moderately good.
- The wood takes a good finish.

e. Sesenduk (*Endospermum spp*)

- Very susceptible to blue stain, termite, pinhole borer and marine borer attack. Timber should be chemically treated or given high temperature treatment to prevent stain and insect attack.
- The timber seasons fairly rapidly without serious degradation, except for some insect attacks. 13 mm thick boards take around 2 months to air dry, while 38 mm thick boards take 3 months.
- Kiln Schedule J is recommended. 25 mm thick boards take approximately 5 days to kiln-dry to 10% moisture content without any degradation. Slight checking may occur during drying.
- Shrinkage is low, with radial shrinkage averaging 1.2% and tangential shrinkage averaging 1.3%.
- It is easy to saw, plane, bore and turn, and produces a smooth surface.
- Good peeling properties, resulting in good quality veneer without any pre-treatment.

- Good gluing, painting, screwing and nailing.

f. Oil Palm Wood (*Elaeis guineensis*)

- The timber is very susceptible to fungal and insect attacks due to the presence of high sugar and starch contents.
- As a monocotyledon plant, sawing of oil palm trunk is difficult tasks and it yields low recovery. The polygon sawing is reported to be the most appropriate sawing method for oil palm trunks. A sawing recovery of about 30% for the best outer lumber can be yielded by this method.
- The lumber is difficult to dry and it also suffers from various drying defects, including raised grain, warping and collapse. Due to its super-high green moisture content (300% to 500% or higher), it takes a very long time to dry. A 2-inch thick oil palm lumber takes more than one month to dry with the current kiln dry practices.
- Processing oil palm wood is difficult. Due to the presence of high-density vascular bundles embedded in low-density parenchymatous ground tissues, the planing is very bad (rated at 5 on a 5-class scale). In particular, raised grain, torn grain and fuzzy grain are the main planing defects. Similarly, crosscutting, shaping and boring are also very bad.

Based on the above physical, mechanical and chemical properties of small diameter logs, theoretical analysis and some experience of products production using small diameter logs can be classified the suitability of the wood sample as bio-composite products (plywood, glulam, LVL, particleboard and MDF). The analysis results of the small diameter logs suitability can be seen in **Table 22.**

Table 22. Utilization of selected small diameter logs for composite products

No.	Wood species	Glulam	Plywood	LVL	Particle board	MDF
A.	**Plantation and community forest**					
1.	Sengon	*No*	***Yes***	***Yes***	***Yes***	***Yes***
2.	Kayu afrika	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***
3.	Tisuk	No	Yes	Yes	Yes	Yes
4.	Suren	No	Yes	Yes	Yes	Yes
5.	Ekaliptus	No	Yes	Yes	Yes	Yes
6.	Sengon buto	Yes	No	No	Yes	Yes
7.	Mindi	Yes	Yes	Yes	Yes	Yes
8.	Kiseseh	Yes	Yes	Yes	Yes	Yes
9.	Mangium	Yes	Yes	Yes	Yes	Yes
10.	Mahoni	Yes	Yes	Yes	Yes	Yes
11.	Rubberwood	Yes	Yes	Yes	Yes	Yes
12.	Puspa	Yes	Yes	Yes	Yes	Yes
13.	Gmelina	Yes	Yes	Yes	Yes	Yes
14.	Pinus	Yes	Yes	Yes	Yes	Yes
B.	**Natural Forest**					
1.	Benuang	No	Yes	Yes	Yes	Yes
2.	Segulang	No	Yes	Yes	Yes	Yes
3.	Merkubung	No	Yes	Yes	Yes	Yes
4.	Jabon	No	Yes	Yes	Yes	Yes
5.	Sungkai	No	Yes	Yes	Yes	Yes
6.	Pisang-pisang	Yes	Yes	Yes	Yes	Yes
7.	Cempening	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***
8.	Kelampai	Yes	Yes	Yes	Yes	Yes
9.	Belatik	Yes	Yes	Yes	Yes	Yes
10.	Sampe	Yes	Yes	Yes	Yes	Yes
11.	Ubar	Yes	Yes	Yes	Yes	Yes
12.	Ketikal	Yes	Yes	Yes	Yes	Yes
13.	Terentang	No	Yes	Yes	Yes	Yes
14.	Meranti merah	No	Yes	Yes	Yes	Yes
15.	Macaranga	No	Yes	Yes	Yes	Yes
16.	Tengkawang	No	Yes	Yes	Yes	Yes
17.	Bayur	No	Yes	Yes	Yes	Yes
18.	Jelutung	No	Yes	Yes	Yes	Yes
19.	Petai hutan	No	Yes	Yes	Yes	Yes
20.	Meranti putih	Yes	Yes	Yes	Yes	Yes
21.	Cempaka	No	Yes	Yes	Yes	Yes
22.	Terap putih	Yes	Yes	Yes	Yes	Yes
23.	Medang	Yes	Yes	Yes	Yes	Yes
24.	Pulai	No	Yes	Yes	Yes	Yes

Remarks: Yes means suitable No means not suitable

Based on the above table it is very clear that small diameter logs which is suitable for glulam is less compared to those of plywood, LVL, particleboard and MDF. This is because glulam is mainly used for structural purposes which is mean the strength of the raw material is very important. Even though the low specific gravity SDL is not recommended for glulam raw material, it doesn't mean that they cannot to be used as glulam raw material. It is possible to use them as core layers in glulam construction and combine with high specific gravity in the outer layers or can be used to produce non structural glulam.

Sengon butho is not recommended as plywood and LVL raw material because its veneer surface is not smooth and produce serious problems in veneer adhesion. This phenomenon caused the produced plywood and LVL performed low quality.

B. Wood and Wood Industry in PNG

The main timber species for the furniture and wood processing industry are mersawa, white tulip oak, rosewood, walnut and kwila-merbau. The major centres for primary timber processing (sawmill and plywood) are Rabaul, Bulolo, Gae, Kaupa and Ialibu.

The potential market for bio-composite industries products of PNG for the time being are the larger settlements and towns of the country. In PNG domestic market, bio-composite products such as plywood and glulam have being used as furniture raw material. Nowadays PNG produces a range of forest products, including furniture, plywood and prefabricated buildings for both domestic and export markets. Processed timber products are exported to Australia, New Zealand and PNG's South Pacific neighbors. Veneer is mainly sold to China and South Korea. Plantation products account for 15% exports.

Major wood industry in PNG include Cloudy Bay Sustainable Forestry Ltd's logging, sawmilling, and timber sales in Port Moresby; Innovision (PNG) Ltd at Makarpa, Western Province; Open Bay Timber Ltd's export of logs and plantation in East New Britain; PNG Forest Products Ltd's sawmilling, plywood and manufacturing at Bulolo, Morobe; Pac-Rim Hardwoods (PNG) Ltd's sawmilling and timber exports in Port Moresby; Rimbunan Hijau (PNG) Ltd's export logging, downstream processing and other interests, PNG-wide; Stettin Bay Lumber Co. Ltd's export of logs, sawmilling and plantations in West New Britain Province; and Turama Forest Ind. Ltd's log exports from the Gulf Province (www.businessadvantageinternational. com/PNG_2011_pp44_45).

Physical and Mechanical Properties of Wood

The average value of the studied physical properties of wood is presented in Table 2. The table shows the density of wood samples collected from PNG small diameter logs ranges between 0.123 (Balsa) to 0.640 (Garcinia). Based on the classification of the wood density, all wood species that have been tested are classified in low density wood, except Garcinia which includes in medium density. The average values of physical and mechanical properties of PNG wood samples can be seen in Table 23.

Table 23. Average values of physical and mechanical properties of PNG-wood

Wood Species, Physical and Mechanical Properties	Value
1. Wau beech *(Elmerillia papuana)*	
• Density, g/cm^3	0.348
• MOR, kg/cm^2	464
• Maximum crushing strength, kg/cm^2	251
• Shear strength, kg/cm^2	
○ Radial	67
○ Tangential	56
• Hardness (side), kg/cm^2	251
• Strength class[1)]	IV
• Durability class[2)]	III
2. Bintangur (*Callophyllum inophyllum*)	
• Density, g/cm^3	0.509
• MOR, kg/cm^2	628
• Maximum crushing strength, kg/cm^2	334
• Shear strength, kg/cm^2	
○ Radial	67
○ Tangential	99
• Hardness (side), kg/cm^2	364
• Strength class[1)]	III - II
• Durability class[2)]	II
3. Balsa (*Ochroma lagopus*)	
• Density, g/cm^3	0.116
• MOR, kg/cm^2	135
• Maximum crushing strength, kg/cm^2	102
• Shear strength, kg/cm^2	

○ Radial	13
○ Tangential	16
• Hardness (side), kg/cm^2	71
• Strength class[1)]	V
• Durability class[2)]	V
4. Taun (*Pometia pinnata*)	
• Density, g/cm^3	0.492
• MOR, kg/cm^2	614
• Maximum crushing strength, kg/cm^2	250
• Shear strength, kg/cm^2	
○ Radial	92
○ Tangential	92
• Hardness (side), kg/cm^2	368
• Strength class[1)]	III – IV
• Durability class[2)]	II
5. Garcinia	
• Density, g/cm^3	0.601
• MOR, kg/cm^2	653
• Maximum crushing strength, kg/cm^2	372
• Shear strength, kg/cm^2	
○ Radial	80
○ Tangential	90
• Hardness (side), kg/cm^2	366
• Strength class[1)]	II - III
• Durability class[2)]	II
6. Canarium	
• Density, g/cm^3	0.377
• MOR, kg/cm^2	447
• Maximum crushing strength, kg/cm^2	248
• Shear strength, kg/cm^2	
○ Radial	53
○ Tangential	62
• Hardness (side), kg/cm^2	252

• Strength class[1)]	IV
• Durability class[2)]	III

Note : [1)]Refer to Indonesian wood strength classification, I (very strong) – V(very week)
[2)]Refer to Indonesian wood durability, I (very durable) – V (very susceptible)

Solubility in Water

Water solubility of the six species of wood from PNG are presented in Table 24.

Table 24. Cold and hot water solubility of six wood species from PNG.

No	Wood Species	Solubility (%)	
		Hot Water	Cold Water
1	Wau beech	5.12	3.30
2	Bintangur	2.76	2.41
3	Balsa	4.30	4.02
4	Taun	8.94	5.44
5	Garcinia	6.50	4.63
6	Canarium	4.96	1.58

Based on the above physical, mechanical and chemical properties, lesson learned from various small diameter logs species in Indonesia, Malaysia, and Philippines, relevant publications related to the small diameter logs and Indonesian bio-composite experts focus group discussion, the suitability of some PNG wood species from small diameter logs for bio-composite products can be seen in Table 25.

Table 25. Utilization of PNG Small Diameter Logs for Bio-composite Products

No.	Wood Species	Air Dry Density (12% MC) kg/m^3	Ply-wood	LVL	Glulam	Particle-board	MDF	Remarks
Research Results								
1.	Wau beech	348	Yes	Yes	Yes	Yes	Yes	Glulam for light construction
2.	Bintangur	509	Yes	Yes	Yes	Yes	Yes	
3.	Balsa	116	No	No	No	Yes	Yes	Too light even for particleboard and MDF
4.	Taun	492	Yes	Yes	Yes	Yes	Yes	

Tabel 25 (continue)

5.	Garcinia	601	Yes	Yes	Yes	Yes	Yes	
6.	Canarium	380	Yes	Yes	Yes	Yes	Yes	Glulam for light construction
Based on literature, experience and professional judgment								
7.	Canarium Grey	560	Yes	Yes	Yes	Yes	Yes	
8.	Cedar Pencil	540-720	Yes	Yes	Yes	No	No	Too heavy for particleboard and MDF
9.	Dillenia	540-620	Yes	Yes	Yes	Yes	Yes	
10.	Erima	320-390	Yes	Yes	Yes	Yes	Yes	
11.	Hekakoro (Gluta)	520	Yes	Yes	Yes	Yes	Yes	Feasible for fancy sliced veneer
12.	Kwila	670-800	Yes	No	Yes	No	No	Glulam for heavy construction, fancy veneer.
13.	Lophopetallum (Perupok)	340-450	Yes	No	Yes	Yes	Yes	Feasible for fancy veneer.
14.	Malas	740-840	No	No	Yes	No	No	Glulam for heavy construction,
15.	Mersawa (PNG)	560-650	Yes	Yes	Yes	Yes	Yes	
16.	Planchonella Red	500-570	Yes	Yes	Yes	Yes	Yes	Glulam for light construction.
17.	Planchonella White	510	Yes	Yes	Yes	Yes	Yes	
18.	Teak	610	Yes	No	No	No	No	Feasible for fancy veneer.
19.	Terminalia Brown	290	Yes	Yes	No	Yes	Yes	
20.	Walnut PNG	530-560	Yes	Yes		Yes	Yes	Decorative veneers
21.	Aglaia	720-960	Yes	No	Yes	No	No	Feasible for fancy veneer
22.	Amoora (Pacific Maple)	540	Yes	Yes	Yes	Yes	Yes	Glulam for light construction.
23.	Antiaris	380-420	Yes	Yes	Yes	Yes	Yes	
24.	Basswood PNG	380-390	Yes		Yes	Yes	Yes	
25.	Cedar Mangrove	630-880	Yes	No	Yes	No	No	Feasible for fancy veneer.
26.	Cedar Red	360-370	Yes	No	Yes	No	No	Feasible for fancy veneer.
27.	Elmerrilia (Beech Wau)	430-480	Yes	Yes	Yes	Yes	Yes	
28.	Hopea Heavy	870-960	No	No	Yes	No	No	Glulam for heavy construction.
29.	Hopea Light	680-710	Yes	Yes	Yes	No	No	
30.	Kamarere	690	Yes	Yes	Yes	No	No	

Remarks: Yes means suitable
No means not suitable

Fundamental Properties of Philippines SDL

I. *Eucalyptus citriodora*

The mean MC of the species ranged from 58.42 - 65.35% while relative density from 0.740 – 0.770. The MC and RD trend was inverse, relative density increased as MC decreased (Figs. 2 & 3). On the other hand, the ranges of strength properties were as follows: MOR, 85.27 – 92.72 MPa; SPL, 34.09 – 43.13 MPa; MOE, 12.72 – 13.77 GPa; MCS, C//, 38.51 – 44.80 MPa; SPL, C/, 4.08 -7.72; Shear, 9.37 -9.69 MPa; Hardness Side, 7.41 – 8.34; Hardness End, 7.41 – 8.34; Toughness Radial , 41.29 – 41.40 and Toughness Tangential, 39.40 – 42.36 Joule/specimen.

Based on FPRDI classification (1980), the species exhibited high RD (Class I, 0.700 above) while strength properties from moderately high (Class II) to High (Class I). The trend of strength properties variations along the height level was not consistent, either increasing from butt to mid and slightly decreasing toward the top (MOR, MOE, MCS and Hardness Side), slightly decreasing from butt to mid and increasing toward the top (SPL, SB; SPL, C/; and Shear), or increasing form butt to top (Hardness End) (Figs. 34 – 39).

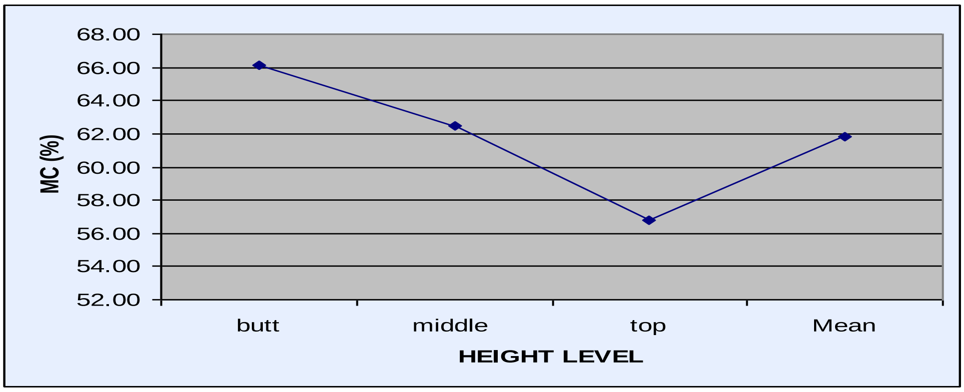


Fig.32. Moisture Content (MC, %) of *E. citriodora* at different height levels.

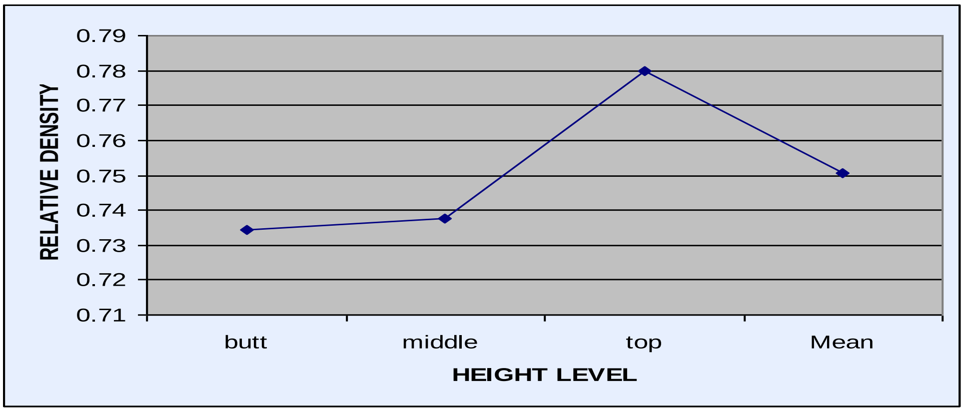


Fig.33. Relative Density of *E. citriodora* at different height levels.

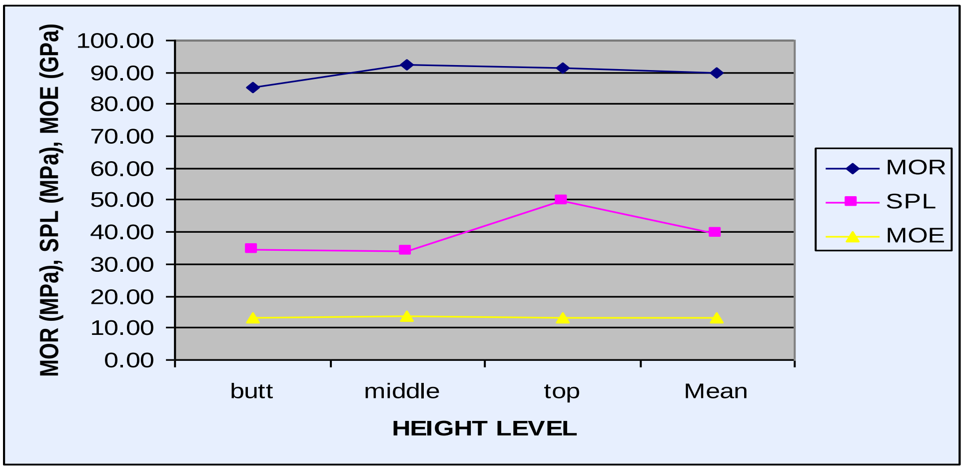


Fig. 34. Static Bending Properties (MOR, SPL, MOE) of *E. citriodora* at different height levels.

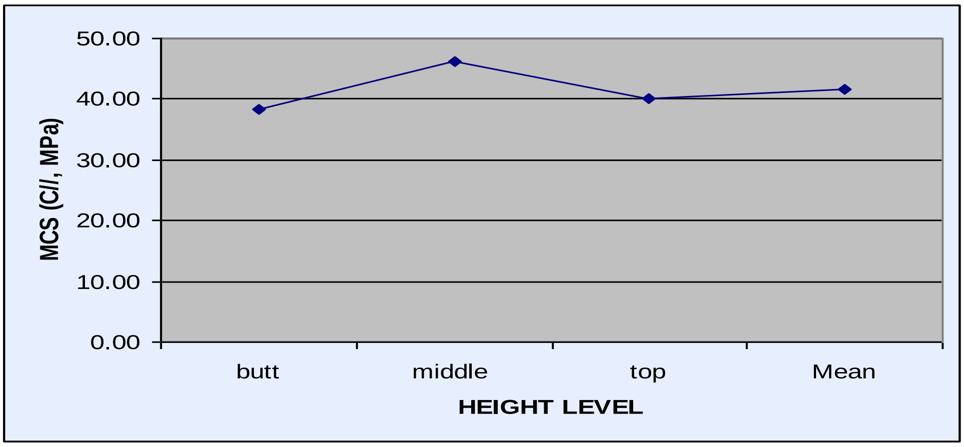


Fig.35. Maximum Crushing Strength in Compression Parallel-to-Grain (MCS, C//) of *E. citriodora* at different height levels.

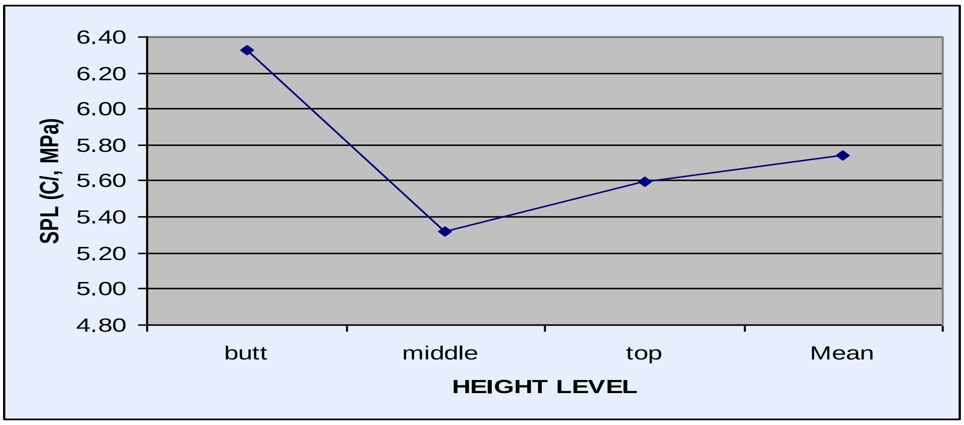


Fig. 36. Stress at Proportional Limit in Compression Perpendicular-to-Grain (SPL, C/) of *E. citriodora* at different height levels.

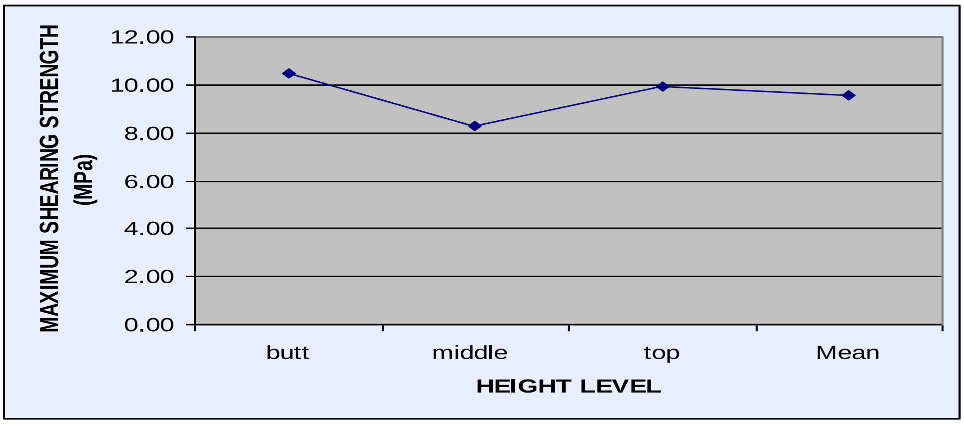


Fig. 37. Maximum Shearing Strength of *E. citriodora* at different height levels.

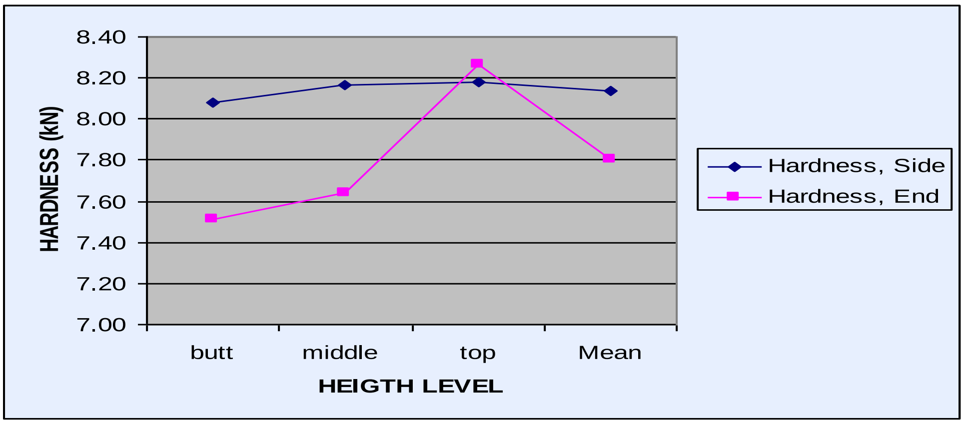


Fig. 38. Hardness of *E. citriodora* at different height levels.

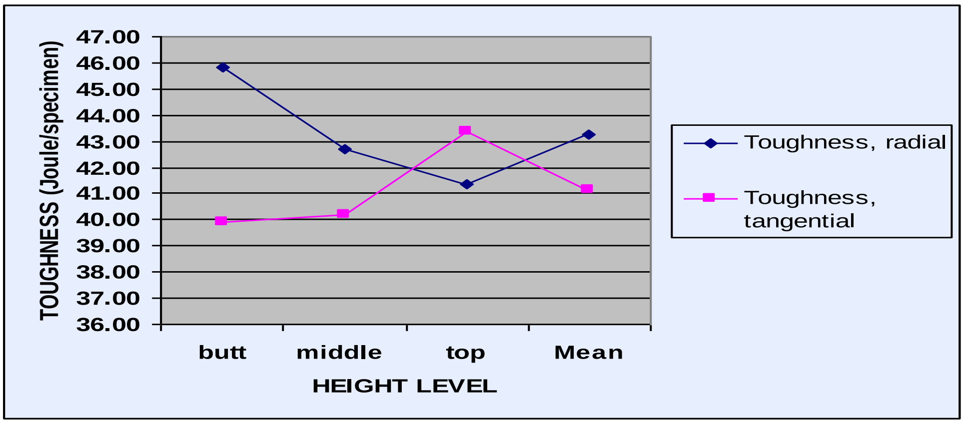


Fig. 39. Toughness of *E. citriodora* at different height levels.

II. Eucalyptus europhylla

The mean MC of the species ranged from 71.05 – 78.19 % while relative density from 0.663 – 0.713. The MC and RD trend was inverse, relative density increased as MC decreased (Figs. 10 & 11). On the other hand, the ranges of strength properties were as follows: MOR, 76.47 – 78.76 MPa; SPL, 27.17 – 39.23 MPa; MOE, 11.04 – 13.25 GPa; MCS, C//, 32.50 – 40.29 MPa; SPL, C/, 6.42 – 8.50; Shear, 7.88 – 10.71 MPa; Hardness Side, 6.03 – 6.69; Hardness End, 6.42 – 6.77; Toughness Radial , 34.37 – 53.38 and Toughness Tangential, 41.99 – 57.75 Joule/specimen.

Based on FPRDI classification (1980), the species exhibited Moderately High RD (Class II,) while strength properties from Moderately High (Class II) to High (ClassI). The trend of strength properties variations along the height level was increasing from butt to top except in the following: MOE and C/, decreasing from butt to mid and increasing toward the top (highest) and Toughness, increasing from butt to mid (highest) and decreasing toward the top (Figs.40 – 47).

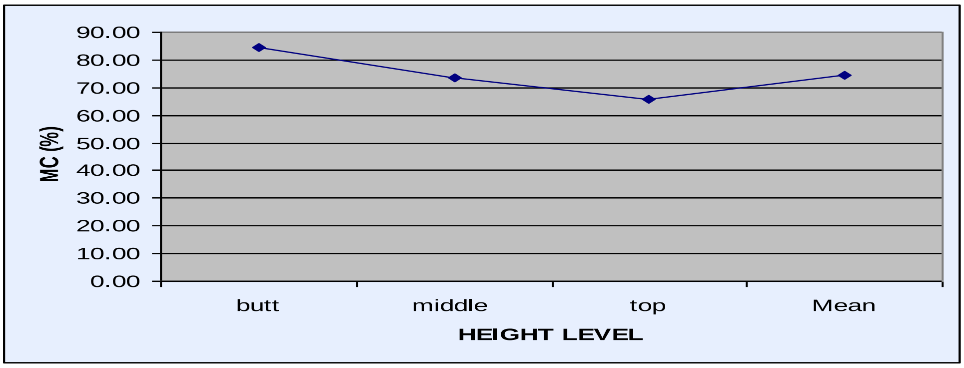


Fig. 40. Moisture Content (MC, %) of *E. urophylla* at different height levels.

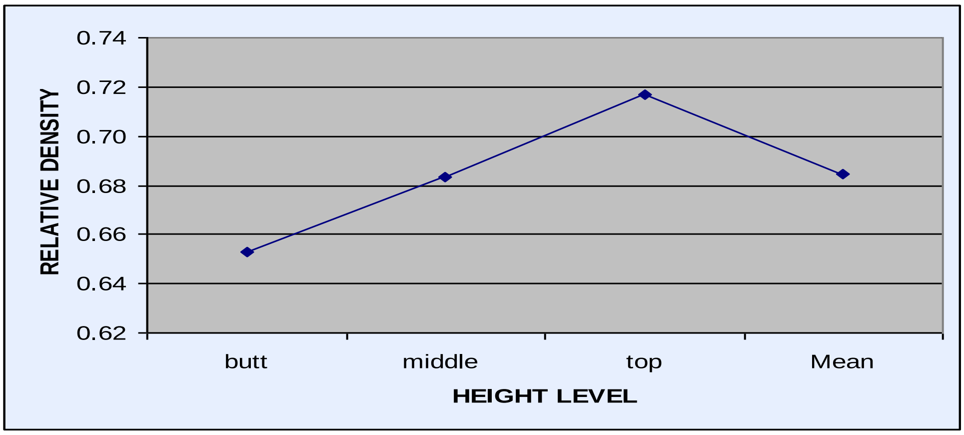


Fig. 41. Relative Density of *E. urophylla* at different height levels.

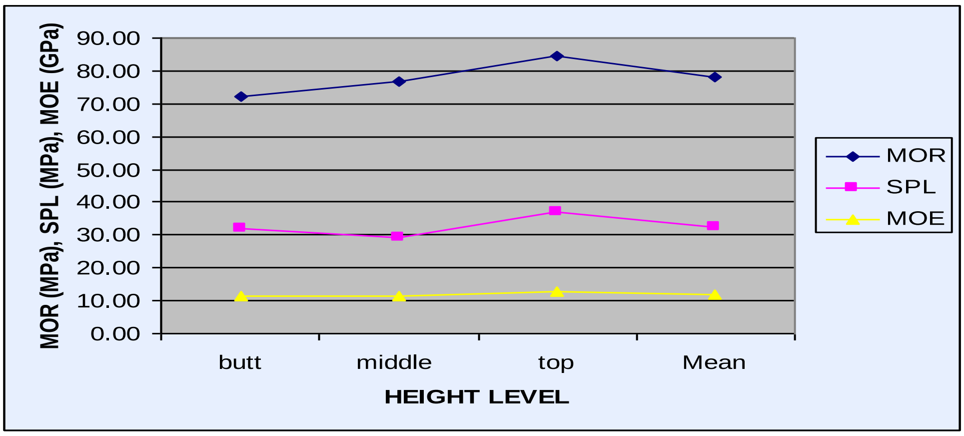


Fig. 42. Static Bending Properties (MOR, SPL, MOE) of *E. urophylla* at different height levels.

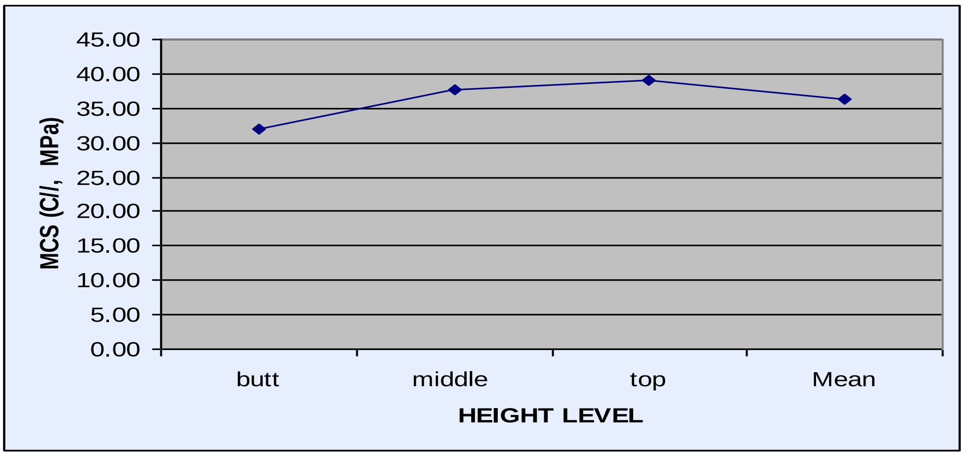


Fig. 43. Maximum Crushing Strength in Compression Parallel-to-Grain(MCS, C//) of *E. urophylla* at different height levels.

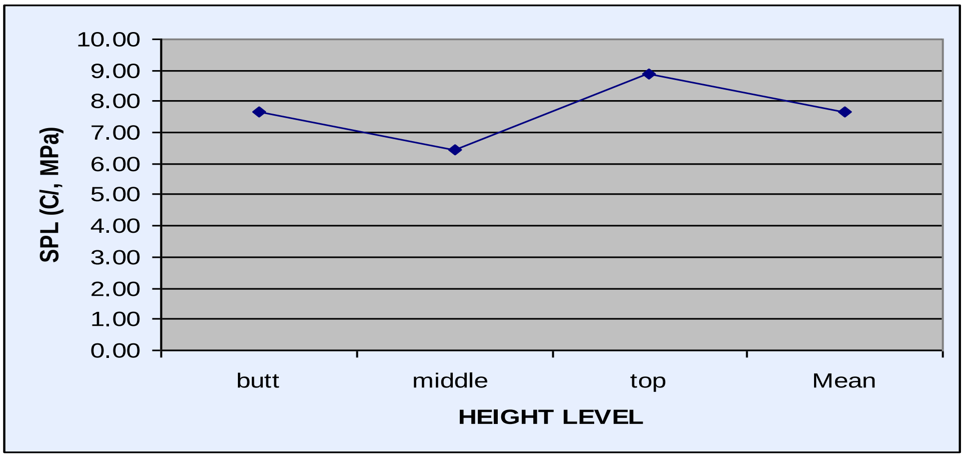


Fig. 44. Stress at Proportional Limit in Compression Perpendicular-to-Grain (SPL, C/) of *E. urophylla* at different height levels.

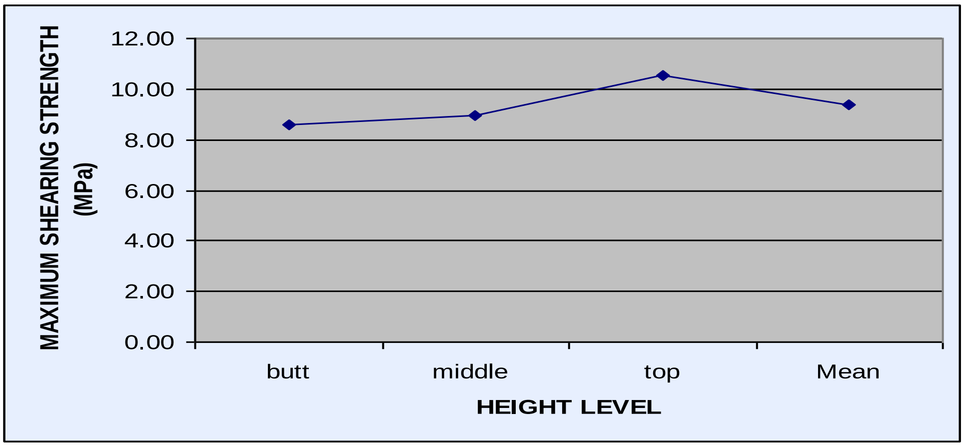


Fig. 45. Maximum Shearing Strength of *E. urophylla* at different height levels.

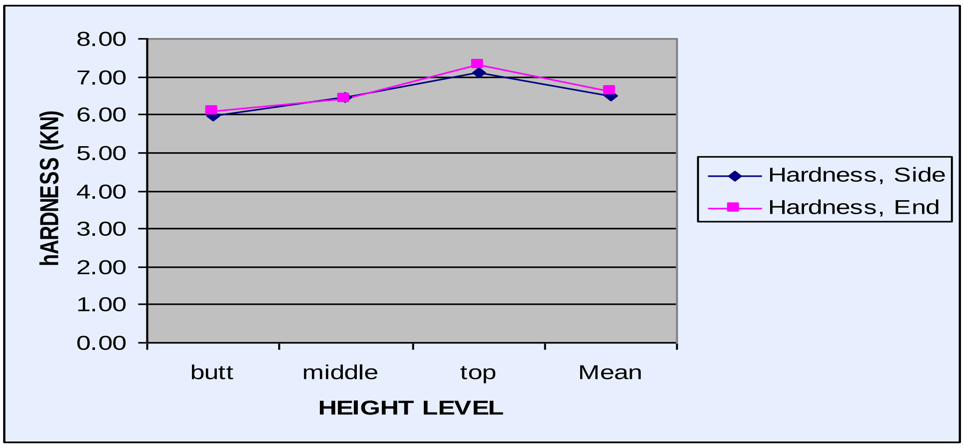


Fig. 46. Hardness of *E. urophylla* at different height levels.

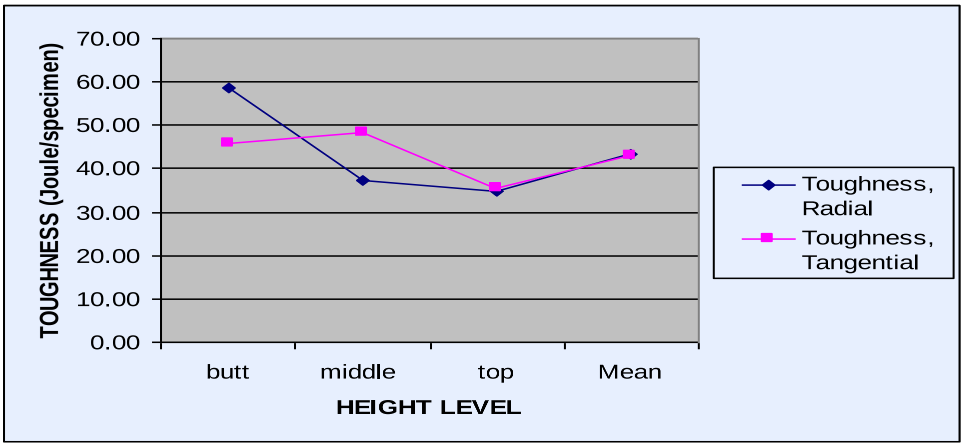


Fig. 47. Toughness of *E. urophylla* at different height levels.

III. *Alstonia macrophylla* G. Don

The mean MC of the species ranged from 99.84 – 105.35% while relative density from 0.551 – 0.560. The MC and RD trend was inverse, relative density increased as MC decreased (Figs. 9 & 10). On the other hand, the ranges of strength properties were as follows: MOR, 55.31 – 75.86 MPa; SPL, 22.12 – 26.18 MPa; MOE, 9.29 – 10.08 GPa; MCS, C//, 27.08 – 29.43 MPa; SPL, C/, 5.43 – 5.81; Shear, 8.11 – 8.93 MPa; Hardness Side, 3.90 – 4.30 kN; Hardness End, 4.49 – 5.06 kN; Toughness Radial , 40.13 – 45.50 and Toughness Tangential, 40.70 – 45.47 Joule/specimen.

Based on FPRDI classification (1980), the species exhibited Medium RD (Class III) while the strength properties from Medium (Class III) to Moderately High (Class II).

The trend of strength properties variations along the height level was not consistent, either decreasing from butt to top (MOR and Hardness), decreasing from butt (highest) to mid (lowest) and slightly increasing toward the top (SPL), decreasing from butt to mid (lowest) and increasing toward the top (highest) (MOE), increasing from butt to mid (highest) and decreasing toward the top (lowest) (C// and Toughness Tangential), increasing from butt (lowest) to mid (highest) and decreasing toward the top (slightly higher than the butt) (C/ and Shear) and decreasing from butt to top (Toughness Radial) (Figs 48 - 55).

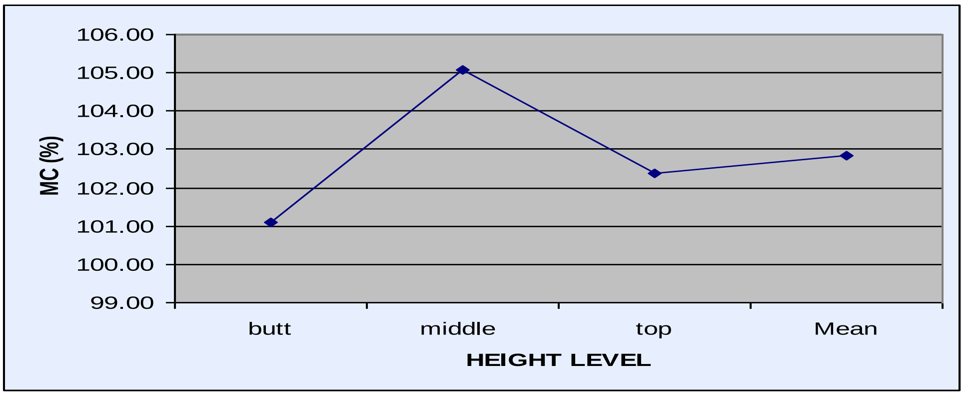


Fig. 48. Moisture Content (MC, %) of *A. macrophylla* (at different height levels).

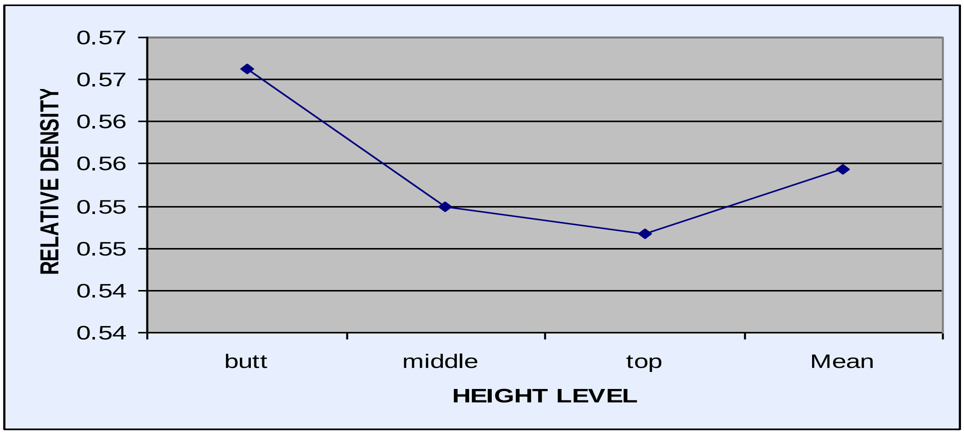


Fig. 49. Relative Density of *A. macrophylla* at different height levels.

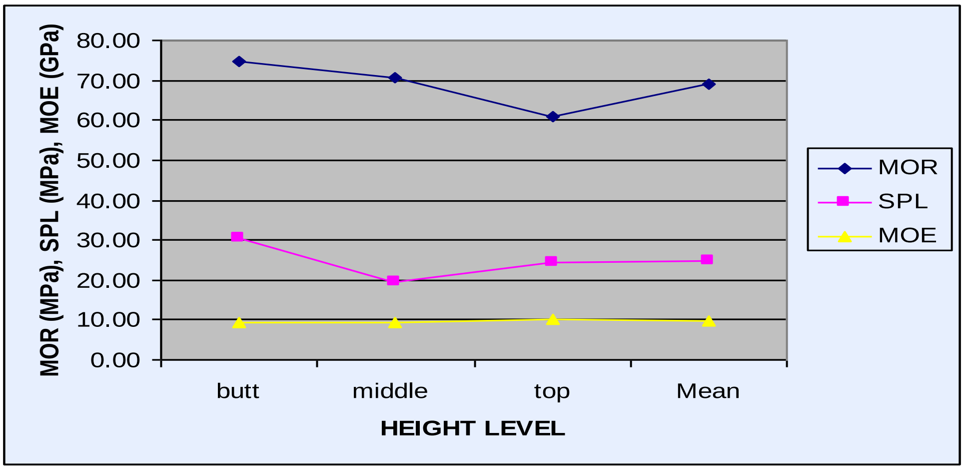


Fig. 50. Static Bending Properties (MOR, SPL, MOE) of *A. macrophylla* at different height levels.

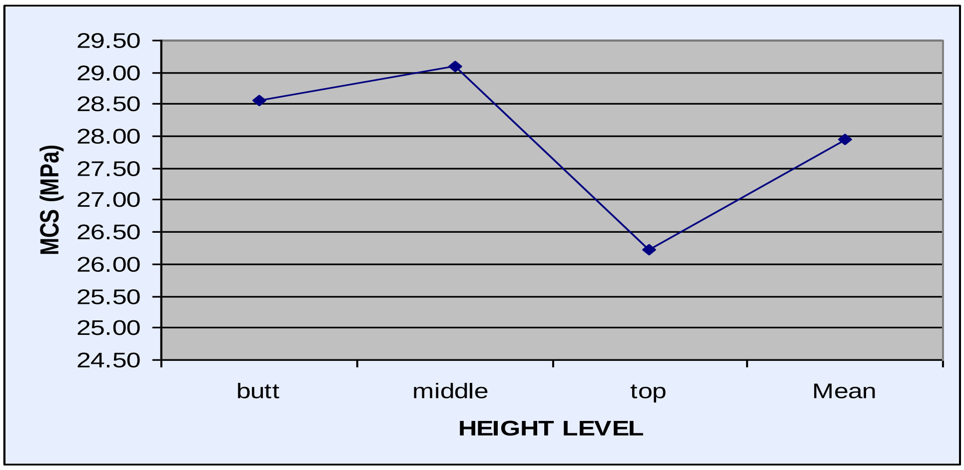


Fig.51. Maximum Crushing Strength in Compression Parallel-to-Grain (MCS, C//) of *A. macrophylla* at different height levels.

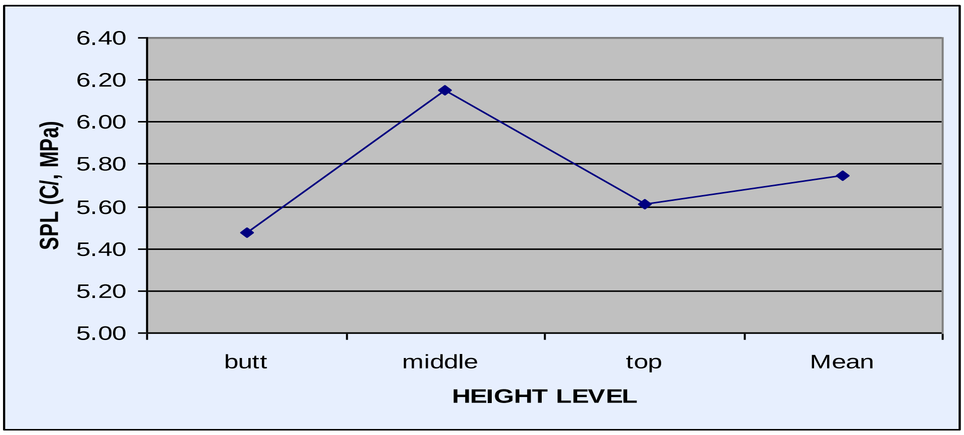


Fig. 52. Stress at Proportional Limit in Compression Perpendicular-to-Grain (SPL, C/) of *A. macrophylla* at different height levels.

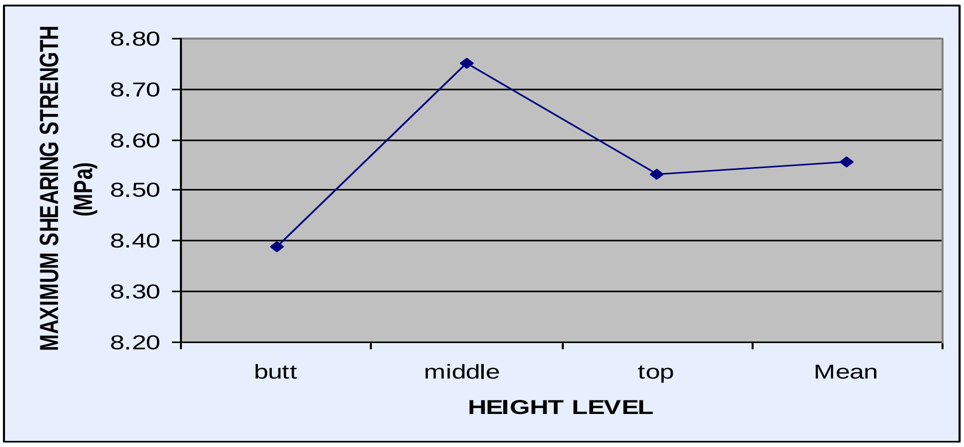


Fig. 53. Maximum Shearing Strength of *A. macrophylla* at different height levels.

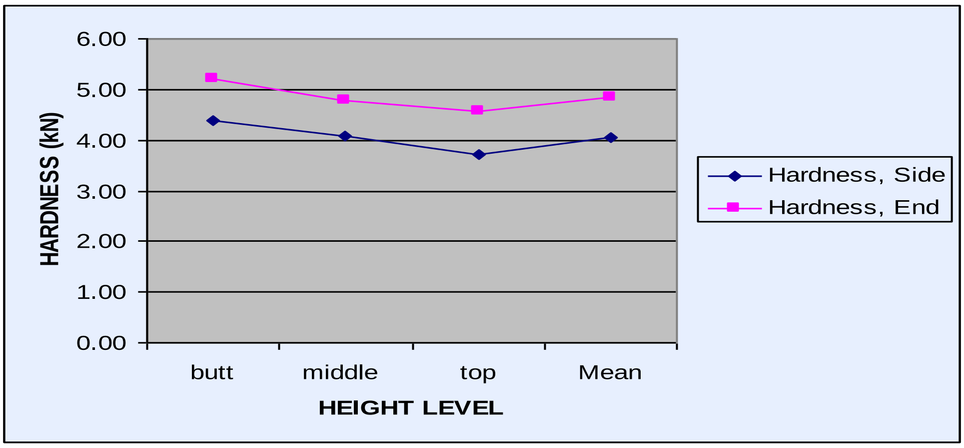


Fig. 54. Hardness of *A. macrophylla* at different height levels.

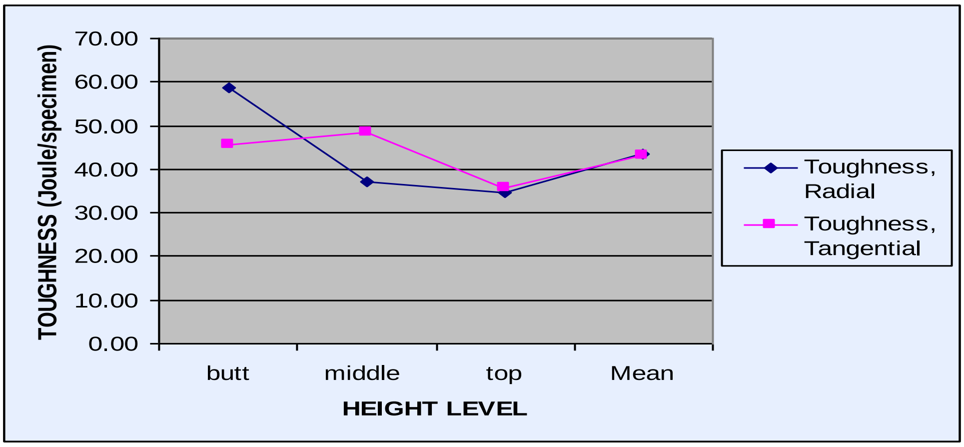


Fig. 55. Toughness of *A. macrophylla* at different height levels.

Between species, *E. citriodora* generally exhibited the highest strength properties except in C/and Toughness (Tangential), lower than *E. urophylla.* Although the ranges of strength properties of *E. citriodora* and *E. urophylla* both fall under Class I to II, the former had more properties falling under Class I than the latter. *A. macrophylla* had lower strength (Class II to III) than the former 2 species.

-Activity 2.1.2. **Identify milling issues.**

Brief introduction to the selected bio-composite products (glulam, LVL, plywood, particleboard and MDF) related to the milling issue in every bio-composite production is as follows:

1. Glulam :

Glued-laminated timber (Glulam) is one of the oldest glued engineered wood products. Glulam is the most popular used as substitute for solid wood in the USA and European countries. However, this kind of bio-composite product is not popular in Indonesia. This product is well known as the oldest and most value-added lumber product. It consists of lumber sections glued together to form a beam. In the future this kind of products will be popular in Indonesia, due to the limited supply of large diameter logs.

According to Moody et al. (1999), the glulam manufacturing process can be divided into four major parts, namely:

a. Lumber drying and grading; to minimize dimensional changes following manufacture and to take advantage of the increased structural properties, the lumber should be properly dried. For most applications, the maximum moisture content permitted in the ANSI standard is 16%; also the maximum range in moisture content is 5% among laminations to minimize differential changes in dimension following manufacture.

b. End jointing; to manufacture glulam in lengths beyond those commonly available for lumber, laminations must be made by end jointing lumber to the proper length. The most common end joint used in glulam production is finger joint, about 28 mm long.

c. Face bonding; the assembly of laminations into full depth members is another critical stage in manufacture. To obtain clear, parallel, and glue able surfaces, lamination must be planed to strict tolerances. Phenol resorcinol is the most commonly used adhesive for face gluing. The laminations are then assembled into the required layup, after the adhesive is given the proper assembly time, pressure is applied. And then the adhesive is allowed to cure at room temperature from 6 – 24 hours.

d. Finishing and fabrication; after the glulam timber is removed from the clamping system, the wide faces are planned to remove the adhesive that has squeezed out between adjacent laminations and to smooth out any slight irregularities between the edges of adjacent laminations. The next step is fabrication, where the final cuts are made, holes are drilled, connectors are added, and a finish or sealer is applied, if specified.

Among the above four steps of glulam production, the first step is the most difficult if the lumber used is made from SDL. Specific drying schedule is need for every SDL species due to the high content of juvenile wood and high internal stress of the SDL. Based on the physical, mechanical and chemical properties of small diameter logs, theoretical analysis and some experience of Glulam production using small diameter logs can be classified the suitability of the wood samples as shown in Table 26.

Table 26. Utilization of selected small diameter logs for Glulam raw material.

No.	Wood species	Glulam
A.	**PLANTATION AND COMMUNITY FOREST**	
1.	Sengon	Not feasible for outer lamella. However, feasible for core lamella.
2.	Kayu afrika	Feasible for outer and core lamellas.
3.	Tisuk	Not feasible for outer lamella. However, feasible for core lamella.
4.	Suren	Not feasible for outer lamella. However, feasible for core lamella.
5.	Ekaliptus	Not feasible for outer lamella. However, feasible for core lamella.
6.	Sengon buto	Feasible for outer and core lamellas.
7.	Mindi	Feasible for outer and core lamellas.
8.	Kiseseh	Feasible for outer and core lamellas.
9.	Mangium	Feasible for outer and core lamellas.

Table 26. continue

10.	Mahoni	Feasible for outer and core lamellas.
11.	Rubberwood	Feasible for outer and core lamellas.
12.	Puspa	Feasible for outer and core lamellas.
13.	Gmelina	Feasible for outer and core lamellas.
14.	Pinus	Feasible for outer and core lamellas.
B.	**NATURAL FOREST**	
1.	Benuang	Not feasible for outer lamella. However, feasible for core lamella.
2.	Segulang	Not feasible for outer lamella. However, feasible for core lamella.
3.	Merkubung	Not feasible for outer lamella. However, feasible for core lamella.
4.	Jabon	Not feasible for outer lamella. However, feasible for core lamella.
5.	Sungkai	Not feasible for outer lamella. However, feasible for core lamella.
6.	Pisang-pisang	Feasible for outer and core lamellas.
7.	Cempening	Feasible for outer and core lamellas.
8.	Kelampai	Feasible for outer and core lamellas.
9.	Belatik	Feasible for outer and core lamellas.
10.	Sampe	Feasible for outer and core lamellas.
11.	Ubar	Feasible for outer and core lamellas.
12.	Ketikal	Feasible for outer and core lamellas.
13.	Terentang	Not feasible for outer lamella. However, feasible for core lamella.
14.	Meranti merah	Not feasible for outer lamella. However, feasible for core lamella.
15.	Macaranga	Not feasible for outer lamella. However, feasible for core lamella.
16.	Tengkawang	Not feasible for outer lamella. However, feasible for core lamella.
17.	Bayur	Not feasible for outer lamella. However, feasible for core lamella.
18.	Jelutung	Not feasible for outer lamella. However, feasible for core lamella.
19.	Petai hutan	Not feasible for outer lamella. However, feasible for core lamella.
20.	Meranti putih	Feasible for outer and core lamellas.
21.	Cempaka	Not feasible for outer lamella. However, feasible for core lamella.
22.	Terap putih	Feasible for outer and core lamellas.
23.	Medang	Feasible for outer and core lamellas.
24.	Pulai	Not feasible for outer lamella. However, feasible for core lamella.

Based on the above table it is very clear that several small diameter logs which is not suitable or feasible for outer lamella of Glulam, because glulam is mainly used for structural purposes which are meaning the strength of the raw material is very important. Even though the low specific gravity SDL is not recommended for outer lamella of glulam raw material, it doesn’t mean that they cannot to be used as glulam raw material. It is possible to use them as core layers in glulam construction and combine with high specific gravity in the outer layers or can be used to produce non structural glulam.

2. Laminated Veneer Lumber (LVL) and Plywood

LVL is classified as a structural building bio-composite product of the future in Indonesia. It is a wood product that conforms to customers requirements for quality and dimensional flexibility while, at the same time, meeting the restrictions of the changing timber supply in Indonesia. LVL consists of veneer sheets laminated together with longwise grain orientation to produce a high quality lumber product with uniform characteristics. Compared to sawn lumber, LVL has some significant advantages such as: (1) higher strength, since it is nearly defect free, (2) consistent dimensions, with little warp or twist, (3) utilization of a wide range of log sizes and species.

Manufacturing process of LVL is similar to the plywood production except all the veneer orientation in LVL is parallel to the length. On the other hand, the veneer orientation of the plywood is perpendicular in the adjacent veneer. The manufacturing process of LVL and plywood in brief are as follows:

a. Logs preparation; logs delivered to the industry are sorted by grade and species, then debarked and crosscut into peeler blocks. Blocks usually are either 4 or 8 feet long for plywood production. The core veneer whose grain is perpendicular to the panel length produced from 4 feet length and face and back from 8 feet length. Peeler blocks are sometimes heated or conditioned by steaming them or immersing them into hot water prior to peeling. This makes the block easier to peel, reduces veneer breakage, and results in smoother, and higher quality veneer.

b. Veneer production; veneer is peeled from the block in a continuous and uniformly thin sheet. Depending on its intended use, the veneer may range in thickness from 1/16 – 3/16 inches.
c. Clipping; the continues sheet of veneer is then transported by conveyor to a clipping station where it is clip into usable width and defects are cut out or repaired. The veneer then sorted by width and grade.
d. Veneer drying; the wet veneer is then dried to an average moisture content of about 5 percent, since it is critical that veneer moisture content be low at the time adhesive applied.
e. Glue spreading and veneer lay up; adhesive is applied to the dried veneer in the layup area by spraying, curtain coating, roller coating, and extrusion and more recently by foaming. The glue spread around 250 g/m^2. After glue spreading, the veneer layup by hand, machine, or combination, for plywood production, the veneer grain orientation is perpendicular to the adjacent veneer layer, while for LVL all of the veneer grain orientation is parallel to the length.
f. Pressing; panels are first given a cold pre pressing to flatten the veneers and transfer the adhesive to the uncoated sheets, then hot pressed. The hot pressed condition based on the adhesive type and thickness of the produced board. The hot pressing temperature around 300^oF, under moderate pressure (100 - 300 psi) for 3 – 10 minutes. LVL is also a product that is undergoing significant development in the way it is manufactured. On the process side, the pressing time is faster by using radio frequency (RF) press heating. This innovation will allow the press time on a 2.54 cm billet to be reduced from 25 minutes to around 8 minutes. This more than doubles the capacity of a single daylight press.
g. Conditioning; after hot pressing, the produced boards are solid-piled or hot stacked to ensure complete curing of the adhesive, then sawn to size.

Several plywood industries in Indonesia such as PT. Andatu Plywood in Lampung and PT. SGS (PT. Sumalindo Jaya Lestari Group) in Balaraja Tangerang now using SDL from *Hevea braziliensis* and *Paraserianthes falcataria*. There is no technical problem facing by the company right now because they use spindless rotary machine and hot press drier. The other SDL species use by PT. Andatu Plywood is *Acacia mangium*, *Maesopsis eminii* and other wood species received from community forest. The quality of the produced plywood is good and fulfills the international standard.

Based on the physical, mechanical and chemical properties of small diameter logs, theoretical analysis and some experience using small diameter logs can be mentioned that all species listed in Table 1 are feasible for plywood and LVL manufacturings, except *Sengon buto* is not recommended as plywood and LVL raw material because its surface is not smooth and produces serious problem in veneer adhesion. This phenomenon caused the produced plywood and LVL performed low quality.

3. Particleboard and Medium Density Fiberboard

All the products in the family of particle and fiber composite materials are processed in similar ways. Raw material for particleboard and MDF dry process is obtained by flaking or chipping round wood. For MDF, chips are reduced to fiber using refiners that usually use steam to soften the wood. The comminuted wood is then dried, adhesive is applied, and a mat of wood particle or fibers is formed, the mat is then pressed in a platen-type press under heat and pressure until the adhesive is cured. The bonded product is allowed to cool and is further processed into specified width, length, and surface qualities.

According to Youngquist (1999), the particleboard is typically made in three layers. The faces of the board consist of fine wood particles, and the core is made of the coarser materials. Producing particleboard this way improves the utilization of the materials and the smooth face presents a better surface for laminating, overlaying, painting or veneering. The brief particleboard production is as follows:

a. Particle preparation; standard particleboard plants based on particulate materials use combination of hogs, chippers, hammer mills, ring flakers, ring mills and attrition mills. To obtain particleboard with good strength, smooth surfaces, and equal swelling, manufacturers ideally use a homogenous material with a high degree of slenderness (long, thin particles), no oversize particle, no splinters, and no dust.

b. Particle classification and conveying; very small particle increase furnish surface area and thus increase resin requirements. Oversize particle can adversely affects the quality of the final product because of internal flaws in the particle. The two basic methods of conveying particles are by mechanical means and by air. The choice of conveying method depends upon the size of the particle.
c. Particle drying; particle moisture content is very important to produce high quality particleboard. The particle dried in the range of 4-8%. The main methods used to dry particle are rotary, disk, and suspension drying.
d. Addition of resin and wax; frequently resins used in particleboard production are urea formaldehyde (UF), melamine formaldehyde (MF), phenol formaldehyde (PF) and in some extent isocyanate (IC). The resin content is usually range from 3 – 10%, but usually ranges between 6 – 9% for urea formaldehyde resin. The resin content of the outer layers is usually higher (about 8 – 15%) than that of the core layer (4-8 %).
e. Mat formation; after the particle has been prepared, they must be laid into an even and consistent mat to be pressed into a panel. This is typically accomplished in a batch mode or by continuous formation.
f. Hot pressing; after pre pressing, the mats are hot pressed into panels. Hot press temperature for UF usually range from 140 – 165^{o}C, pressure depends on a number of factors, but it is usually in the range of 1.37 – 3.43 MPa for medium density board.
g. Conditioning and finishing; after hot pressing, the boards are conditioning to release the internal stress during hot pressing and cut into size for further process.

Based on the physical, mechanical and chemical properties of small diameter logs, theoretical analysis and some experience using small diameter logs can be mentioned that all species listed in Table 1 are feasible for particleboard and MDF manufacturings. However in economic point of view, several industries avoiding using very low density wood such as Sengon.

Important Issues Related to The Utilization of SDL as Bio-Composite Raw Material

1. Dimensional Stability in Bio-Composite Products

The dimensional stability of most bio-composite products corresponds closely to unrestrained values of wood used as raw material. In the previous research results, it is found that the dimensional stability of SDL is lower compared to those of large diameter logs. Products such as glulam, LVL all behave in a similar way in regard to radial, tangential, and longitudinal shrinkage. Plywood, particleboard and MDF which are produced from veneer, particles, and fiber respectively, in contrast have unique dimensional behaviors under moisture change. These differences result from three basic causes, namely: (a) The degree of swelling and shrinkage of one element is influence by the other elements in the product, (b) The degree of compression or crushing that the wood elements (veneer, particle, or individual fibers) undergo during the manufacture of the product; and (c) The effects that adhesives and other additives have on the ability of the wood elements to respond dimensionally to moisture change. In some cases, additives bulk the cell walls to some degree, thus lowering the EMC of the wood (Bowyer et al., 2003).

Plywood is produced by face laminating veneer, generally 4/2 mm (0.17 in) or less in thickness, in such a way that in alternate layers (veneers), the longitudinal direction is at 90 degrees to the adjacent layer. If the veneers are not glued together, they can shrink or swell as normal wood. However, when glued into plywood, the face veneers restrain swelling of the core veneer in its transverse direction, whereas the core restrains the swelling of the faces in their transverse directions. As a result, plywood is relatively dimensionally stable in the panel plane. These exhibit much less dimensional change in either direction than normal radial or tangential characteristics of their constituent species. These panels shrink or swell slightly more, however, than the normal longitudinal change for the species. Dimensional changes in plywood do occur, however it is very small.

The second factor that affects the dimensional change of bio-composite products is the amount of compression the product undergoes during manufacture.

The thickness swelling or shrinking of plywood with moisture change is about the same as that of normal solid wood because little compression occurs. However, in some cases, thickness swelling in plywood may be slightly more than normal wood is excessively high pressures occurred during the pressing process. Wood that is compressed tends to partially recover its original dimension when rewet.

The crushed wood tends to recover its original shape. Much the same thing can happen to an entire of particleboard. In the manufacture of particleboard, small shavings, flakes, strands, or wafers of wood are sprayed with droplets of synthetic resin adhesive. These wood elements are compressed between 1.2 and 2.0 times their original density and simultaneously the resin are cured. If such a product is subjected to steaming or other instances of elevated moisture content, the wood swells normally and, in addition, the crushed particles tend to return to their original thickness. For this reason, compressed particleboard and MDF often exhibit greater thickness swelling than normal wood.

The third factor is the amount of product additives. Synthetic resin adhesives and waxes are the most common additives. The wax (or sizing) is intended to provide resistance to liquid water pick-up. Wax does not bulk the cell wall or change the ultimate EMC; rather it helps the product shed liquid water making it water repellent. Synthetic adhesives can, however, alter the recovery of the crushed particles or fibers. Generally, the greater the amount of adhesives used to manufacture a composite product, the less the thickness-swell response to moisture pick-up.

In addition to the wood elements in a product being held more tightly when more resin is used, some resin penetrates into the cell walls and provides a degree of *bulking*, or replacement of water molecules. Most particleboard and MDF are manufactured under commercial or industry standards that place limits on the swelling properties. Specific property limitations in the standards vary depending upon use of the product. Because of plywood is a relatively stable product and its dimensional characteristics cannot be easily altered by manufacturing variables, there are few specifications in the plywood product standard as to dimensional stability.

2. Effect of Juvenile Wood and Reaction Wood

The density of juvenile wood is usually less than that of mature wood, and such wood has a correspondingly lower strength. Low strength may be of concern when the portion of a log near the pith is utilized for lumber or veneer. Another problem in the utilization of juvenile wood is the tendency of exhibit abnormally high longitudinal shrinkage. In such lumber, shrinkage results in excessive warp, which renders the product unusable for most applications. This is less serious in cross-laminated panels such as plywood.

The specific gravity of compression wood in softwoods, in contrast to juvenile wood, is generally greater than that of normal wood-up to 40 percent greater. This higher density can often be detected visually because of the higher proportion of latewood. Yet in some cases, the density of compression and normal wood may not differ significantly. Despite its usually higher density, compression wood is generally avoided in glulam production because of its high longitudinal shrinkage and erratic strength properties.

3. Density of Bio-composite Products

The density of glulam, LVL, plywood, particleboard and MDF differs from the density of the wood raw material because of the weight of adhesives and other additives and the compression of the wood that occurs during the manufacturing process. Plywood is ordinarily only slightly denser than the wood from which it produced, usually 5 to 15 percent greater. The pressure used to press plywood is intended only to provide good contact between the veneers and not to density the wood, although a slight amount of densification does occur. Particleboard and MDF, by contrast, are usually produced at densities 1.2 to 2.0 times the density of the species used. Particleboard and MDF densities in the range of 600 to 800 kg m^{-3} are common. Of this weight, 8 to 12 percent is the weight of the resin (adhesive) and wax used to impart water repellency.

4. **Knots content**

Knots are the most common wood characteristic that reduce the strength of lumber. The effect knot is often considered equivalent to that of a hole. In some cases, the knot may have a greater effect than a drilled hole because of the distortion in the grain that accompanies it. The amount that a knot reduces strength depends not only upon the size of the knot but also upon its location in the piece. A knot on the top or bottom edge of a beam is much more critical than the same knot located near the centerline. Recall that the maximum bending stresses occur on the top and bottom edges of a beam. Knots on the bottom edge of a beam are more serious than on the top edge because knots have a more drastic effect in tension than a compression. Skilled carpenters inspect and install floor joists with the largest knots on the top edge, not on the bottom.

The amount of strength loss from knots of various sizes is outlined in ASTM Standard D 245. Table below lists percent of strength loss that results from knots in the center and on the edge of beams of several widths. Note the strength-loss difference between boards with knots located in the center as compared to the edge. A 50 mm (2 in.) diameter knot in a 38 x 185 (2 x 8 in. nominal) beam will reduce the strength by 24 percent if it is in the center and by 43 percent if it is on one edge.

5. Wood decay

Decay is generally prohibited in grades of lumber used for structural purposes (some localized types such as “white specks” are sometimes permitted) because it is often impossible to estimate by visual inspection the extent to which decay has weakened the piece. By the time decay is visually apparent, the loss in strength may be severe. Impact strength declines as a result of decay much faster than static strength. The sapwood specimen on the left is normal, and the heartwood specimen on the right has a slight amount of decay. The splinter-free fracture on the right (*brash failure*) is typical of decayed wood. In this case, the scaffold plank from which the specimen on the right was cut had its toughness reduced 85 percent by decay but appeared normal to the user until failure occurred. Mills must be alert for decay when producing lumber from large, over-mature logs in which decay is occasionally encountered.

Some grades of dimension lumber permit blue stain. Blue-stain fungi do not cause a weakening of the wood. They live upon food materials in the cell lumina, not upon the cell wall substance. One problem encountered with stain, however, is that it can occur in combination with decay and make the decay difficult to detect. In high-moisture situations, stain and decay can occur in buildings within wood that was previously kiln dried. Common sources of moisture in wood structures are as follows: water leakage from roofs, walls and pipes; condensation; poor ventilation; and foundation moisture. Proper design engineering, construction, and maintenance with regard to moisture are paramount for the life and health of a building and for its occupants. If undetected, the results range from wood stain and incubation of minor forms or mold allergens to complete structural strength loss due to decay.

6. **Slope of grain**

Slope of grain in lumber is expressed as the length through which a deviation in the grain occurs. Slope can result from logs containing spiral grain. In this case, even though the growth rings appear parallel to the edges of the piece, the slope of the grain may be quite significant. The best way to detect this type of grain deviation visually is to look at resin streaks, surface checks, mineral stains, or other minor defects that tend to be oriented with the cells.

The strength of wood is affected whenever there is a slope of the grain greater than about 1-in-20. Tension strength is more severely affected by grain deviation than either bending or compression. Ali grades of structural lumber carry limitations to the slope of grain. These are especially strict for critical, non-redundant structural members such as ladder rails.

Recent issues rise during laboratory research and field survey to the several bio-composite industries Indonesia, namely:

1. Glulam

The problem raised in glulam production using SDL, namely:

a. Board production; converting straight board from SDL is not easy because the produced board tend to bow, curve, even splitting just after band sawing the SDL. This is because the juvenile content of the SDL is very high (60 – 89%) compared to mature wood (40 – 11%). The solution for bowing and curving is cut in smaller pieced, while checks or splits should be cut off or worked around.

b. Drying; drying board produced from SDL should be more careful compared to those of mature board. In some cases most of the board will curve, bowing, checking, splitting, and even twisting. These kinds of problems are very serious in low density SDL such as *Paraserianthes falcataria* L. Nielsen.
c. Gluing; problems in gluing come from the higher extractive content of the lumber (lamella) and the defect of the lumber. Several research results using SDL from plantation forest and community forest in Indonesia shown that the physical and mechanical properties are good enough. However, the yield of the board is very low due to the lower yield lumber production and increasing defect after kiln dried.

All of the machines use in glulam production using large diameter wood can be used to produce glulam from SDL. However, dry kiln schedule should be change based on the SDL properties.

2. LVL and Plywood

The rotary machine used in LVL and plywood industry which process large diameter logs should be accompanied by spindles rotary machine if the SDL will be processed in the industry due to the limited wood diameter to be converted into veneer. The other thing is veneer drying. In some cases, continuous veneer drier is not suitable to dry veneer sheet produce from SDL, due to the wavy surface of the SDL veneer. Several LVL and plywood industry in Indonesia developed hot press drier to overcome the problem.

3. Particleboard and MDF

Particleboard industry (PT. Paparti Pratama in Sukabumi, West Java Province) and MDF industry (PT. Sumalindo Jaya Lestari) reported that there is no technical problem in producing high quality particleboard and MDF using SDL. However, low density SDL is avoided due to the economical point of view.

In case of Philippines, one of the pressing problems in the utilization of SDL is converting them into conventional products such as lumber and veneer.

Most of the present primary processing equipment of the wood industry are designed for large-diameter logs (Rojo 1990). The use of inappropriate equipment for processing entails low mill recovery, low productivity and high processing costs.

Lumber products produced from small diameter species and logging residues are 25 and 50-mm thick boards with widths of 10 to 40 cm plantation species and a maximum of 15 cm wide and 1.8 m long for logging residues. Small sized logs have low lumber yield and high labor costs when processed in sawmills designed for large logs. Sorting into diameter classes prior to sawmilling increases lumber production rate and sawmill efficiency in small log processing by 5% to 11%. (1998 Compendium on low cost houses from small diameter logs, thinning, tops and branches)

Table 27. Mechanical properties of lumber produced from some small diameter logs.

Name	Static Bending		Compression		Hardness		Toughness	
	MOR MPa	MOE 1000 MPa	Max crushing strength MPa	MOE 1000 MPa	Side grain kN	End grain kN	Shear parallel to grain MPa	Av. of radial and tangential Joule/ specimen
Diospyros pyrrhocarpa	69.30	10.50	32.40	13.20	4.94	4.98	8.50	40.40
Amoora ahemiana	71.40	12.80	36.90	15.80	5.89	5.86	8.58	34.90
Swintonia foxworthyi	66.10	11.80	32.60	16.50	4.59	4.80	9.16	38.00
Lithocarpus llanosii	66.90	9.02	35.70	12.70	6.04	5.77	10.40	33.30
Ziziphus talanai	72.10	9.80	34.60	11.60	4.95	5.29	10.10	49.00
Celtis luzonica	55.70	8.32	25.20	10.20	3.09	4.25	8.70	40.80
Gmelina arborea	45.90	6.18	24.80	7.84	3.84	3.80	8.91	27.70
Duabanga moluccana	43.00	7.80	19.60	7.33	2.02	2.56	5.74	21.60
Octomeles sumatrana	31.60	6.81	16.70	8.25	1.44	1.57	3.70	18.90
Erythrina subumbrans	24.60	4.03	11.90	4.77	1.01	1.24	3.65	11.50
Endospermum peltatum	35.50	5.08	17.20	7.51	1.39	1.82	5.47	14.90

Source: 1998 Compendium on low cost houses from small diameter logs, thinning, tops and branches

Internal defects on the logs cause conversion problems and reluctance to convert some SDL species. Fluting, buttressing and high tapering of some SDL also make milling difficult. Blunting of saws and other cutters in subsequent machining operations are affected by density and high strength properties. Grain characteristics also affect other processing operations. Interlocked grain, which characterizes some SDL, are often more difficult to machine, finish and kiln dry (prone to warping)

Retooling of equipment

A number of mini-bandmills in the country have been installed particularly in Mindanao to cope with the problems in sawmilling SDL. Some companies are also using spindleless lathe for the rotary cutting of veneers from veneer log cores. The conventional lathe entails a log core with about 20 to 25 cm diameter after peeling while in the spindleless lathe, the diameter of the log core is reduced to about 5 cm. Thus, if the two spindleless lathe are used in tandem, veneer recovery per log will be higher. The spindleless lathe can also be used for veneering SDL but the raw materials should first undergo the rounding process to have a cylindrical form.

The known users of spindleless lathe in the Philippines are PICOP in Bislig, Surigao del Sur; M&S in Recodo, Zamboanga City; UCP in Malungan, El Salvador Misamis Oriental; EverSun Plywood in Cotabato City and C. Alcantara and Sons (ALSONS) in Davao City.

Table 28. Small Diameter Logs Widely Used in Veneer and Plywood Manufacture

Species	Remarks
Bagras (*Eucalyptus deglupta*)	• substitute material for face veneer • must be peeled within 3 days after harvesting to prevent curling of veneer during drying
Duguan (*Mynstica phil*)	• for veneer production
Igyo (*Dysoxylum decandum*)	• for veneer production
Loktob (*Duabanga moluccana*)	• for veneer production

Tangisang bayawak (*Ficus sanyata*)	• for veneer production
Anabiong (*Trema orientates*)	• for veneer production
Moluccan sau (*Paraserianthes falcataria*)	• one of the most widely planted introduced species in the Philippines. • Peeler logs from old-growth plantations (4 years and up) produce smooth face veneers, otherwise, veneers are wooly usually for corestock veneer
Yemane (*Gmelina arborea*)	• can be easily sliced and peeled into veneers and are mostly used for face stock • veneer sheets are easy to handle and resistant to tear.
Mangium (*Acacia mangium*)	• proper grading of veneer logs is essential to produce good quality veneers due to prevalence of knots • used for face and core veneers
Gubas (*Endospermum peltatum*)	• a potential source of veneer for plywood in the Philippines
Big-leafed mahogany (*Swietenia macrophylla*)	• sliced and peeled into fine decorative veneers without preliminary treatment. • wooly surface in veneer is experienced in small diameter logs with off- centered pith, indicating presence of reaction wood.
Kaatoan bangkal (*Anthocephalus chinensis*)	• smooth, uniform in thickness and moderately tight 1 mm thick veneers are produced with this species
Malapapaya (*Polyscias nodosa*)	• smooth, uniform in thickness and moderately tight 1 mm thick veneers are produced with this species

Source: Strategies for enhancing the growing and utilization of lesser known species. Paper presented at the National Symposium on Forestation Research and Practices, April 2002, CFNR-UPLB, College, Laguna, Philippines

In a study conducted on veneer production, it was recommended that the process needs to be altered to accommodate the properties of alternative raw materials such as SDL and logging wastes. There is thus a need to develop production or processing equipment and techniques appropriate for these materials. For the economic benefits, producing veneers from SDL using 60-cm lathe was shown to be feasible. The 60-cm lathe is suitable for logs which have small diameters, short lengths and with crook and sweeps. (1998 Compendium on low cost houses from small diameter logs, thinning, tops and branches)

Wood Wool Cement Board (WWCB) in Philippines

WWCB is a panel product made-up of wood excelsior bonded with a General Purpose Portland Cement. It is versatile because of its various applications such as exterior and interior paneling; it can be used in dry and wet construction; it can be used as ceiling and eaves; and it can also be used as cabinet and furniture components. WWCB is considered dimensionally stable and termite resistant. Dimensionally stable because it does not swell even when immersed in water for at least 24 hours. At FPRDI, an on-going study on its termite resistance indicates that WWCB is not attacked by termites after seven (7) years of termite exposure test.

Milling issues for the four (4) wood species studied (Component 2.1 Address technical gaps in producing bio composite products Activity 2.1.1 Identify suitable species and evaluate physical and mechanical properties) revealed that the high densities of *E. citriodora and E. urophylla* will affect handling of these species during harvesting and transport operations. Higher costs will be incurred as more man (and animal) power is required during felling, skidding the logs to roadside, and hauling as less volume is transported per truckload. Overall cost of raw material will be higher for high density (*E. citriodora and E. urophylla*) than low density species (*A. macrophylla and P. nodosa*). This situation is typical in a developing country like the Philippines where the use of mechanical equipment is limited.

As indicated by the relative densities of the four (4) species investigated, *Eucalyptus citriodora and E. urophylla* would pose problems during shredding operation preparatory to WWCB production while *Alstonia macrophylla and Polyscias nodosa* would be easily shredded into excelsior. Shredding cost is higher since production per hour is less due to downtime in blade replacement and sharpening, loading (mounting of wood blanks on shredding machine) and during actual shredding where there is greater resistance in the vertical (or horizontal) movement of the blanks against the knives. However in this study, *E. urophylla* has been considered and used in WWCB production (Component 2.1: Address technical gaps in producing bio composite products - Activity 2.1.4: Evaluate the appropriate properties of products manufactured form SDL)

The following table shows the different wood species used in the production of WWCB.

Table 29. Relative density of different wood species in the Philippines (Alipon et al. 1987, Alipon & Floresca 1991) and their respective bending strength when manufactured in to WWCBs (Mallari et al. 1994, Cabangon 1997, Pablo & Cabangon 1997, Eusebio et al. 2002a & 2002b, Eusebio et al. 2003)

Common Name	Scientific Name	Relative Density (Green)	Bending Strength* (MPa)
Antipolo	*Artocarpus blancoi* (Elmer) Merr.	0.42	5.7
Auri/Earpod Wattle	*Acacia auriculiformis* A. Cunn. Ex Benth	0.50 – 0.65**	5.4
Banilad	*Sterculia cosmosa* Wall	0.32	4.5
Binuang	*Octomeles sumatrana* Miq.	0.27	6.0
Binunga	*Macaranga tanarius* (L.) Muell. Arg.	0.30 (12%)	6.2
Gubas	*Endospermum peltatum* Merr.	0.3	6.4
Kaatoan Bangkal	*Anthocephalus chinensis* (Lamk.) A. Rich. Ex Walp.	0.34	6.4
Loktob	*Duanbanga moluccana* Blume.	0.37	5.5
Big-leafed Mahogany	Swietenia macrophylla King	0.54	5.7
Mangium	*Acacia mangium* Willd.	0.46	6.5
Moluccan Sau	Paraserianthes falcataria (L.) Nielsen	0.25	8.2
Rarang	*Erythrina subumbrans* (Hassk.) Merr.	0.24	7.1
River red gum	*Eucalyptus camaldulensis* Dehnh.	0.68	5.9

Rose gum	*Eucalyptus grandis* W. Hill ex Maiden	0.42-0.50**	6.1
Ulaian/Celebes oak	*Lithocarpus celebicus* (miq.) Rehd.	0.67	3.3
Yemane/ Gmelina	*Gmelina arborea* Roxb.	0.41	7.3

*Obtained from 12-mm thick boards manufactured at a density of 750 kg/m3 (except for E. camaldulensis with a board density of 600 kg/m3), wood/cement ratio of 40/60, 3% addition of CaCl2 and using wood wool soaked in tap water for 24 hours.

** Data obtained from species not grown in the Philippines (Shikaputo et al. 1986, Anonymous 1996)

Particleboard

Particleboard is a made-up of small wood particles and other fibrous materials. These are bonded together with a suitable adhesive and cured under heat and pressure.

In the Philippines, there is only one commercial plant that is operational. It uses wood wastes from furniture manufacturers, sash factory, veneering wastes or any type of wood wastes available in their vicinity. It never used industrial plantation species or small diameter logs.

At FPRDI, laboratory studies on particleboard production and technology were conducted several years ago. Industrial plantation species such as Kaatoan bangkal (*Anthocephalus chinensis*), giant ipil-ipil (*Leucaena leucocephala*), molulucan sau (*Albizia falcataria*), Yemane (*Gmelina arborea*), balobo, magabuyo, and gubas (*Endospermum peltatum*) were found to be technically feasible for the production of resin bonded particleboard.

-Activity 2.1.3. **Identify quality control concerns for raw material and how to address them suitable.**

Quality control of raw material is one of the very important sections in bio-composite industries. In some cases, the key success of the industry starts from raw material quality control system and execution in the field. In Indonesia, all the visited bio-composite industries have an in-house program and system for monitoring the quality and quantity of incoming raw materials. Species, grade, moisture content, dimensions, volume, and visual appearance of the raw material (wood) are checked. However, in most cases, the raw material was tested and checked in the field before sending to the bio-composite industry to minimize financial lost due to the improper quality control practices.

SDL is well known as low quality raw material for bio-composite products. However, in the future it will become the basis of tomorrow's resource supply and the bio-composite industry must accommodate this kind of raw material. In this case, quality control of the SDL as raw material for bio-composite products is very important. The objective of this research is to identify several factors which should be taking into account for SDL as raw material quality control activities and to find out the simple and applicable practices to overcome the raised issues.

There are several important issues should be recognized related to the utilization of SDL as raw material for bio-composite products (Glulam, plywood, LVL, particleboard and MDF). The important issues are as follows:

1. **Wood Density**; Based on the research conducted in activity 2.1.1, it was found that the range of SDL wood density is classified as low to the high wood density. Low wood density is not feasible for structural bio-composite products such as glulam. However, it can be used as raw material if combine with medium or high density SDL. Several research experiences in laboratory scale for producing glulam, LVL and plywood made from low density SDL showed acceptable physical and mechanical properties. However, utilization of low density SDL for producing particleboard and MDF is not feasible in term of cost point of view. Even though the produced particleboard and MDF fulfill international standard such as JIS (Japanese Industrial Standard). On the other hand, high density wood is not preferable for particleboard and MDF production due to the higher board density should be produced to obtain acceptable physical and mechanical properties of the board (compression ratio should be more than 1).
2. **Spiral and Interlocked Grain**; the grain is a direction which is parallel to the long axis of most of the long tapered fibers of wood. Fibers are normally oriented with their length essentially parallel to the long axis of the stem. Not

uncommon, however, is fiber arrangement at a slight angle to the stem axis rather than the exception. Occasionally, the deviation from parallel is large, resulting in an obvious spiraling grain pattern. This kind of grain orientation can significantly affect wood properties. Trees in which fibers are spirally arranged about the stem axis are said to have *spiral grain*. This condition is apparently caused by anticline division in which new cambial cell formation occurs in one direction only, that is, walls formed during fusiform initial division consistently slant the same way. When SDL exhibiting spiral grain is sawn, the lumber formed has a grain direction that is not parallel to the board length. Such lumber is said to have slope of grain, it is typically low in strength and stiffness and may tend to twist as it dries. Planning of such lumber to a high-quality surface may also be difficult (Bowyer, et al., 2003).

In some SDL tree, grain may spiral in one direction for several years and then reverse direction to spiral oppositely. Wood produced in this way is said to have interlocked grain. Reversing spiral grain is evidently genetically controlled, occurring very frequently in some species and seldom if at all in others. Woods with interlocked grain are difficult to split, shrink longitudinally upon drying, warp unpredictably, or both. Occurrence of interlocked grain is occasionally considered undesirable for glulam, LVL, plywood production standpoint. However, there is no technical problem were identified for particleboard and MDF production process.

3. **Knots;** Knot is the very important factor which is producing several problems related to the bio-composite production. In plywood production, knot tend to make rotary knife dull faster, uneven veneer thickness, excessive shrinkage, producing big hole and increase working time.

   Knot caused by the seasonal addition of new wood results in progressive layering over previously produced wood. As new growth increases the diameter of the main stem, branch bases become more and more deeply embedded in the trunk. The living branch is usually extending to the pith, the point at which most branches originate. The base of the branch is cone shaped, appearing as a tapered wedge when sectioned. The cone-shaped appearance arises from the fact that cambium, which sheaths and the main stem, moves ever farther from the embedded branch base as the main stem grows larger, preventing further diameter increase at this location. Because main stem and branch growth are simultaneous, incorporation of living branches into the main stem results in knots that are an integral part of the surrounding wood. Such knots do not become loose or fall out upon drying and called inter-grown or tight knots (Bowyer, et al., 2003).

4. **Juvenile wood;** several research results regarding the fundamental properties of SDL show that the physical and mechanical properties is significantly affect by juvenile wood. Juvenile wood formed in the early (or juvenile) stages of growth of a tree stem and is formed as part of the developmental process of tree growth and is found in the center portions of stem cross sections. It is present in every tree, and virtually every living tree, regardless of age, continues to form juvenile wood during each growing season. By most measures, juvenile wood is lower in quality than mature wood; this is particularly true of the softwoods. In both hardwoods and softwoods, for example, juvenile wood are shorter than those of mature wood. Mature of softwoods may be three to four times the length of juvenile wood cells, whereas the mature fibers of hardwoods are commonly double the length of those found near the pith. In addition to differences in cell length, cell structure also differs. There are relatively few latewood cells in the juvenile zone and high proportion of cells has thin wall layers. The result is low density and a corresponding low strength in comparison with adult wood (Haygreen et al., 2003).

   According to Haygreen et al. (2003) in conifers of the United States, density is typically 10-15 percent lower in juvenile core, with strength of such material reported to range from only slightly lower to commonly 15-30 percent and as much as 50 percent less than normal mature wood for same strength properties. These reductions appear mild when compared to findings of Senft et al. (1986) in Bowyer et al., (2003). In a study of sixty-year-old Douglas-fir, they found an average specific gravity difference of 32 percent when wood formed in the first fifteen years was compared to wood formed thereafter. Moreover, though they found the average strength of mature wood to be about 40-60 percent high than that of juvenile wood, differences as high as several hundred percent were found when comparing stiffness of the first several growth rings to rings formed much later. Similar numbers were documented for loblolly pine, and cottonwood (Bendtsen and Senft (1986) in Bowyer et al. (2003)). Pandit (2003) found that the fundamental properties of SDL are as follows: (1) sapwood portion and moisture content are higher compared to those of mature wood, (2) natural durability, specific gravity, dimensional stability and stiffness is low, and (3) longitudinal shrinkage is high.

Again comparing juvenile and mature woods, there appears to be a greater tendency for spiral grain in juvenile word. Within the cell, the micro fibril angle in the S-2 part of the secondary wall is characteristically greater in juvenile wood. The large micro fibril angle causes a high degree long longitudinal shrinkage and a corresponding decrease in transverse shrinkage; along-the-grain shrinkage of juvenile wood has been reported to average from three times that of mature wood to nine or ten times as much as mature wood several investigators have noted, however, that not all juvenile wood shows excessive longitudinal shrinkage and that pieces may actually increase in length upon drying, possibly due to growth stresses. Large fibril angles are also associated with low tensile strength (Bowyer et al. (2003) and Pandit (2008). Field survey to the PT. SGS in Balaraja Tangerang West Java and PT. Andatu Plywood in Lampung shown that the veneer surface resulted from SDL is clearly rougher compared to those of mature wood. This is because SDL contain high portion of juvenile wood compared to those of mature wood. Table 30 shows ratio of juvenile and mature wood of several SDL.

Table 30. Ratios of juvenile and mature wood of SDL.

No.	SDL species	Diameter (cm)	Juvenile (%)	Mature (%)
1.	Agathis lorantifolia	22.0	86.5	13.5
2.	Acacia mangium	16.0	61.5	38.5
3.	Tectona grandis	15.0	84.6	15.4
4.	Shorea sp.	20.5	88.5	11.5
5.	Paraserianthes falcataria	21.5	82.5	17.5
6.	Alstonia scholaris	24.0	79.8	21.1

Source : Pandit (2008).

5. **Decay.** Decay SDL is generally not acceptable for bio-composite production, especially for structural purposes such as glulam, LVL and plywood. However, some localized types such as "white specks" are sometimes permitted because it is often impossible to estimate by visual inspection the extent to which decay has weakened the piece. Glulam industry must be alert for decay when producing lumber/lamella from SDL which decay is encountered.

   Some grades of dimension lumber permit blue stain. Blue-stain fungi do not cause a weakening of the wood. They live upon food materials in the cell lumina, not upon the cell wall substance. One problem encountered with stain, however, is that it can occur in combination with decay and make the decay difficult to detect. In high-moisture situations, stain and decay can occur in buildings within wood that was previously kiln dried.

6. **Extractive content;** Extractive content of the wood is one of the important factor which is potentially to decrease the bonding quality for bio-composite products such as glulam, plywood, LVL, MDF, and particleboard. The extractive content indicates by cold and hot wáter solubility as shown in Table 31.

Table 31. Average cold and hot water solubility of SDL.

No	Wood species	MC	Sg	Water Solubility,%		Class
				Cold	Hot	
Plantation forest						
1	Sengon	12.54	0.28	3.40	4.30	Med-high
2	Kayu Afrika	16.10	0.41	1.79	1.99	Low
3	Tisuk	14.92	0.43	3.33	3.87	Low-medium
4	Surian	17.18	0.47	3.00	6.50	Med-high
5	Eucalyptus	14.00	0.47	2.20	2.80	Medium
6	Sengon Buto	13.49	0.49	5.71	6.18	High
7	Mindi	14.62	0.53	1.50	3.80	Low-medium
8	Kisereh	13.77	0.56	1.30	4.80	Med-high
9	Gmelina	12.01	0.57	3.80	5.30	Med-high
10	Mahoni	13.40	0.57	0.40	4.50	Med-high
11	Puspa	17.30	0.61	1.20	2.00	Low
12	Karet	11.46	0.66	3.90	4.69	High
13	Pinus	14.64	0.73	2.53	3.94	Medium
14	Mangium	16.79	0.50	5.75	7.28	High
Natural forest						
1	Benuang	16.13	0.26	0.20	2.60	Medium
2	Terentang	16.00	0.26	0.8	4.5	Medium
3	Meranti merah	14.00	0.32	2.58	2.67	Low
4	Macaranga (2)	13.36	0.34	3.92	4.02	Med-High
5	Segulang	15.30	0.38	0.23	1.84	Low
6	Tengkawang	14.70	0.39	2.47	2.62	Low
7	Bayur	13.50	0.39	-	11.19	High
8	Jelutung	15.50	0.40	1.00	5.60	Med-High
9	Merkubung	17.48	0.41	1.15	3.90	Medium
10	Jabon	16.02	0.41	1.60	3.10	Low
11	Petai	14.72	0.41	2.43	3.91	Medium
12	Meranti putih	15.00	0.42	0.90	4.5	Medium
13	Cempaka	10.42	0.34	8.42	8.92	High

14	Terap putih	12.60	0.43	4.77	8.52	High
15	Sungkai	16.82	0.46	5.73	7.28	High
16	Medang	15.62	0.5	5.80	7.46	High
17	Pulai	14.90	0.55	3.10	11.10	Med-High
18	Pisang - pisang	14.00	0.58	3.75	4.80	Medium
19	Cempening	16.86	0.75	0.70	1.39	Low
20	Kelampai	15.27	0.78	1.78	3.10	Medium
21	Belatik	21.00	0.79	1.07	2.30	Low
22	Sampe	16.55	0.81	1.54	1.47	Low
23	Ubar	16.99	0.85	4.08	7.27	High
24	Ketikal	16.39	0.98	3.30	4.80	High

Extractive content defines as a total amount of wood solubility in neutral solvent such as water, benzena, eter and alkohol. Extractive type which is soluble in water is sugar, colour, tannin and starch, while extractive type which is soluble in organic solvent is resin, fat and paraffin. Classification of Indonesian Wood based on chemical compound can be sawn in Table 2.

Table 31 shows the cold and hot water solubility of SDL from plantation and community forest range from 0.40-5.75% (average 2.89%) and 2.00-7.28% (average 4.67%), respectively. The cold and hot water solubility of SDL from natural forest range from 0.20-5.80% (average 2.35%) and 1.39-11.19% (average 4.82%), respectively. Based on the above data, most of the SDL classified as low solubility (<4%).

Common SDL Defects Related to The Bio-Composite Products

The natural properties of wood produce from SDL is far from a stable, consistent material because high content of juvenile wood, shorter wood fiber, high portion of sapwood, higher moisture content and the natural durability is lower compared to those of large diameter wood. One of the biggest challenges of producing bio-composite products is learning to work within the constraints of a SDL properties. Table 32 shows wood defect, features, caused by, effect and solution to handle the wood defect problem in producing bio-composite products.

Table 32. Wood defect, features, caused by, effect and solution to handle the wood defect problem in producing bio-composite products.

Raw material/Wood Defect	Features	Caused By	Effect to the bio-composite products	Solution
Blue stain	A bluish gray discoloration on the woods surface is the most common.	Mold that grows in warm and moist area, usually poorly ventilated, delayed processed.	Discoloration of glulam, LVL and plywood. However he effect to the particleboard and MDF is not significant.	Can be cut off, placed out of sight, or concealed with a dark stain for glulam, LVL and plywood. However for particleboard and MDF is not necessary.
Bow	A curve along the face of board that usually runs from end to end.	Improper storage. Usually moisture evaporation from one side and not the other.	Stock is difficult to work with and cut for glulam, LVL and plywood. No problem for particleboard and MDF	Cut in smaller pieced for glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF
Checks or Splits	Breaks at the end of a SDL/ board that runs along the grain. Checks and splits are usually restricted to the end of a SDL/board.	Significant different moisture content between surface and inner of the SDL or rapid drying or extreme drying condition.	Can affect the strength and appearance of the glulam. No problem for LVL, plywood, particleboard and MDF.	Should be cut off or worked around for glulam. No problem for LVL, plywood, particleboard and MDF.
Crook	Warping along the edge from one end to the	Can be caused by improper	Can be difficult to work with for	The higher spots can be cut away on

	other. This is most common in wood that was cut from the center of the tree near the pith.	drying and storage or the presence of reaction wood.	glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF	a table saw or jointer using a special jig for glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF
Cup	Warping along the face of a board from edge to edge. This defect is most common of plain-sawn lumber.	This defect can be caused when one board face dries at a faster rate than the other.	Stock can be difficult to work with. Trying to "force it flat" can cause cracking along the grain for glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF .	You can try allowing the board to dry at the same moisture content under pressure, rip it into smaller pieces on a table saw, or use a jointer to remove the high spots for glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF
Dead or Loose Knot	A dark, usually loose knot.	This defect can be caused by a dead branch that was not fully integrated into the tree before it was cut down.	Can mar the appearance of the wood, fall out, become loose, or weaken mechanical properties for glulam. Can be repair for LVL and plywood. No problem for	Should be cut out, around, or glued in place and filled with wood putty for glulam, LVL and plywood. No problem for particleboard and MDF

			particleboard and MDF	
Gum, Sap, and Pitch	Accumulations of a resinous liquid on the surface or in pockets below the surface of wood.	Injury to the tree.	May cause difficulty in production and finishing glulam, LVL, plywood, particleboard and MDF	Should either be cut off or scraped out
Machine Burn	Dark streaks along the face of a board.	Usually caused by planer blades that are dull or spun on part of the board for too long.	Discoloration to the surface. Sometimes the burn can penetrate into the board for glulam. Nothing to do with LVL, plywood, particleboard and MDF	Can be sanded off or cut down with a jointer. The depth of the board often determines the amount of work needed. for glulam. Nothing to do with LVL, plywood, particleboard and MDF
Ring Check	Breaks in the wood along the annual growth rings.	Extreme difference of SDL moisture content or improper drying or damage during transport.	Can effect strength or appearance for glulam. No problem for LVL, plywood, particleboard and MDF	Should be cut around, place out of sight, or glued down for glulam. No problem for LVL, plywood, particleboard and MDF
Tight Knot	A know which is tightly integrated into the surrounding wood.	This was once a branch that was incorporated into the tree as its girth increased.	Does not effect the lumber’s strength for glulam.	May be removed for appearance purposes.
Twist	Warping in	Growing	Can be	Can be cut

	lumber where the ends twist in opposite directions. (Like twisting a towel)	conditions, uneven drying or the presence of reaction wood.	difficult to work with for glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF	into shorter boards or the high spots can be removed on a jointer for glulam. Not feasible for LVL and plywood. No problem for particleboard and MDF
Wormholes	Small holes in the wood.	This is caused by insects boring through the wood.	Can be used as long as the intensity not too high for glulam, LVL and plywood. No problem for particleboard and MDF	Cut around worm holes. The insects should be absent for glulam. For LVL and plywood can be repaired by putty. No problem for particleboard and MDF

Figure 56 – 61 show the condition of SDL which is used as plywood raw material in PT. Andatu Plywood, Lampung Province. Figure shows that some SDL were check or split in the end of log. If this phenomena doesn't minimize by using plastics S nail, the check or split will be bigger from time to time. It depend on the difference of moisture content between outer part of SDL compared to the inner part of SDL. In case of wood come from natural forest, plastic S nail changed with metal S nail. This method is proven very effective to control check or split at the end of the log.

Figure 56. SDL check and split defects and how to minimize them.

Figure 57. Comparison of plywood raw material from SDL (left)

and large diameter logs (right)

Figure 57 shows the comparison of plywood raw material from SDL and large diameter logs (LDL) come from natural forest. Visually it is very clear that the SDL contain knot higher compared to those of LDL. In general the quality of the SDL raw material for plywood is lower compared to those of LDL.

Figure 58 – 60 shows the veneer production and its quality made from SDL. During field survey in PT. Andatu Plywood industry, it was found that in general the veneer production is discontinue and the produced veneer quality is lower compared to those of LDL from natural forest. The critical veneer quality is discontinue, so many defect (torn, interlocked grain, juvenile wood, blue stain) and uneven veneer thickness. Production of plywood using SDL need more labor compared to those of LDL. However, the quality of plywood mare from SDL can be the same as those of made from LDL.

Figure 58. Veneer production using SDL as raw material

Figure 59. The quality of veneer produced from SDL

Figure 60. Different knot content between veneer produced from Acacia mangium (left) and Paraserianthes falcataria (right)

Figure 61. Veneer appearance attacked by mold due to the high moisture content

-Activity 2.1.4. **Evaluate the appropriate properties of products manufactured from SDL.**

Performance of Plywood Made of Small Diameter Logs

The plywood industry in Indonesia was predicted to have bright prospect after recession period, due mainly 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 enabled the industry to utilize SDL obtained from plantation and community forests. Among the plywood industries which have used SDL from plantation and community forests in Indonesia are PT. Sumber Graha Sejahtera (PT. SGS) (in Balaraja, West Java Province), PT. Andatu Plywood Industry (in Lampung Province), PT. Erna Djuliawati (in Sanggau, West Kalimantan Province), PT. Wijaya Tri Utama (in Banjarmasin, South Kalimantan Province) and PT. Kutai Timber Indonesia (in Ponorogo, East Java Province) which were very successful in their business and showed high quality products during the three years research activities.

A. Veneer Yield

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

In order to find out the yield of SDL obtained 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 are mixture of species where the dominant species are jabon (*Anthocephalus cadamba* Miq), manii (*Maesopsis eminii*), and sengon (*Paraserianthes falcata* L Nielsen).

The rotary veneer yield was 62.0 % on the average with standard deviation of 9.9 %. The obtained results were higher compared to the same research conducted by Kliwon and Iskandar (1998), and were even slightly higher compared to those of Ministry of Forestry Standard of rotary veneer yield (55 – 60%). According to Kliwon and Iskandar (1998), the rotary veneer yield of SDL using a 10 cm chuck is 40 %. The reason of the higher rotary veneer yield is that because the SDL chosen for the research is very well selected with minimum wood defects which potentially reduce 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 Iskandar (1998) research. The research results have shown that utilization of a spindle-less or center-less lathe allow peeling of cores down to diameters of 50 mm (2.0 inch) or less. The increased veneer yield is especially important for mill that relies 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, which has the highest occurrence of knots, and tends to be excessively wavy, an artifact of producing flat veneer from small diameter logs (Bowyer *et.al.*, 2003).

The research results of rotary veneer yield using spindle-less rotary machine can be seen in Table 33.

Table 33. Rotary veneer yield using SDL coming from plantation and community forests.

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.[illegible]
20	1.3	25	63781	19	36840	7	4312	51.0

Table 33. (*continue*)

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
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

Table 33. (*continue*)

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 falcataria* L Nielsen) which were bonded by UF, MF and PF were presented in Table 34. 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 34. 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														
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														

Table 34. (continue)

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 exhibited dirty surfaces because PF glue penetrated until the surface of the produced plywood and was 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, 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 exhibited dirty surfaces because PF glue penetrated until the surface of the produced plywood and was clearly conspicuous. This phenomenon happened due to the combination of factors between the color of the PF glue (dark brown) which is very contrasting 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 the critical quality factors. Excess moisture in plywood may cause molding, decay or rotting. However, it is not correct to say that the lower the moisture content, the better the quality. It's only partly correct. If the plywood is too dry, the plywood becomes very weak. For example, very dry plywood of 2.4 mm thickness 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 62. 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 similar for all of the plywood bonded by UF, MF and PF.

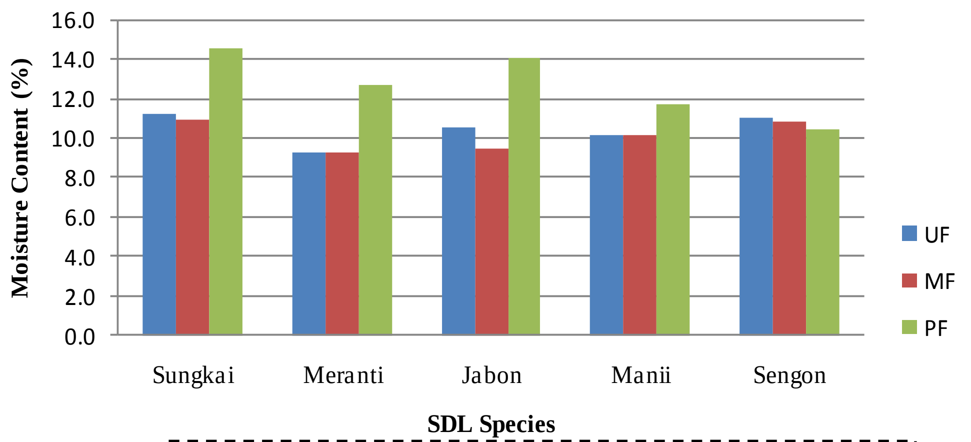


Figure 62. Histogram of Plywood moisture content

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 is affected by surface quality of the veneer, species, type of adhesive, pressing time, and pressing temperature.

It is essential for 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 in this case, a strong bond is needed most. 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 requirements 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, such as oil or waxy materials which may bleed to the surface during drying or storage and create a poor gluing surface, or create 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 63 and 64 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 types resulted in 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 them cool down, and then they were 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 ± 3 °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 them cool down, and then tested in wet condition.

Figure 63 and 64 show that the wet shear strength are 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.

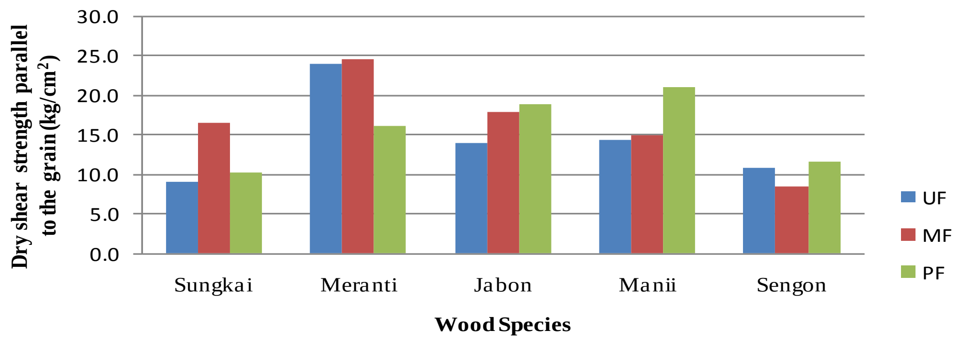


Figure 63. Histogram of plywood dry shear strength parallel to the grain

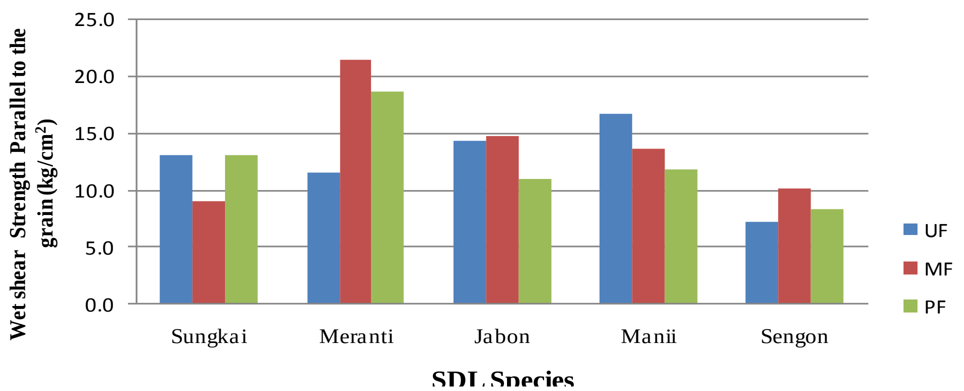


Figure 64. Histogram of Plywood wet shear strength parallel to the grain

Figure 65 and 66 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 which were parallel to face / back grain. Figure 8 shows that most of the produced plywood failed to fulfill the JAS Standard, except Meranti PF bonded plywood.

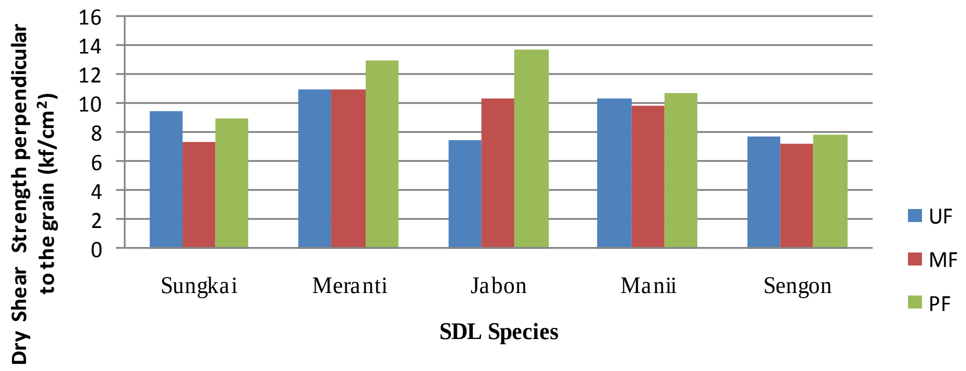


Figure 65. Histogram of dry shear strength perpendicular to the grain

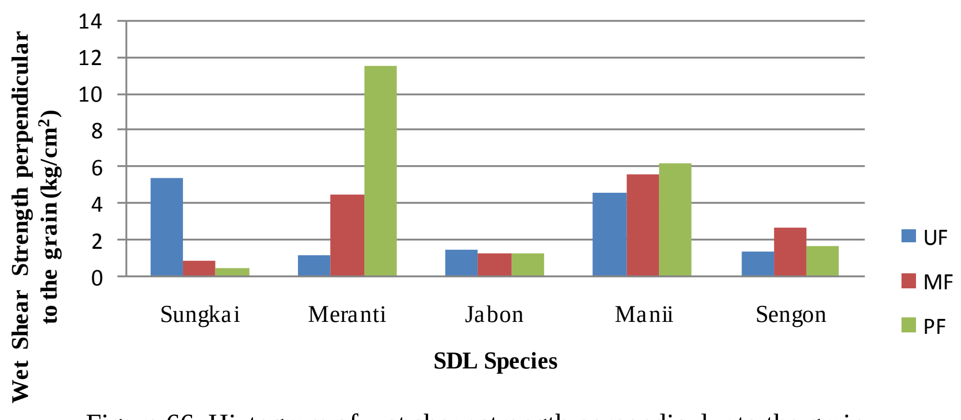


Figure 66. Hiatogram of wet shear strength perpendicular to the grain

Performance of LVL Made of SDL

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 (Hadjib, Massijaya, and Hadi, 2009). 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.

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 35.

Table 35. 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 of the stem before the peeling process. There was also one 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 one 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 67. 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 woods, 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 68. 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 36.

Table 36. 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 69.

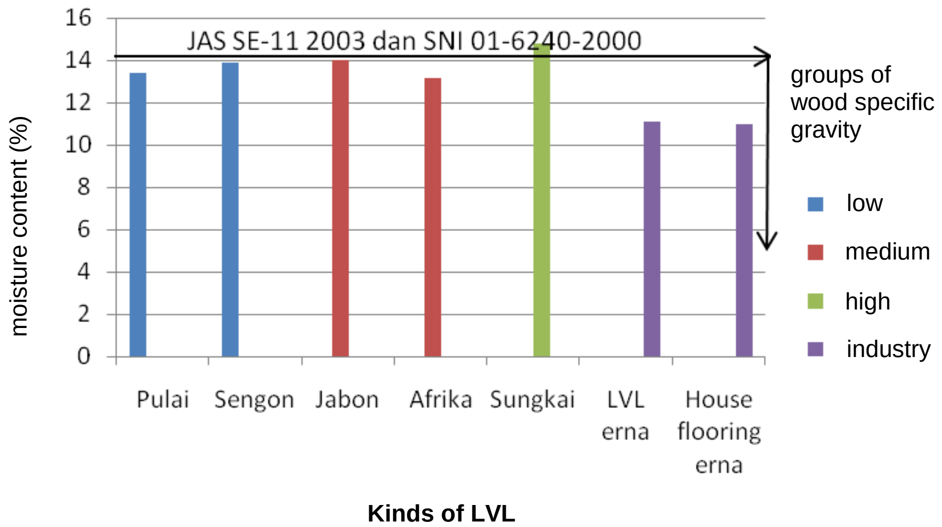


Figure 69. Histogram of moisture contents of LVL.

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.

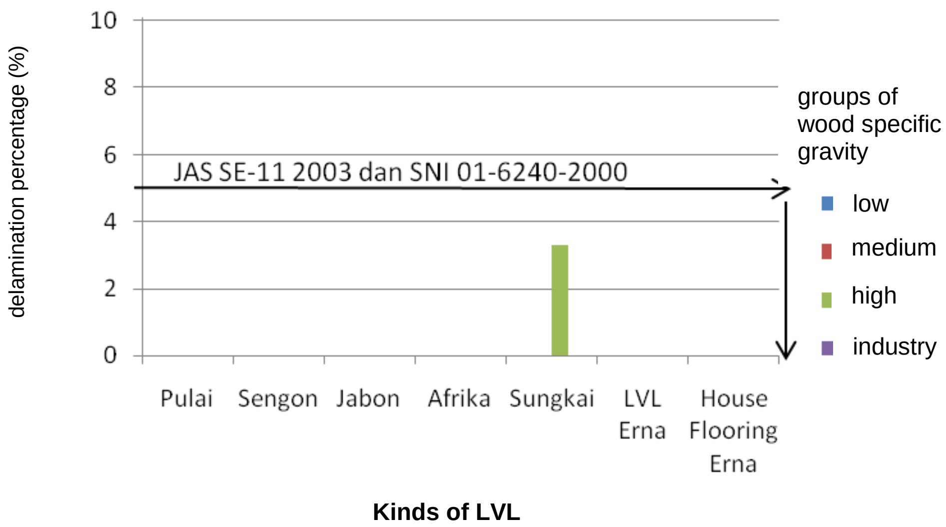


Figure 70. Histogram of delamination percentage of LVL


(A)


(B)


(C)


(D)


(E)

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 71. 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.

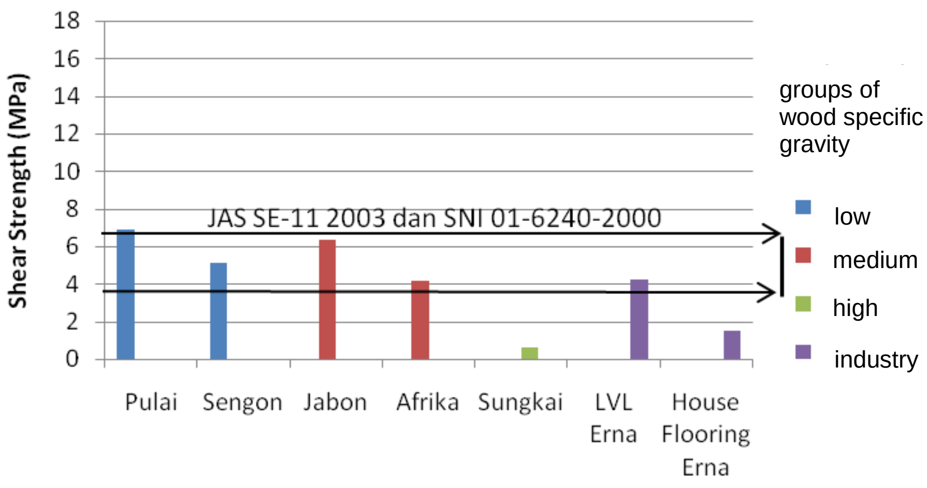


Figure 72. Histogram of Shear Strength of LVL


Figure 73. 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 *74* and *75*.

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.

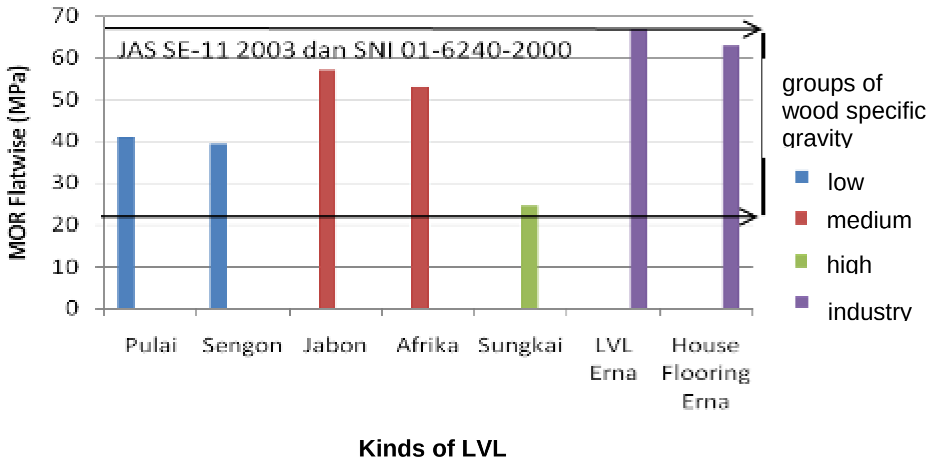


Figure 74. Histogram of Flatwise Modulus of Rupture (MOR) of LVL

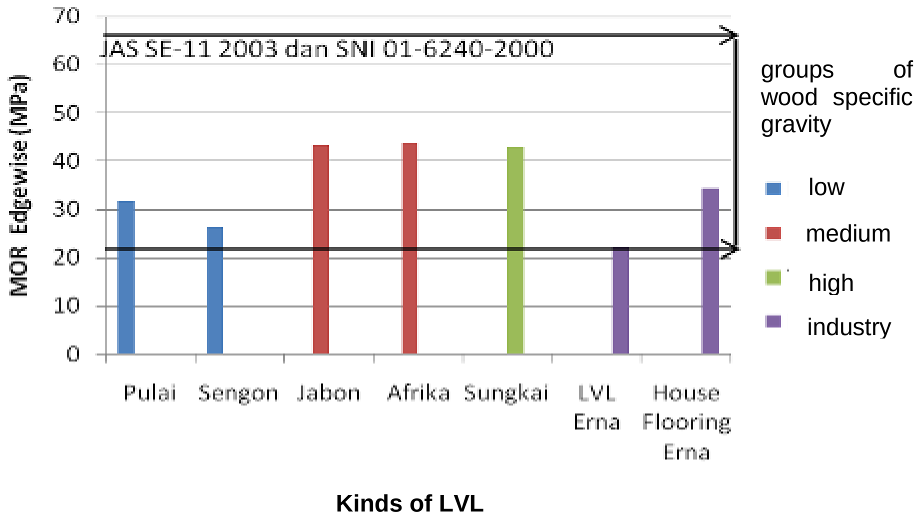


Figure 75. Histogram of edgewise Modulus of Rupture of LVL

(Flatwise Bending Test) (Edgewise Bending Test)

Figure 76. 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.

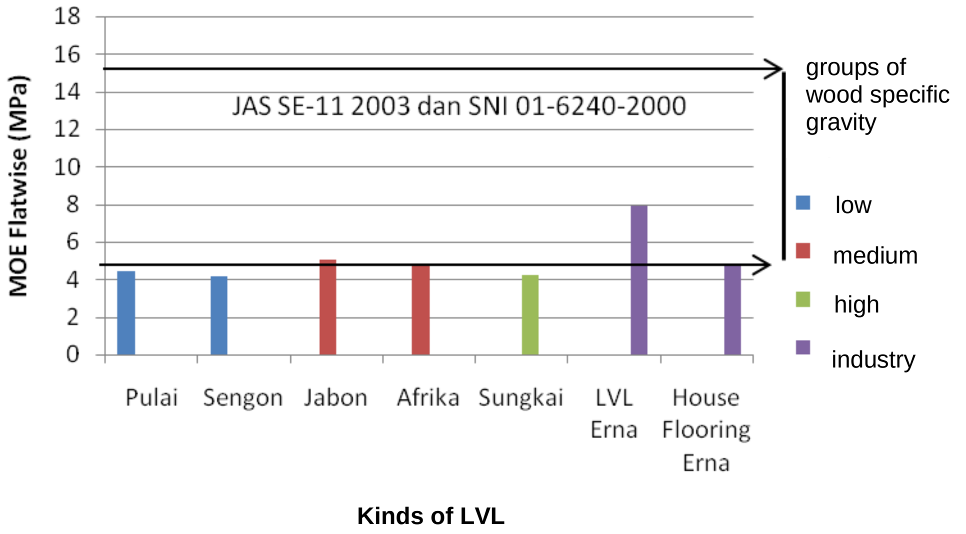


Figure 77. Histogram of flatwise Modulus of Elasiticity (MOE) of LVL

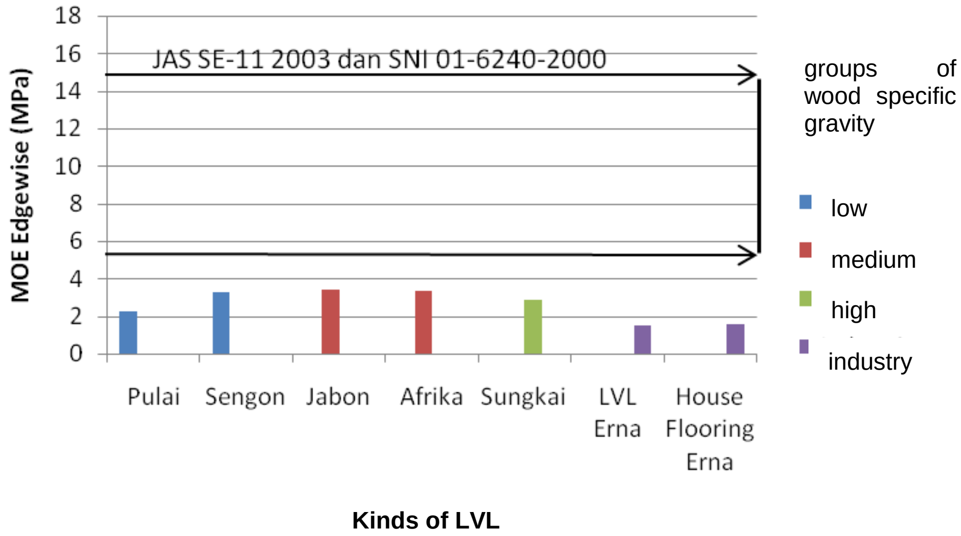


Figure 78. Histogram of edgewise Modulus of Elasticity (MOE) of LVL

Performance of Glulam Made of Small Diameter Logs

Glulam or commonly called as laminated wood or laminated timber is Glued laminated timber which is obtained by bonding together a number of laminations with their grains are essentially parallel. In this way, a member with a rectangular solid cross-section can be produced. Other non-rectangular shapes can also be produced (Wirjomartono, 1958).

A. **Recovery of board manufacturing**

Small diameter sawmill recovery mounting into a board with thickness of 2.5 cm are presented in table 37.

Table 37. Recovery of board manufacturing

No.	Wood species	Average Diameter, cm	Recovery, %
1.	Pine	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 recovery of the wood sawing of small diameter logs into 2.5 cm board ranged from 51.3 – 67.78 % with an average of 55.4 %. This value is slightly lower than the recovery of sawing results from Supriyadi and Rachman (1998) which amounted to 56.39 %. Recovery of glulam manufacturing ranged from 31 – 53 % with an average of 38 %. Variation of the recovery values were due to log's shape, condition, and wood defects.

B. **Wood Drying**

Wood drying aims to obtain the required moisture content. The results of drying by using a solar furnace are presented in table 38. The use of diesel oil is tailored to the need, especially at night. When the moisture content of wood has not reached 30 %, the temperature was maintained so it is not to exceed 50 %. The results of wood drying for each of the 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 %. Of the five types of the wood, wood drying quality of manii is the worst. Stress of the manii timber which on the experiment was high was indicated by the breaking of the end sample, which was quite severe. This is probably because of log quality, means higher portion of green wood (juvenile) finally result the growth of severe stress (Hilis, 1997).

Table 38. There are three types of wood drying, which comprise species of manii, jabon, and mangium with a combination of solar drying method and the heat from the furnace type II

No.	Wood species	Initial MC (%)	Time drying to obtain 10% MC (days)	Drying rate (%/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	69.3	6.5	8.89	C-D
5.	Pine	85.9	8	6.67	B

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

Based on the research results in Table 38, it is clear that Japan and Pine classified as good for drying quality. However the other wood species (mangium, manii and sengon) classified as medium to less drying quality.

C. **Physical characteristics**

Moisture content and density of glulam consist of same species or mixture are presented in Table 39. Moisture contents and densities of glulam which comprise wood from one species or mixed species are presented in Table 39. Moisture content of glulam ranged from 9.13 to 14.87 % with an average of 10.83 %. Density range between 0.255 – 0.630 g /cm ^{3} with an average of 0.467. The highest moisture content was found at mangium and the lowest of density was found at sengon. These phenomena have been described by Bodig and Jayne (1982). Based on the value of its density, then the glulam which have been made were categorized as ranging from minor to moderate. According to Haygreen and Bowyer (1986), wood density can be used for light construction.

Table 39. Density and moisture content Glulam

Type	Moisture content,%	Density (g/cm^3)
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

Densities of mixed glulam of sengon-mangium were still relatively low, this was because of higher portion of sengon than mangium, and therefore, it did not affect the density of the formulation of glulam. Sengon density values being observed were very low and hence it is not a 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 core. The result showed that using glulam density 2/3 part of the sengon is still low, so that's the necessary to reduce sengon portion.

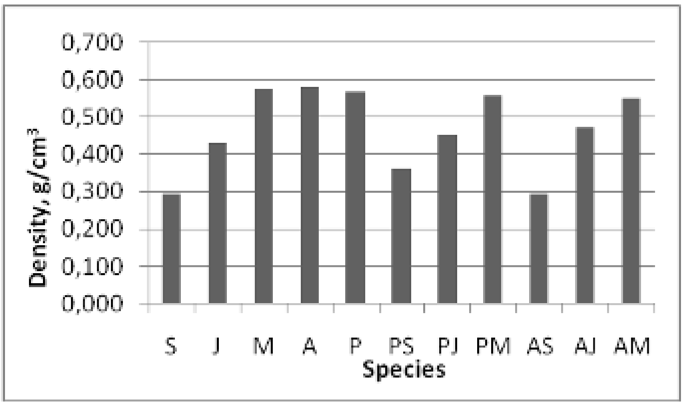


Figure 79. Histogram of glulam densities.

Based on statistical analysis by Duncan test, it could be reported that the highest density value was contained in the glulam mangium. Density of glulam made of mangium is not significantly different from the glulam manii, pine, and pine- manii. The lowest density value occured in the glulam sengon. Glulam sengon density was not significantly different with that of mixed-glulam sengon-mangium and was significantly different with the other group of glulam.

D. **Mechanical characteristics**

The average value of mechanical characteristics, including static bending strength (modulus at proportional limit, modulus of rupture and modulus of elasticity) of glulam in the experiment, are presented in table 40, figure 80 and 81

Table 40. The average value of the mechanical characteristic of glulam beams

Type	Static bending test			Delamination, kg/cm^2	
	MPL, MPa	MOR, MPa	MOE,GPa	Cold	Hot
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 on it without any change in shape. Higher value of MOE means stronger wood to make a change in shape (Setiawan, 2008)

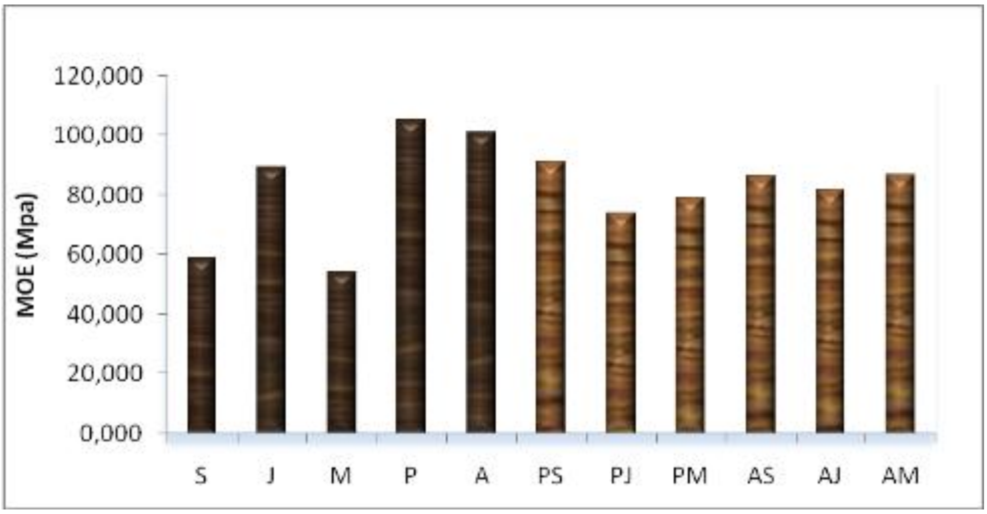


Figure 80. Histogram of MOE

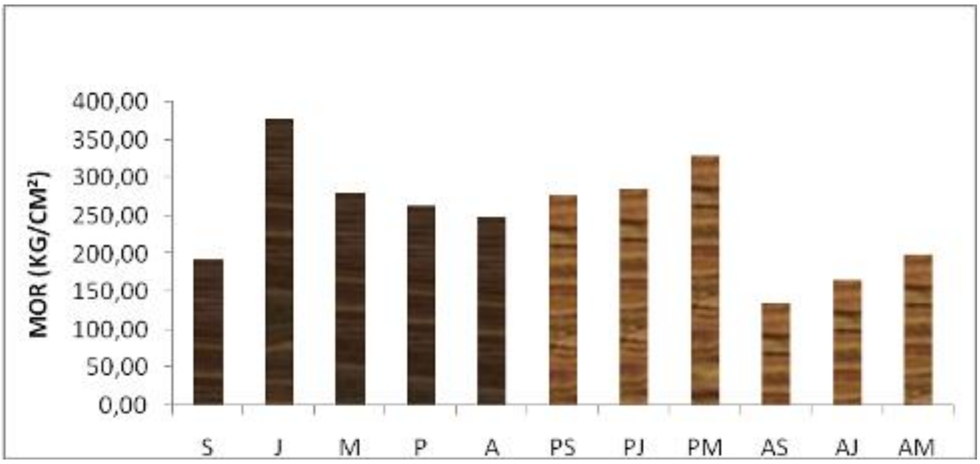


Figure 81. Histogram MOR

The highest average MOE value of glulam whih are ranked from the highest until the lowest is a pine, mangium, a combination of pine – sengon, jabon, mangium-manii combination, combination of sengon-mangium, mangium-jabon, pine-jabon, sengon and the lowest MOE values held by manii glulam. Based on the literature, the pine has a higher density value than mangium, but from the test result, it was known that the MOE mangium was slightly smaller than the MOE value of the pine, MOE value is directly proportional to density. It is caused by finger joint connection factors contained in the timber of 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. Of the 3 types of the wood, mani has the lowest MOE value but it has the highest density as compared with the other.

MOR (modulus of Rupture) is ability of an object to wishstand the maximum bending load until the object is damaged. Histogram of MOR being studied are presented in figure 79.

From the graph above, it can be seen that MOR values which are ranked from highest to lowest are exhibited consecutively by those of jabon, a combination of pine – manii, a combination of pine-jabon, manii, a combination of pine-sengon, pine, mangium, combination – maniimangium, sengon, mangium – jabon combination, and the last one is mangium sengon. Based on the graph, it is known that the value of MOR of combined pine is better than pine which is not combined. However, for glulam which were not combined, the highest MOR value was generated by the jabon timber. This condition can happened because most of the pine wood used in the process of making glulam timber had inclined fiber and had a lot of knots that affect the strength of wood. For mangium wood, MOR values are smaller than jabon. This was because there were finger joint in mangium which has a high level of risk damage when the test occured. Combination of the wood sengon – mangium, mangium – jabon and mangium manii possessed low MOR values when compared with wood of sengon, mangium, and jabon which were 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 adhesive strength of glulam only for manii, pine–manii, and mangium manii (Anonymous, 2003).

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

Tests were 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 was generated by the combination of mangium and manii. This happened 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, it could be suggested that a combination of pine-sengon and mangium-sengon, does not met the standard of JAS (2003).

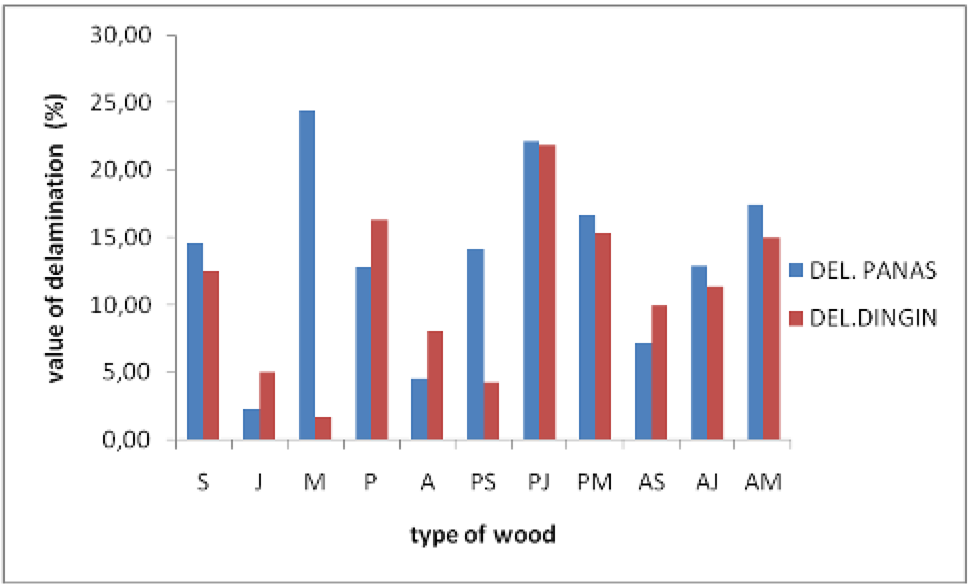


Figure 82. Histogram of Glulam Delamination

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 it can be seen that most of the highest values of delamination always found delamination heat either. This means that the wood was more susceptible to temperature change and heat damage as compared to that of 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 that of heat delamination.

The highest value of heat delamination was found on manii wood, while the lowest value of delamination was 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 was 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.

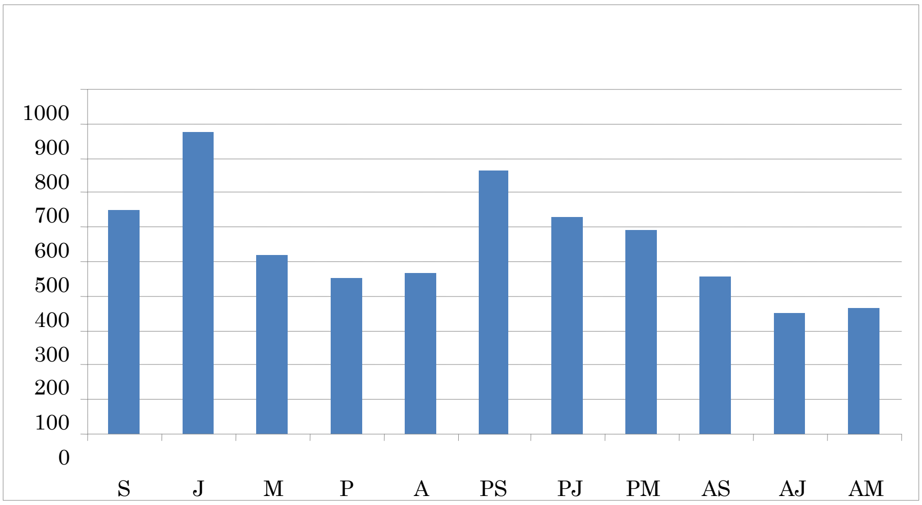


Figure 83. histogram of S/W glulam

The figure above shows that the value of S/W glulam made ranged from 363 to 875 with an average of 590. Highest value of S/W was contained in the jabon glulam and the lowest value is on mixture of jabon mangium glulam. This difference is affected by the differences in density and strength of the lamina (Anonymous, 2010).

Performance of Particleboard Made of SDL

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 particleboard made from small diameter log from natural and plantation forests.

C.1. Density

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

The average density of particleboards resulted from this study are shown in Figure 84.

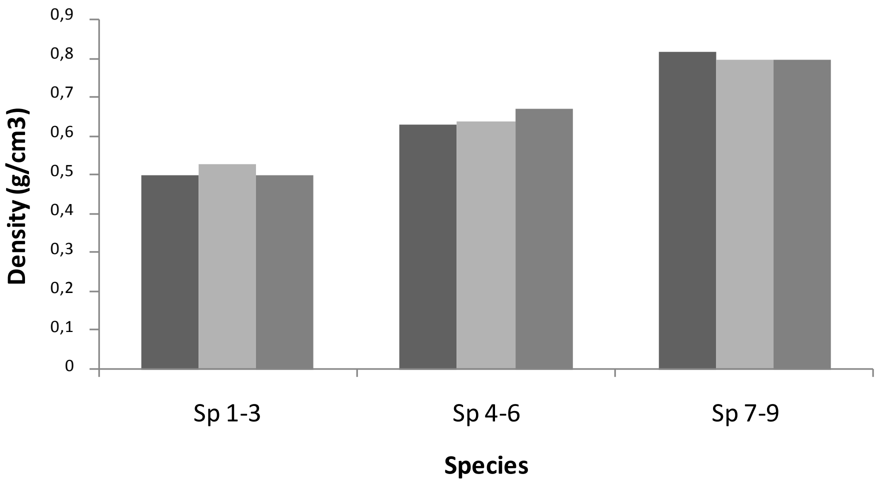


Figure 84. The average density of the particleboards

The average density of the low density particleboards was 0.51 ± 0.02 g/cm^3 and ranged between 0.50-0.53 g/cm^3; those of medium density particleboard was 0.65 ± 0.02 g/cm^3 and ranged between 0.63-0.67 g/cm^3, while those of high density particleboard was 0.81 ± 0.01 g/cm^3 and ranged between 0.80-0.82 g/cm^3. There are no significant differences between wood species in the same particleboard density. It can be suggested 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.

The average moisture content of the boards resulted from this study are shown in Figure 85.

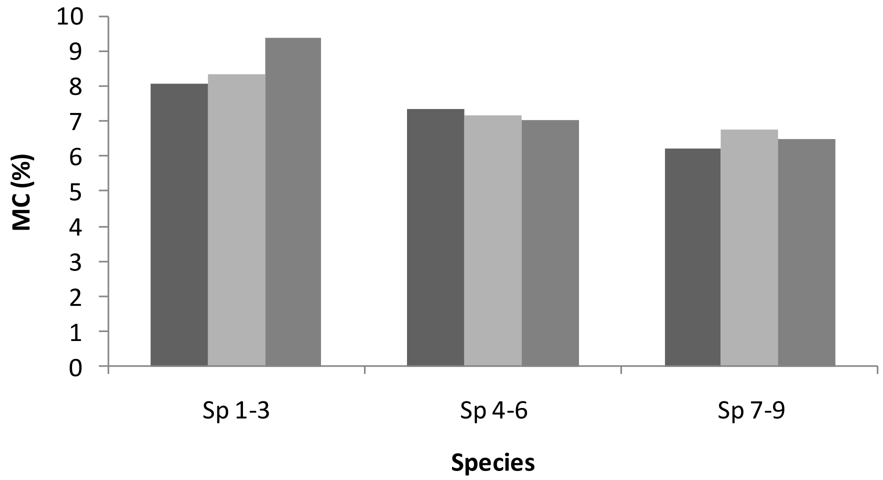


Figure 85. Average moisture content of the boards

The average moisture content of low density particleboards was 8.64 ± 0.07% and ranged between 8.11-9.43%, those of the medium density particleboard was 7.22 ± 0.16% and ranged between 7.07-7.38%, and those of the high density particleboard was 6.52 ± 0.26% and ranged between 6.26-6.78%. The moisture content for all density prticleboards were still in conformity with the standard of JIS and SNI. According to analysis of variance, wood species did not affect moisture content of the board at the same particleboard density. However, as the target density increase, the moisture content of the boards decreased.

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. The average value of thickness swelling is shown at Figure 86.

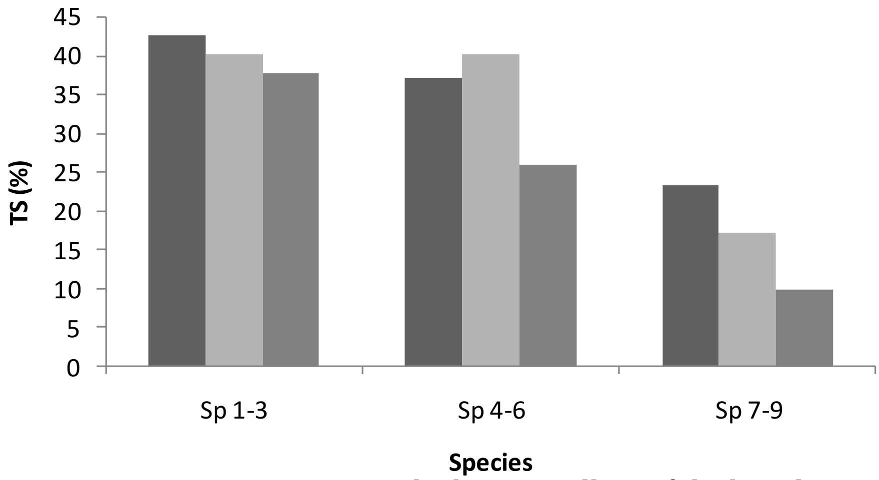


Figure 86. Average thickness swelling of the boards

The average thickness swelling of low density particleboards was 40.28 ± 2.51 % and ranged between 37.28 - 42.81%, those of the medium density particleboard was 34.56 ± 7.57% and ranged between 26.01-40.41%, while those of high density particleboard was 16.92 ± 6.72% and ranged between 10.05-23.48%. According to analysis of variance, wood species did not affect thickness swelling of the board, and there are no significant difference between partcleboard in the same particleboard density. The TS decreased as the density of the boards increase. 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, while those of the others were smaller, and there should be some attention toward this to reduce it. All thickness swellings of the boards 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 which indicates 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 87.

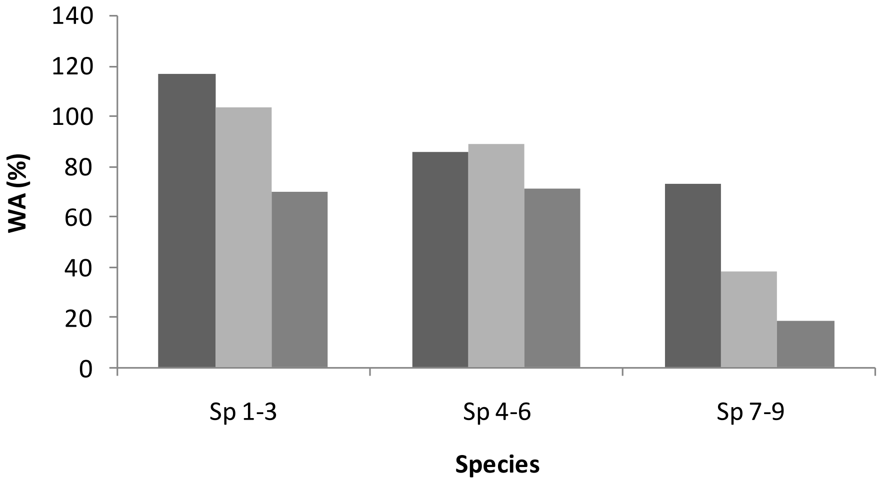


Figure 87. Average water absorption of the boards

The average water absorption of low density particleboards was 96.93 ± 24.23% and ranged between 70.07 - 117.14%, those of the medium density particleboard was 82.23 ± 9.33% and ranged between 71.58-88.98%, while those of high density particleboard was 43.32 ± 27.87% and ranged between 18.43-73.43%. According to analysis of variance wood species did not affect water absorption, and there are no significant differences between partcleboard in the same particleboard density. The WA of the board decreased as the density increase. 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, while those of the others were smaller, and there should be some attention to reduce it.

C.5. Modulus of Rupture (MOR)

Modulus of rupture (MOR) is one parameter which indicates particleboard mechanical properties. The MOR will indicate how much load can be supported, and it can be classified with reference to JIS. The average value of MOR is shown at Figure 88.

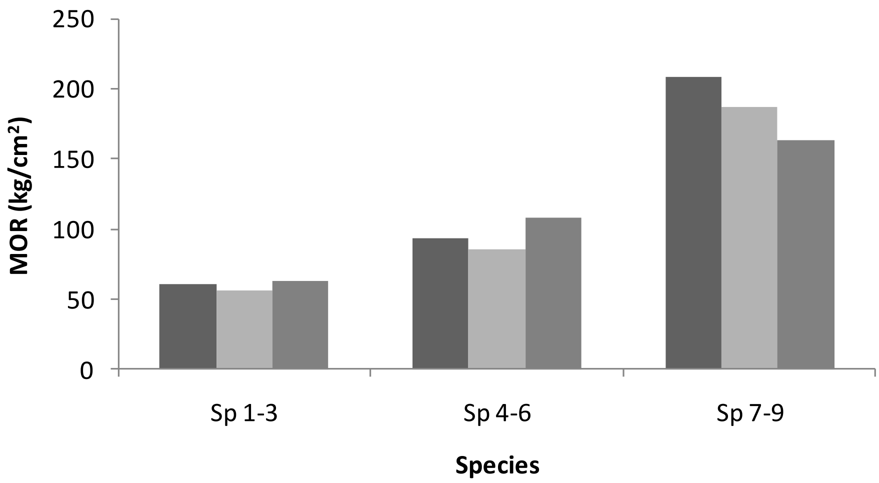


Figure 88. Average modulus of rupture of the boards

The average MOR of low density particleboards was 60.48 ± 3.03 kg/cm^2 and ranged between 57.12 – 63.02 kg/cm^2, those of the medium density particleboard was 96.08±11.42 kg/cm^2 and ranged between 86.02-108.49 kg/cm^2, while those of high density particleboard was 187.19 ± 23.02 kg/cm^2 and ranged between 163.75-209.77 kg/cm^2. There are no significant differences between partcleboard in the same particleboard density. In addition, wood species did not affect MOR of the boards. It can be suggested that every wood can be made for particleboard.

The MOR of low density boards were still lower than the standard, while those for medium and high density board, the boards can fulfill Type 18 of JIS and Type 200 of SNI. For low densities particleboards, there must be some efforts to increase MOR, so it can fulfill the standards for lower grades.

C.6. Modulus of Elasticity (MOE)

Modulus of elasticity (MOE) is one parameter which indicates particleboard mechanical properties. This property will indicate how much load can be supported while the board could still perform under plasticity limit. The average value of MOE is shown at Figure 89.

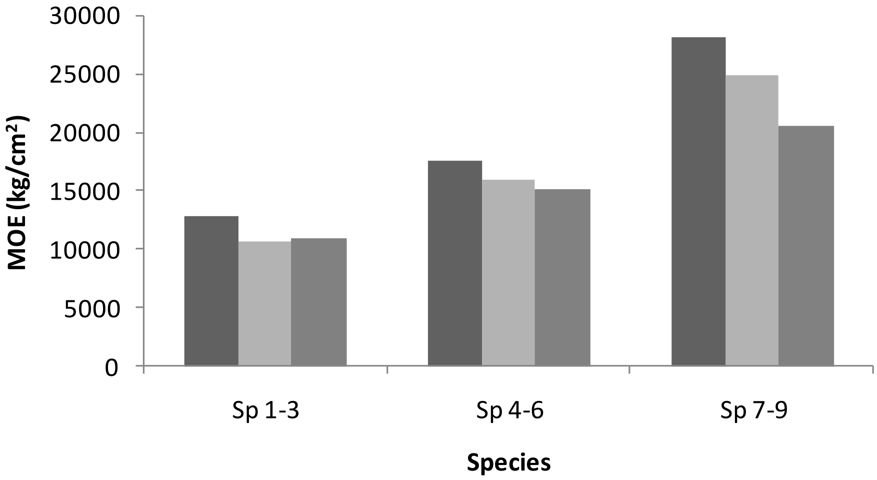


Figure 89. Average modulus of elasticity of the boards

The average MOE of low density particleboards was 11497.5±1194.4 kg/cm^2 and ranged between 10960.5 – 12866.1 kg/cm^2, those of the medium density particleboard was 16268.74±1252.16 kg/cm^2 and ranged between 15190.13-17641.92 kg/cm^2, while those of high density particleboard was 24645.91±3856.88 kg/cm^2 and ranged between 20605.61-28288.56 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 significant difference between partcleboard 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 and medium density boards were still lower than the standard and could not fulfill the requirement. The high density board could fulfill Type 13 of JIS and Type 150 of SNI. For low and medium densities of particle boards, there should be effort to increase MOE, so that it can fulfill the standards for lower grades.

C.7. Internal Bond (IB)

Internal bond (IB) is one parameter which indicates particleboard mechanical properties, and the average value of IB is shown at Figure 90.

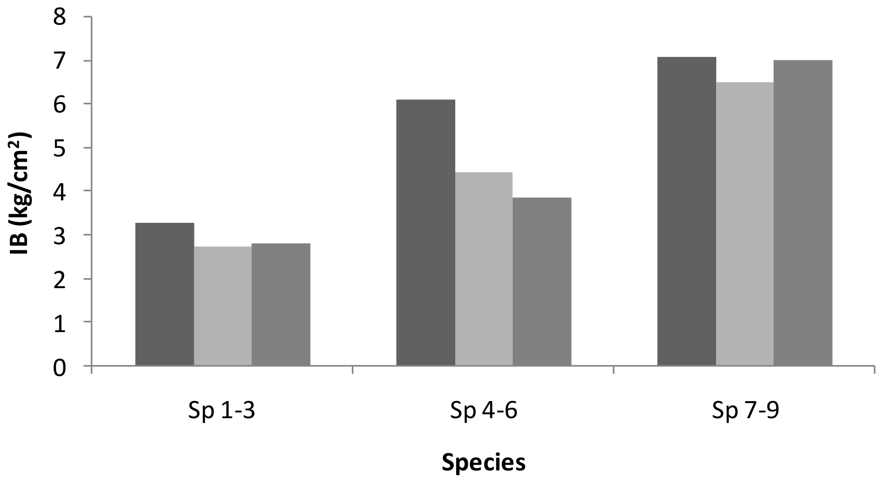


Figure 90. Average internal bond of the boards

The average IB of low density particleboards was 2.95 $\pm$ 0.29 kg/cm^2 and ranged between 2.75 – 3.28 kg/cm^2, those of medium density particleboard was 4.82 $\pm$ 1.17 kg/cm^2 and ranged between 3.86-6.13 kg/cm^2, while those of high density particleboard was 6.88 $\pm$ 0.32 kg/cm^2 and ranged between 6.51-7.10 kg/cm^2. According to analysis of variance, wood species did not affect IB, and there are no significant difference between partcleboard 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 the requirements of Type 200 of SNI and Type 18 of JIS. Sengon fulfilled the Type 200 of SNI and Type 18 of JIS, cempaka fulfilled Type 100 of SNI and Type 8 of JIS, and manglid and mixture of species fulfilled Type 100 of SNI and Type 8 of JIS.

C.8. Screw Holding Strength

Screw holding (SH) strength is one parameter which indicates particleboard mechanical properties, and the average value of screw holding strength is shown at Figure 91.

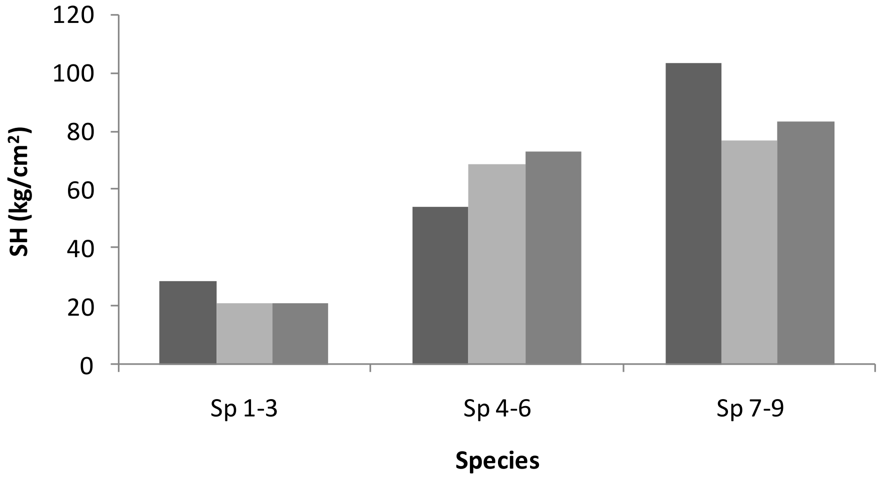


Figure 91. Average screw holding strength of the boards

The average screw holding strength of low density particleboards was 23.48±4.49 kg/cm^2 and ranged between 21.03 – 28.98 kg/cm^2, those of the medium density particleboard was 65.45±9.69 kg/cm^2 and ranged between 54.54-73.04 kg/cm^2, while those of high density particleboard was 87.99±13.92 kg/cm^2 and ranged between 76.95-103.93 kg/cm^2. According to analysis of variance wood species did not affect screw holding strength, and there are no significant difference between particleboard 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, there should be some efforts to increase screw holding strength, so that it can fulfill the standard for lower grade.

Performance of Medium Density Fiberboard Made of Indonesian SDL

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 *et al*. 2003). Various 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.

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 *et al*. 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 conformity with standards is generally accomplished by the oven-dry method. The average MC of the MDFs are shown in Figure 92.

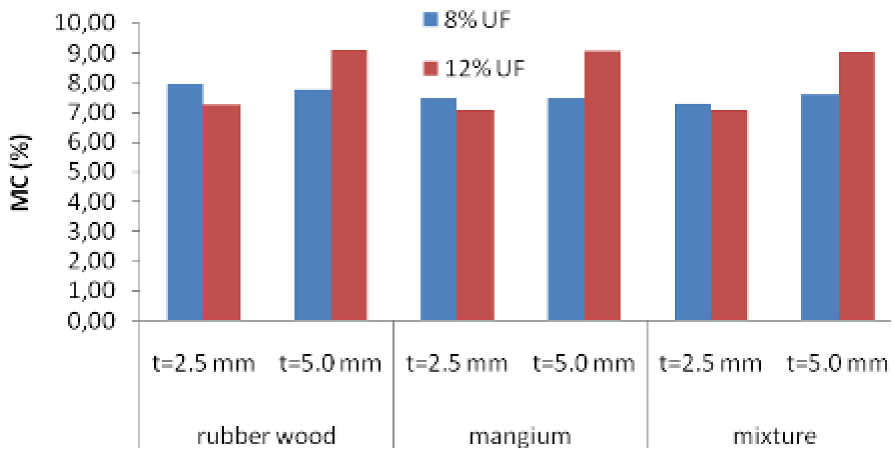


Figure 92. The average moisture content of MDFs

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 of 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, losing the 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 93.

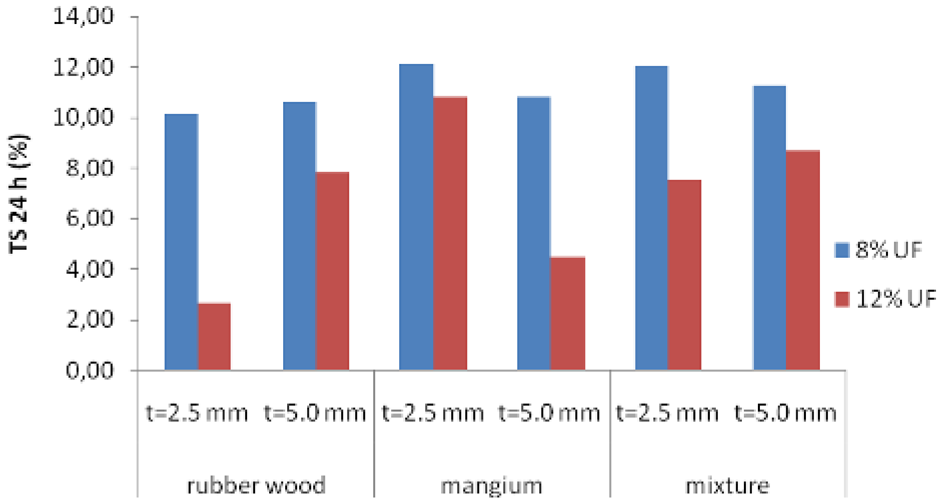


Figure 93. The average thickness swelling of MDFs

In general, the thickness swelling of 8 % UF boards was highest than that of 12 % UF boards. The average value of 12 % boards was in between 2.7 – 10.8 %, while that for 8 % UF board was 10.2 – 12.2 %. All the produced MDFs could fulfill the JIS Standard 5905-2003, and statistically there are no differences between species used. The average thickness swelling resulted in this study was lower than that of 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 in length and a 4.3-15.0% increase 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 undergo; 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 being 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 94.

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 there were no differences between species and adhesive being used. Also the same trend resulted from 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, and other manufacturing variables (Tsoumis 1991). The imperfection of the fine and coarse fiber 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 which has ever been conducted showed that temperature at pressure of up to 190^{o}C had a favorable effect on bending strength (Tsoumis 1991).

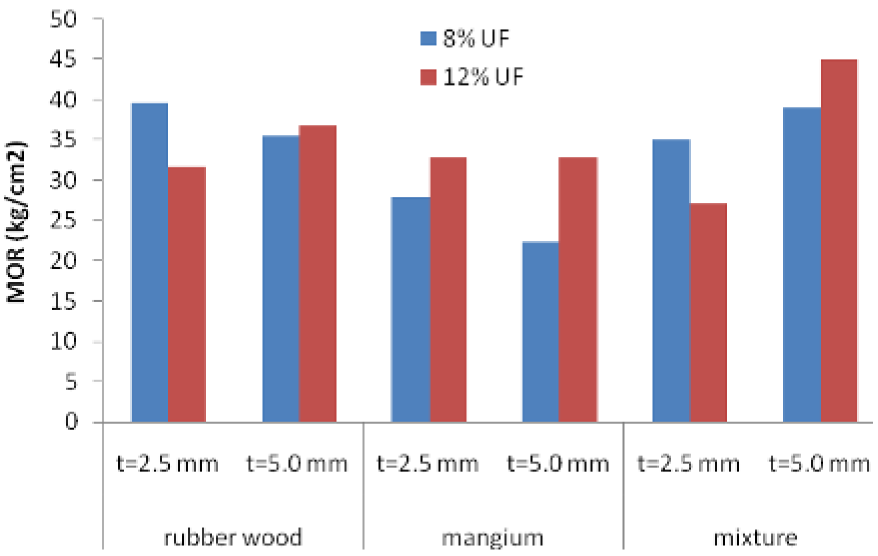


Figure 94. The modulus of rupture (MOR) of MDFs

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 greater 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 95.

The average MOE of 8 % UF board were 14,880 – 25,620 kg/cm^2, and in the range of 12,230 – 30,360 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 mixed wood achieved the maximum MOE of 30,360 kg/cm^2 by using 12 % UF and 5.0 mm of thickness. The MDF resulted in this study achieved the value of JIS 5905-2003 requirements, except for the MDF of 2.5 mm thickness of rubber wood and mangium.

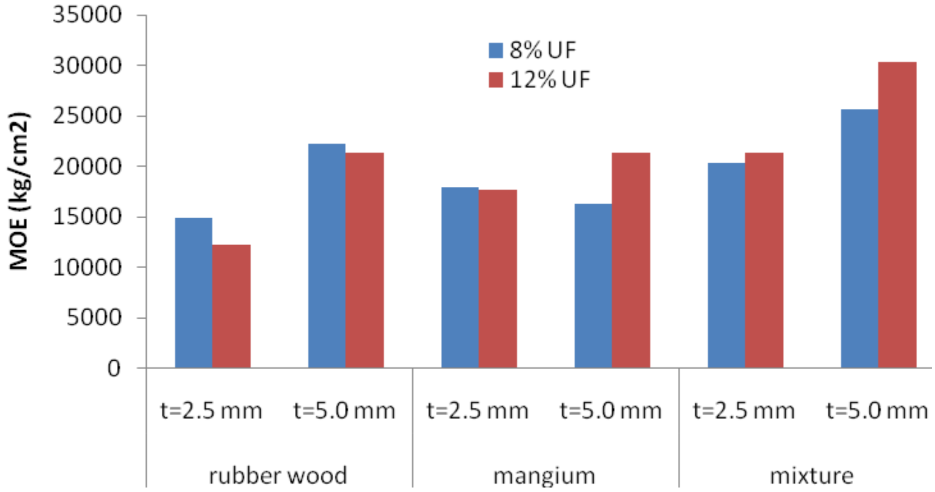


Figure 95. Modulus of elasticity of MDFs

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 96.

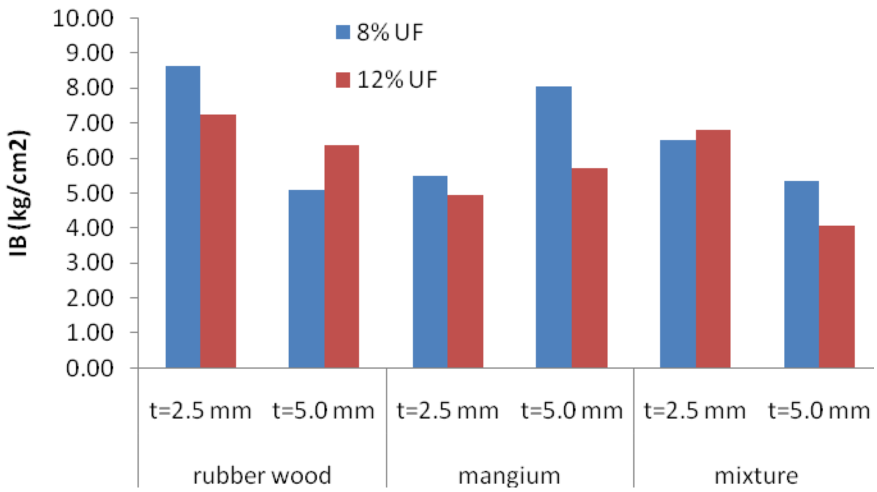


Figure 96. The internal bond strength of MDFs

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

Fundamental Properties of Cement Board made of SDL

Polyscias nodosa (Blume) Seeman

Properties of 8mm WWCB

The MOR, MOE, NHPT, TS and WA of *P. nodosa* WWCB with a thickness of 8-mm as affected by chemical accelerator at wood/cement (W/C) ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs.12,13,14, 15 and 16, respectively. It shows that MOR, MOE and NHPT were favorably affected by the addition of $CaCl_2$ particularly at 0.75 g/cm^3 and 0.85 g/cm^3 densities. Improvement in MOE was very distinct at W/C ratio of 30/70. The highest MOR of 50 kgf/cm^2 (Fig. 12) was obtained from boards with $CaCl_2$ and W/C ratio of 50/50 at a density of 0.85 g/cm^3 while the highest MOE value of 9330 kgf/cm^2 (Fig. 13) was exhibited by boards with a W/C ratio of 30/70 of the same chemical and density as MOR. Increasing the amount of wood, i.e. 30/70 to 50/50 W/C, showed no direct relationship to the increase in MOR and MOE on all set of boards without and with chemicals.

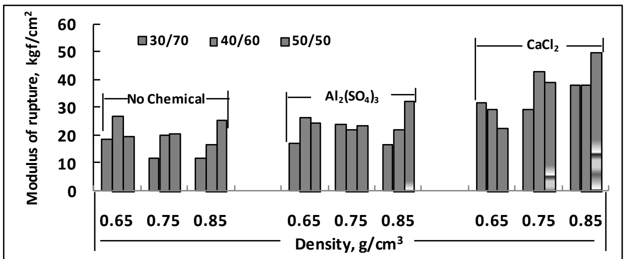


Fig. 12. MOR of 8-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

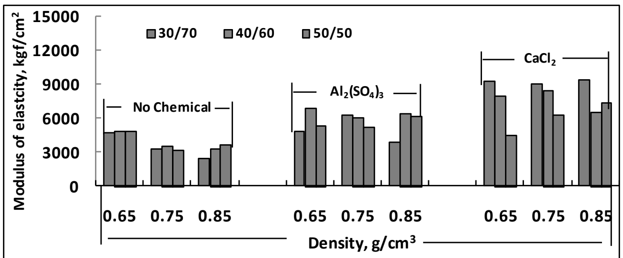


Fig. 13. MOE of 8-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Unexpectedly, low NHPT values (Fig. 14) were obtained when $Al_2(SO_4)_3$ was used as cement setting accelerator. It shows however that NHPT increased as the amount of wood is increased implying that tightness of fibers resulted to higher resistance when nail is pulled. It is remarkable that increasing the density resulted to an improved NHPT particularly for the set of boards with $CaCl_2$.

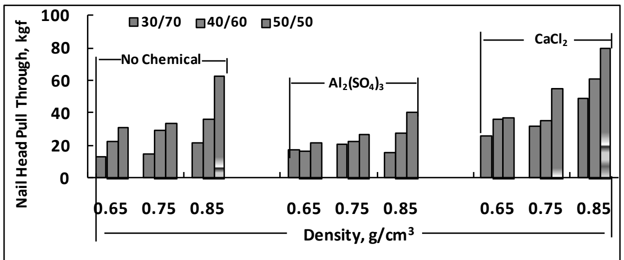


Fig 14. NHPT of 8-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Compared to boards with no chemicals, TS (Fig. 15) and WA (Fig. 16) remarkably improved when $CaCl_2$ was added at board densities of 0.75 g/cm^3 and 0.85 g/cm^3. High TS values were obtained from boards without chemicals particularly at W/C of 40/60 and 50/50 at 0.65 g/cm^3 and 0.75 g/cm^3 density levels. It is however not clear as to why some boards with 40/60 W/C exhibited higher TS than boards with 50/50 W/C although the difference lies below 1%. Obviously, WA is high at W/C of 50/50 due to the highest percentage of wood compared to W/C of 30/70 and 40/60. More amount of wood accommodated more water thus resulted in higher WA. This outcome holds true on all set of boards without and with chemicals.

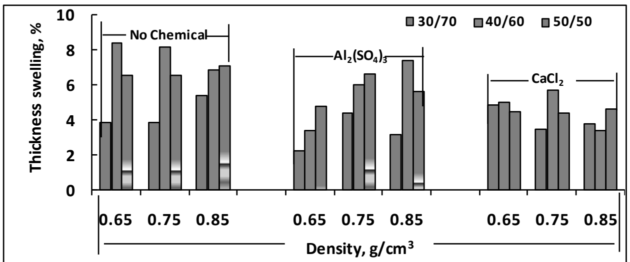


Fig. 15. TS of 8-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

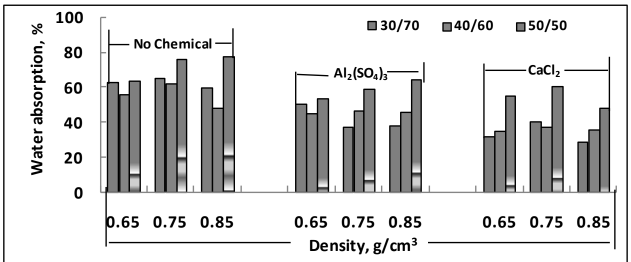


Fig. 16. WA of 8-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

ANACOVA on the MOR, MOE, NHPT, TS and WA of *P. nodosa* WWCB with a thickness of 8-mm is presented in Table 41. All sources of variation significantly affected the properties of the board except for the effect of interaction between chem*W/C on MOR, NHPT and WA as well as for the effect of W/C ratio on MOE and WA. DMRT on Table 1a revealed that the MOE of all boards with $CaCl_2$ at all W/C ratios are not significantly different.

Table 41. ANACOVA on the MOR, MOE, NHPT, TS and WA of *P. nodosa* (Blume) Seeman WWCB with a thickness of 8-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	1069.74	14.53**	57571051.60	22.67**	2732.43	18.69**	29.46	7.99**	3152.60	50.12**
Chemical	2	2329.71	31.65**	92092443.70	32.27**	5568.85	38.08**	54.33	14.73**	1065.99	16.95**
W/C	2	1192.06	16.19**	2935971.90	1.16ns	5741.16	39.26**	68.94	18.69**	115.64	1.84ns
chem*W/C	4	20.71	0.28ns	10299680.70	4.06**	187.13	1.28ns	6.68	1.81ns	17.50	0.28ns
Den	1	1742.71	23.67**	90109681.70	35.49**	2451.96	16.77**	21.21	5.75*	8328.08	132.40**

CV = 33.047 (MOR) 27.904 (MOE) 36.746 (NHPT) 36.869 (TS) 15.468 (WA)
R^2 = 0.511 (MOR) 0.620 (MOE) 0.573 (NHPT) 0.365 (TS) 0.783 (WA)

Table 41a. DMRT of the MOE of *P. nodosa* (Blume) Seeman WWCB with a thickness of 8-mm

Treatment		MOE
Chemical	Wo/Ce	
$CaCl_2$	30/70	8114.60a
$CaCl_2$	40/60	7172.32a
$CaCl_2$	50/50	6836.50ab
$Al_2(SO_4)_3$	50/50	5909.64 bc
$Al_2(SO_4)_3$	40/60	5729.53 bc
None	50/50	5198.15 cd
$Al_2(SO_4)_3$	30/70	4408.40 de
None	40/60	4345.88 de
None	30/70	3677.85 e

Properties of 12-mm WWCB

The MOR, MOE, NHPT, TS and WA of *P. nodosa* WWCB with a thickness of 12-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs.17,18,19, 20 and 21, respectively.

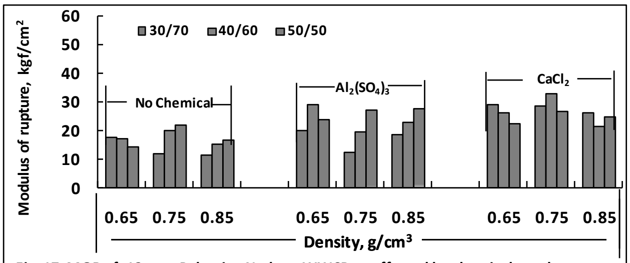


Fig. 17. MOR of 12-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Generally, MOR and MOE improved with the addition of $Al_2(SO_4)_3$ and $CaCl_2$. The highest MOR value of 32 kgf/cm^2 (Fig. 17) was exhibited by boards with $CaCl_2$ and W/C ratio of 40/60 at 0.75 g/cm^3 density while the highest MOE of

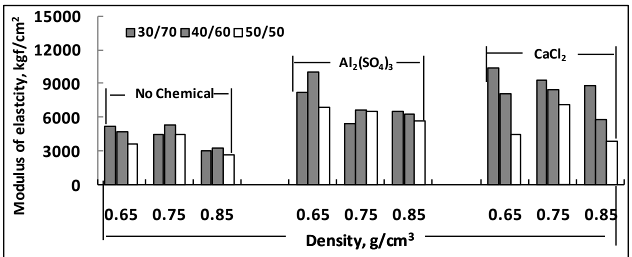


Fig 18. MOE of 12-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

10,327 kgf/cm^2 (Fig. 18) was obtained from boards with $CaCl_2$ and W/C ratio of 30/70 at 0.65 g/cm^3 density. In terms of MOE, $CaCl_2$ may have imparted a more favorable effect on cement considering high values at 30/70 W/C. There is no general trend that MOR and MOE would increase as density is increased or the amount of wood is increased.

It is interesting to note that NHPT (Fig. 19) increased as the density and the amount of wood are increased for boards with chemicals. Compared to boards with no chemicals, the improvement in NHPT is very distinct on boards with $CaCl_2$. The highest NHPT value of 82.60 kgf was obtained from boards with $CaCl_2$ and W/C ratio of 50/50 at 0.85 g/cm^3 density. The NHPT values at this thickness are rather higher than those obtained from WWCBs with a thickness of 8mm.

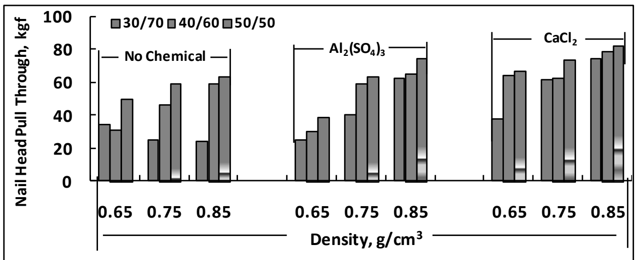


Fig 19. NHPT of 12-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

The effect of treatments, chemicals, W/C ratio and interactions between chem*W/C on MOR was significant as shown in Table 2. DMRT on Table 2a shows that MOR of boards with $CaCl_2$ & 50/50 W/C; $Al_2(SO_4)_3$ & 50/50 W/C; $CaCl_2$ & 40/60; no chem & 50/50 W/C are not significantly different. All sources of variation significantly affected the MOE and NHPT of the boards except for W/C ratio and for the interaction between chem*W/C. DMRT (Table 2b) revealed that MOE values are not significantly different on boards with $CaCl_2$ & 50/50 W/C; $Al_2(SO_4)_3$ & 50/50 W/C and $CaCl_2$ & 40/60 W/C.

TS (Fig. 20) was adversely affected by the addition of $Al_2(SO_4)_3$ compared to boards without chemicals showing an increasing values particularly at densities of 0.65 g/cm^3 and 0.75 g/cm^3. On the other hand, $CaCl_2$ greatly improved the TS of the boards wherein the lowest value of 1.76% was obtained from W/C of 30/70 at 0.85 g/cm^3 density. The WA (Fig. 21) of the boards

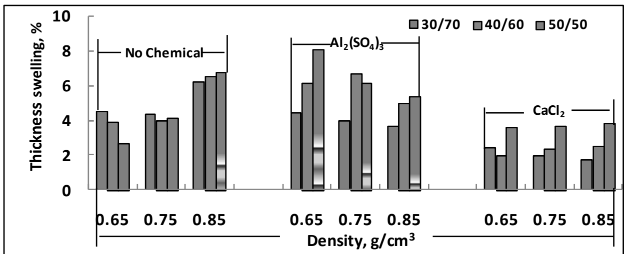


Fig. 20. TS of 12-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

remarkably improved when $CaCl_2$ was added compared to boards with no chemicals and boards with $Al_2(SO_4)_3$. There is a general trend that WA increased as the amount of wood is increased except for the set of boards with no chemicals added at 0.75g/cm^3. For boards with $CaCl_2$, WA decreased as density is increased.

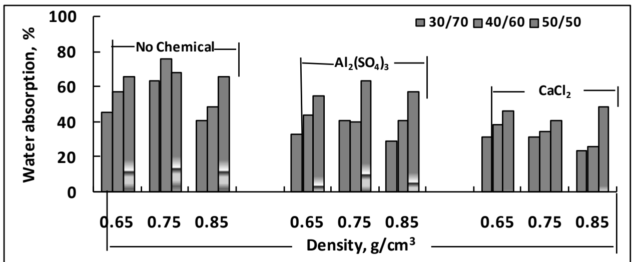


Fig. 21. WA of 12-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

For TS and WA, all sources of variation significantly affected both properties except for the interaction between chem*W/C on WA of the boards. DMRT (Table 42c) showed that the high TS values are not significantly different on boards with $Al_2(SO_4)_3$ & 50/50 W/C and $Al_2(SO_4)_3$ & 40/60 W/C.

Table 42. ANACOVA on the MOR, MOE, NHPT, TS and WA of *P. nodosa* (Blume) Seeman WWCB with a thickness of 12-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	584.25	17.74**	69199549.50	27.59**	3190.57	10.53**	30.848	11.21**	3439.27	82.92**
Chemical	2	566.49	17.20**	41878996.20	16.70**	4304.66	14.20**	95.86	34.84**	8360.98	201.57**
W/C	2	881.22	26.76**	6522555.30	2.60ns	7736.34	25.53**	19.08	6.94**	657.05	15.84**
chem*W/C	4	114.27	3.47**	12511009.20	4.99**	149.39	0.49ns	11.89	4.32**	58.99	1.42ns
Den	1	1915.09	58.16**	182047387.60	72.59**	3410.00	11.25**	5.25	1.91ns	9017.90	217.41**

CV = 26.448 (MOR) 25.7222 (MOE) 31.814 (NHPT) 38.276 (TS) 13.795 (WA)
R^2 = 0.560 (MOR) 0.665 (MOE) 0.431 (NHPT) 0.446 (TS) 0.856 (WA)

Table 42a. DMRT of the MOR of *P. nodosa* (Blume) Seeman WWCB with a thickness of 12-mm

Treatment		MOR
Chemical	Wo/Ce	
$CaCl_2$	50/50	28.79a
$Al_2(SO_4)_3$	50/50	28.03a
$CaCl_2$	40/60	26.34ab
None	50/50	24.69abc
$CaCl_2$	30/70	22.30 bcd
$Al_2(SO_4)_3$	40/60	20.25 cd
None	40/60	20.27 d
None	30/70	13.97 e
$Al_2(SO_4)_3$	30/70	10.58 e

Table 42b. DMRT of the MOE of *P. nodosa* (Blume) Seeman WWCB with a thickness of 12-mm

Treatment		MOE
Chemical	Wo/Ce	
$CaCl_2$	30/70	7783.57a
$CaCl_2$	40/60	7335.12ab
$Al_2(SO_4)_3$	50/50	6933.43abc
$Al_2(SO_4)_3$	40/60	6584.13 bc
$CaCl_2$	50/50	6506.20 bc
None	50/50	5806.92 cd
None	40/60	5337.29 de
None	30/70	4801.51 de
None	30/70	4324.73 e

Table 42c. DMRT of the TS of *P. nodosa* (Blume) Seeman WWCB with a thickness of 12-mm

Treatment		TS
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	6.762a
$Al_2(SO_4)_3$	40/60	6.008ab
None	40/60	4.895 bc
None	30/70	4.806 bc
None	50/50	4.537 c
$CaCl_2$	50/50	3.906 c
$Al_2(SO_4)_3$	30/70	3.867 c
$CaCl_2$	40/60	2.311 d
$CaCl_2$	30/70	1.918 d

Properties of 19-mm WWCB

The MOR, MOE, NHPT, TS and WA of *P. nodosa* WWCB with a thickness of 19-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 22, 23, 24, 25 and 26, respectively. Figs. 22 and 23 revealed that MOR and MOE of the boards were favorably affected by the addition of $CaCl_2$ and $Al_2(SO_4)_3$ compared to those with no chemicals although improvement was more distinct on boards with $CaCl_2$.

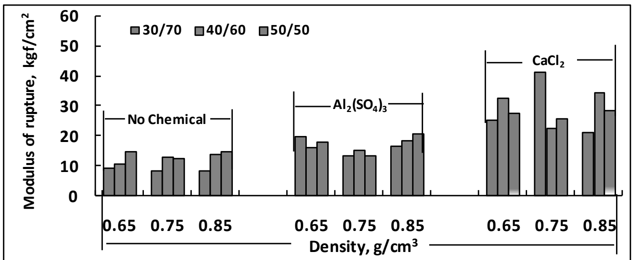


Fig. 22. MOR of 19-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

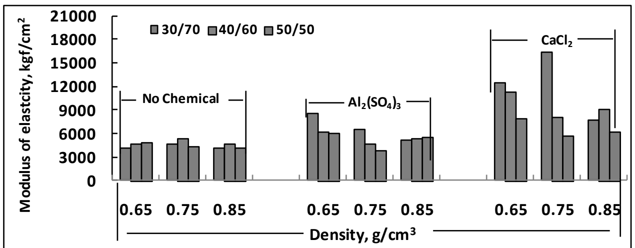


Fig 23. MOE of 19-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

There was no definite trend that MOR and MOE would increase as board density and the amount of wood are increased. Boards with $CaCl_2$ and W/C of 30/70 at 0.75 g/cm^3 exhibited the highest MOR and MOE values of 41.02 kgf/cm^2 and 16,338 kgf/cm^2, respectively. ANACOVA on Table 43 revealed that all sources of variation significantly affected both properties except for the interactions between chem*W/C and W/C on MOR and MOE, respectively. DMRT on Table 3a revealed that MOE values of the boards with $CaCl_2$ at three W/C ratios are not significantly different.

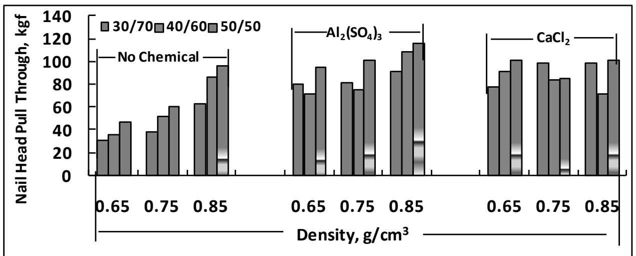


Fig 24. NHPT of 19-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

NHPT (Fig. 24) improved with the addition of $Al_2(SO_4)_3$ and $CaCl_2$ compared to boards without chemicals particularly at densities of 0.65 and 0.75 g/cm^3. The highest NHPT value of 117 kgf was exhibited by boards with $Al_2(SO_4)_3$ and W/C of 50/50 at 0.85 g/cm^3 density. ANACOVA on Table 2 showed that all sources of variation significantly affected NHPT except for the interaction between chem*W/C.

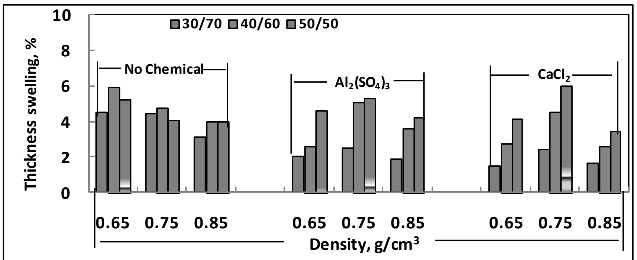


Fig. 25. TS of 19-mm *Polysias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Fig. 25 shows that the TS of the boards are lower than 6% at any manufacturing combination although there is no definite trend that this would improve with the addition of chemicals or increasing the amount of cement or increasing board density. ANACOVA on Table 3 shows that all sources of variation significantly affected TS. DMRT on Table 3b shows that TS of the first six treatment combination are not significantly different from each other.

Fig 26 shows that $CaCl_2$ favorably affected WA compared to boards without chemicals and on boards with $Al_2(SO_4)_3$. The lowest value of 20.6% was obtained from boards with $CaCl_2$ and 30/70 W/C at 0.65 g/cm^3 density while the highest was exhibited by boards without chemicals and with 40/60 W/C at 0.65 g/cm^3. ANACOVA on Table 43 revealed that all sources of variation had significant effect on WA. DMRT on Table 3b shows that WA values of the first six treatment combinations are not significantly different from each other.

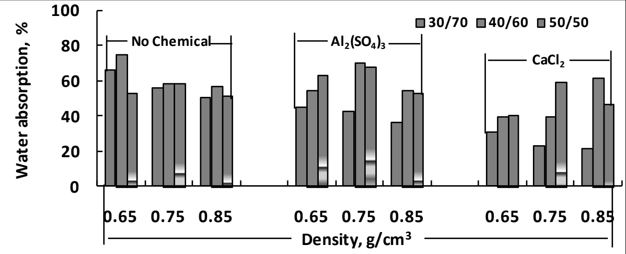


Fig. 26. WA of 19-mm *Polyscias Nodosa* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Table 43. ANACOVA on the MOR, MOE, NHPT, TS and WA of *P. nodosa* (Blume) Seeman WWCB with a thickness of 19-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	891.33	27.25**	117722150	35.95**	8020.89	16.74**	19.19	5.76**	2272.61	16.73**
Chemical	2	1250.69	38.24**	66369090.20	20.27**	9152.75	19.10**	14.67	4.40*	2380.63	17.52**
W/C	2	350.07	10.70**	2624604.80	0.80ns	11989.12	25.02**	41.30	12.39**	1615.29	11.89**
Chem*W/C	4	5.34	0.16ns	11596832.40	3.54**	807.30	1.68ns	8.42	2.53*	433.36	3.19*
Den	1	897.42	27.44**	219505506.30	67.03**	25186.44	52.55**	0.08	0.03ns	2658.44	19.56**

CV = 29.901 (MOR) 27.357 (MOE) 27.638 (NHPT) 46.935 (TS) 22.857 (WA)
R^2 = 0.662 (MOR) 0.721 (MOE) 0.546 (NHPT) 0.293 (TS) 0.546 (WA)

Table 43a. DMRT of the MOE of *P. nodosa* (Blume) Seeman WWCB with a thickness of 19-mm

Treatment		MOE
Chemical	Wo/Ce	
$CaCl_2$	30/70	9070.48a
$CaCl_2$	40/60	8058.74ab
$CaCl_2$	50/50	7742.61ab
$Al_2(SO_4)_3$	50/50	6718.10 bc
None	50/50	6329.76 cd
None	40/60	6021.65 cd
$Al_2(SO_4)_3$	40/60	5857.78 cd
$Al_2(SO_4)_3$	30/70	5198.70 de
None	30/70	4535.58 e

Table 43b. DMRT of the TS of *P. nodosa* (Blume) Seeman WWCB with a thickness of 19-mm

Treatment		TS
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	40/60	5.110a
None	40/60	4.872a
$Al_2(SO_4)_3$	50/50	4.714a
$CaCl_2$	50/50	4.524ab
None	50/50	4.415ab
None	30/70	4.014ab
$CaCl_2$	40/60	3.316 bc
$Al_2(SO_4)_3$	30/70	2..167 cd
$CaCl_2$	30/70	1.872 d

Table 43c. DMRT of the WA of *P. nodosa* (Blume) Seeman WWCB with a thickness of 19-mm

Treatment		WA
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	40/60	5.110a
None	40/60	4.872a
$Al_2(SO_4)_3$	50/50	4.714a
$CaCl_2$	50/50	4.524ab
None	50/50	4.415ab
None	30/70	4.014ab
$CaCl_2$	40/60	3.316 bc
$Al_2(SO_4)_3$	30/70	2..167 cd
$CaCl_2$	30/70	1.872 d

<u>*Alstonia macrophylla* G. Don</u>

Properties of 8-mm WWCB

The MOR, MOE, NHPT, TS and WA of *Alstonia macrophylla* G. Don WWCB with a thickness of 8-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 27, 28, 29, 30 and 31, respectively. The MOR and MOE of the boards as

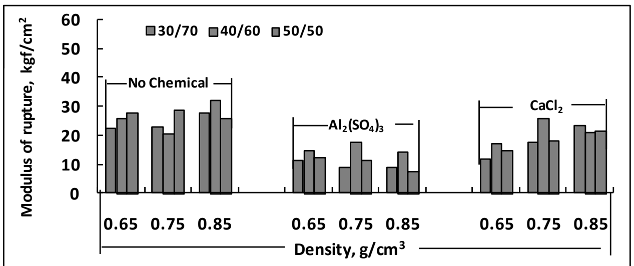


Fig. 27. MOR of 8-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

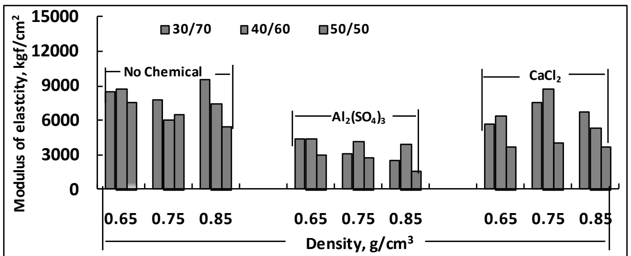


Fig 28. MOE of 8-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels

presented in Figs. 27 and 28, respectively, were adversely affected by the addition of $Al_2(SO_4)_3$ and $CaCl_2$. It can be speculated that the residual water soluble extractives still present in wood wool may have reacted with both chemicals in such a way that the hardening of cement was adversely affected. The effects of W/C and densities were overshadowed by the effects of chemicals. ANACOVA in Table 44 revealed that all sources of variation significantly affected the MOR except for the interaction between chem*W/C. The highest MOR value of 32.31 kgf/cm^2 was obtained from boards without chemicals and with W/C of 40/60 at 0.85 g/cm^3 density. On the other hand, MOE was affected only by the treatments and chemical.

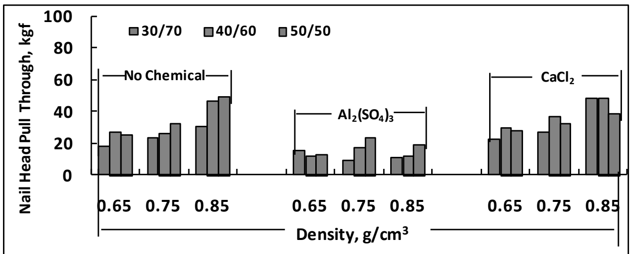


Fig 29. NHPT of 8-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) at three density levels.

In Fig. 29, it shows that there was a remarkable decrease in NHPT when $Al_2(SO_4)_3$ was used as cement setting accelerator while the addition of $CaCl_2$ imparted no improvement on NHPT. For boards with no chemicals, NHPT increased as board density and the amount of wood, i.e. 50/50 W/C, is increased. For boards with $CaCl_2$, more wood did not mean higher NHPT as manifested in the figure although the higher the density resulted to higher NHPT. The highest NHPT value of 48.90 kgf was exhibited by boards without chemicals and with W/C ratio of 50/50 and 0.85 g/cm^3. ANACOVA in Table 4 revealed that all sources of variation significantly affected the NHPT except for the interaction between chem*W/C.

TS of the boards (Fig. 30) improved with the addition of chemicals while WA (Fig. 31) was adversely affected by the addition of $Al_2(SO_4)_3$. The addition of $Al_2(SO_4)_3$ may have opened more avenues to absorb water thus accommodating more water which resulted to high WA. The effect of density may have been overshadowed by the effect of chemicals for TS. There is a general trend that WA becomes higher as the amount of wood is increased. With the result on WA, it is not advisable that $Al_2(SO_4)_3$ be added as cement setting accelerator when *A. macrophylla* is used as raw material for the production of cement bonded board.

ANACOVA on Table 4 shows that all sources of variation significantly affected TS and WA except for the interaction between chem*W/C. DMRT of the WA (Table 4a) revealed that the value at treatment combination of $Al_2(SO4)_3$ and 50/50 W/C is significantly different from the others.

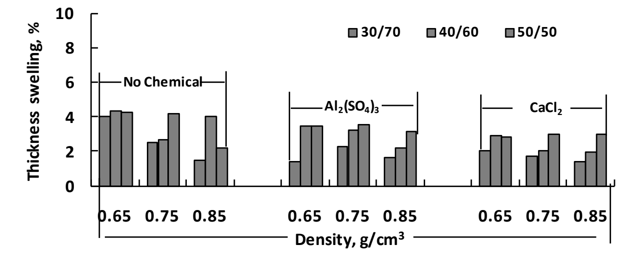


Fig. 30. TS of 8-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

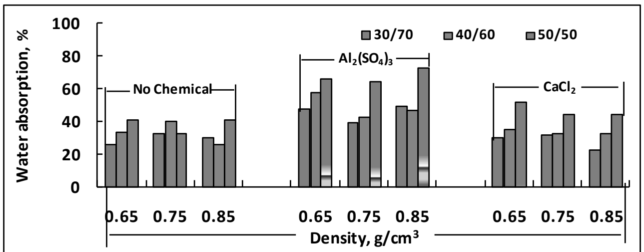


Fig. 31. WA of 8-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Table 44. ANACOVA on the MOR, MOE, NHPT, TS and WA of *A. macrophylla* WWCB with a thickness of 8-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	756.15	22.87**	77925988.20	38.22**	1638.23	13.06**	8.16	6.17**	2679.70	179.04**
Chemical	2	329.82	9.98**	25150530.20	12.33**	1712.46	13.65**	8.17	6.17**	696.13	46.51**
W/C	2	382.38	11.57**	2695414.70	1.32ns	1612.68	12.86**	23.76	17.94**	408.92	27.32**
Chem*W/C	4	29.07	0.88ns	3869476.40	1.90ns	115.98	0.92ns	1.09	0.82ns	201.89	13.49**
Den	1	1806.23	54.63**	164063976.20	80.46**	2615.17	20.85**	8.68	6.56*	4635.22	309.70**

CV = 30.248 (MOR) 25.830 (MOE) 41.657 (NHPT) 41.259 (TS) 9.357 (WA)

R^2 = 0.622 (MOR) 0.733 (MOE) 0.484 (NHPT) 0.307 (TS) 0.928 (WA)

Table 44a. DMRT of the WA of *A. macrophylla* WWCB with a thickness of 8-mm

Treatment		WA
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	53.114a
$Al_2(SO_4)_3$	40/60	46.115 b
$CaCl_2$	50/50	42.880 c
None	30/70	41.233 cd
None	50/50	40.606 cd
$Al_2(SO_4)_3$	30/70	39.929 d
None	40/60	39.317 d
$CaCl_2$	40/60	34.588 e
$CaCl_2$	30/70	34.303 e

Properties of 12-mm WWCB

The MOR, MOE, NHPT, TS and WA of *Alstonia macrophylla* G. Don WWCB with a thickness of 12-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 32, 33, 34, 35 and 36 respectively. Results revealed that addition of chemicals imparted no remarkable improvement on the MOR and MOE (Figs. 32 & 33) of the boards. The highest MOR of 38.32 kgf/cm^2 was obtained from boards with $CaCl_2$ and W/C of 50/50 at 0.75 g/cm^3 density while the highest MOE value of 12,332 kgf/cm^2 was exhibited by boards with no chemicals and W/C ratio of 30/70 at a density of 0.65 g/cm^3. For MOE, there is a general trend that MOE decreased as density and the amount of wood are increased. This is ironical because more wood should have higher MOE. In this case, the residual wood extractives that are present in boards with more wood wool may have adversely affected MOE. ANACOVA on Table 45 revealed that all sources of variation affected MOR and MOE except for the interaction between chem*W/C.

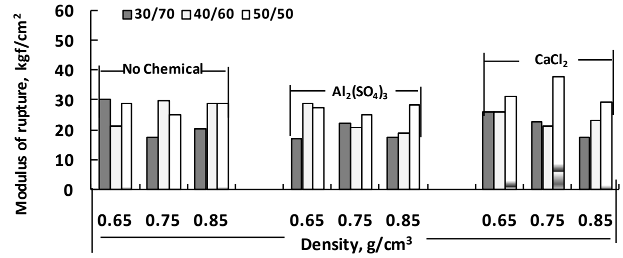


Fig. 32. MOR of 12-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels

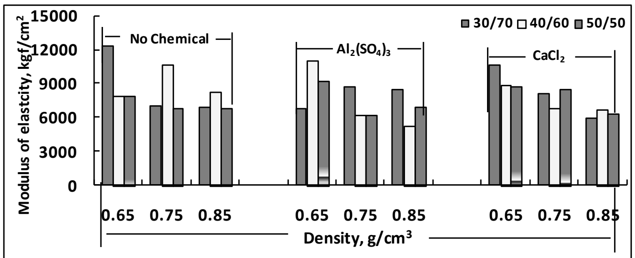


Fig 33. MOE of 12-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels

Fig. 34 shows that NHPT of boards with chemicals are lower than NHPT of boards with no chemicals implying that chemicals did not favorably affect NHPT. For boards with no chemicals and with $Al_2(SO_4)_3$, increasing the

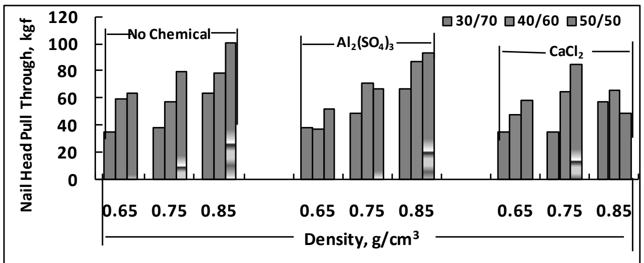


Fig. 34. NHPT of 12-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) at three density levels.

amount of wood resulted to an increased in NHPT at all density levels. The same trend was observed on boards with $CaCl_2$ except for boards with 0.85 g/cm^3 density. The highest NHPT value of 101.5 kgf was exhibited by boards with no chemicals and W/C of 50/50 at 0.85 g/cm^3. ANACOVA on Table 5 shows that the effect of chemical and the interactions between chem*W/C did not significantly affect NHPT.

TS of all the boards (Fig. 35) are encouraging considering that all values are lower than 6%. A slight improvement when $CaCl_2$ was added was observed with the lowest value of 1.07% that was obtained from boards with $CaCl_2$ and W/C of 30/70 at 0.85 g/cm^3 density. There is a general trend that TS increased as the amount of wood is increased for boards with chemicals but it seemed that density has no direct effect on TS. ANACOVA on Table 5 revealed that all sources of variation significantly affected TS. DMRT on Table 5a shows that the first five treatment combinations are not significantly different from each other.

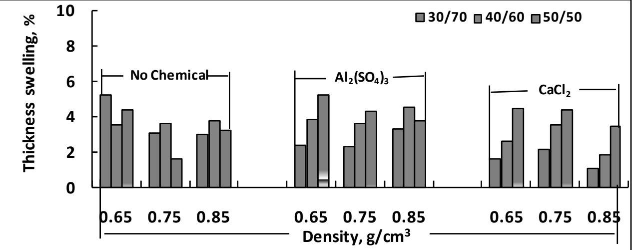


Fig. 35. TS of 12-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Fig. 36 shows that addition of chemicals adversely affected WA particularly on boards with $Al_2(SO_4)_3$. For boards with $CaCl_2$, there is a slight decrease in WA as density is increased but increasing the amount of wood did not result to higher WA. ANACOVA on Table 5 revealed that W/C and the interactions between chem*W/C did not significantly affect WA.

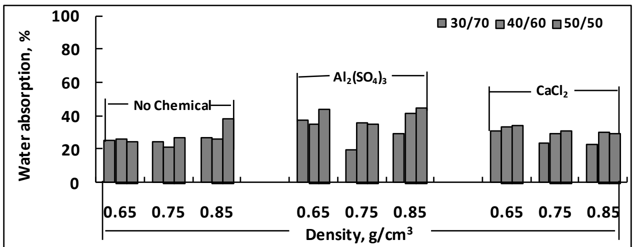


Fig. 36. WA of 12-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Table 45. ANACOVA on the MOR, MOE, NHPT, TS and WA of *A. macrophylla* WWCB with a thickness of 12-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	503.76	15.39**	38660884.00	9.19**	2515.46	5.54**	11.05	5.47**	932.80	10.25**
Chemical	2	337.98	10.32**	14607018.90	3.47*	626.80	1.38ns	10.23	5.07**	2476.15	27.21**
W/C	2	1708.62	52.18**	14188940.10	3.37*	9597.51	21.14**	13.62	6.74**	28.33	0.31ns
Chem*W/C	4	21.30	0.65ns	1310080.40	0.31ns	231.09	0.51ns	11.16	5.52**	8.99	0.10ns
Den	1	2442.66	74.60**	303399027.70	72.12*	3330.29	7.34**	0.00	0.00ns	4379.33	48.12**

CV = 22.915 (MOR) 25.851 (MOE) 31.814 (NHPT) 42.706 (TS) 31.049 (WA)
R^2 = 0.525 (MOR) 0.398 (MOE) 0.431 (NHPT) 0.282 (TS) 0.424 (WA)

Table 45a. DMRT of the TS of *A. macrophylla* WWCB with a thickness of 12-mm

Treatment		TS
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	4.451a
$CaCl_2$	50/50	4.122ab
$Al_2(SO_4)_3$	40/60	3.994ab
None	30/70	3.751ab
None	40/60	3.668abc
None	50/50	3.065 bc
$CaCl_2$	40/60	2.665 c
$Al_2(SO_4)_3$	30/70	2.659 c
$CaCl_2$	30/70	1.585 d

Properties of 19-mm WWCB

The MOR, MOE, NHPT, TS and WA of *Alstonia macrophylla* G. Don WWCB with a thickness of 19-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 37, 38, 39, 40 and 41 respectively.

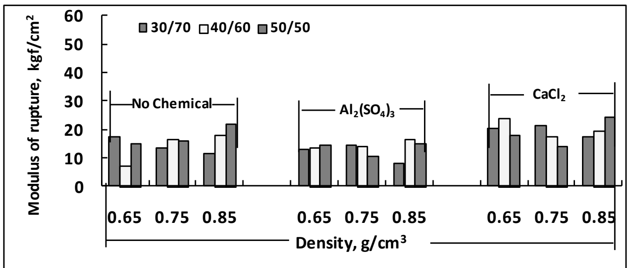


Fig. 37. MOR of 19-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Fig. 37 shows that MOR of the boards slightly decreased when $Al_2(SO_4)_3$ was added while improvement was observed with the addition of $CaCl_2$. For each set of board (with no chemical, with $Al_2(SO_4)_3$ and with $CaCl_2$), the effect of density and W/C was not clear. The highest MOR value of 24.38 kgf/cm^2 was exhibited by boards with $CaCl_2$ and W/C of 50/50 at 0.85 g/cm^3 while the lowest value of 7.51 kgf/cm^2 was on boards with no chemicals and W/C of 40/60 at 0.65 g/cm^3 density. ANACOVA on Table 46 shows that all sources of variation significantly affected the MOR except for the interaction between chem*W/C.

Similarly, MOE (Fig. 38) was adversely affected by the addition of $Al_2(SO_4)_3$ while $CaCl_2$ has a favorable effect particularly at 0.65 and 0.75 g/cm^3 densities and W/C ratios of 30/70 and 40/60. Surprisingly, boards with higher amount of wood, i.e. 50/50 W/C, exhibited low MOE compared to boards with low amount of wood, i.e. 30/70 W/C. The highest MOE value of 10,979 kgf/cm^2 was exhibited by boards with $CaCl_2$ and W/C of 40/60 at 0.65 g/cm^3. Unexpectedly, boards with a density of 0.85 g/cm^3 had lower MOE values. This is the same as the results obtained from 12 mm thick boards and for the same reason as stated. ANACOVA on Table 6 shows that W/C ratio and the interactions between chem*W/C did not significantly affect the MOE of the boards.

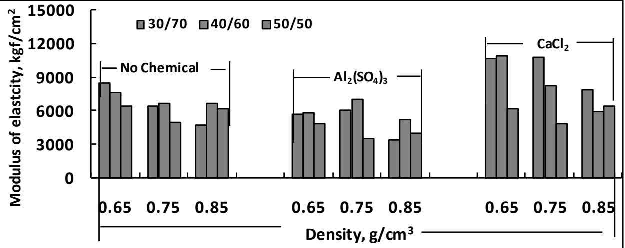


Fig 38. MOE of 19-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) and at three density levels

Fig. 39 shows that NHPT was adversely affected with the addition of $CaCl_2$. On the other hand, a slight reduction was observed on boards with $Al_2(SO_4)_3$ particularly at densities of 0.65 and 0.75 g/cm^3. The highest value of 138.5 kgf was obtained from boards with no chemicals and 50/50 W/C at 0.85 g/cm^3 density while the lowest value was exhibited by boards with $CaCl_2$. In this case, the same trend was observed like for 12 mm thick boards wherein NHPT increased as density and the amount of wood are increased except on boards with $CaCl_2$ although much higher values were obtained from the 19 mm thick boards indicating more resistance when nail is pulled. ANACOVA on Table 6 revealed that all sources of variation significantly affected NHPT. DMRT of the NHPT (Table 6a) showed that NHPT of boards without chemicals and with $Al_2(SO_4)_3$ both with W/C of 50/50 had no significant difference.

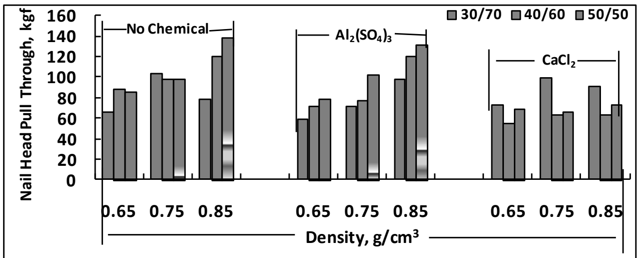


Fig. 39. NHPT of 19-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) at three density levels.

Fig. 40 shows encouraging results in general because all values are below 4%. Interestingly however, boards with no chemicals had lower values than those with

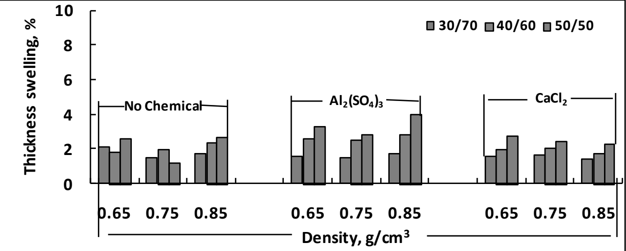


Fig. 40. TS of 19-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

$Al_2(SO_4)_3$. The lowest value of 1.21% was obtained from boards with no chemicals and W/C of 50/50 at 0.75 g/cm^3 density. ANACOVA on Table 46 revealed that all sources of variation significantly affected TS except for the density which is a covariate. DMRT of the TS on Table 6b indicates that TS of boards with $Al_2(SO_4)_3$ and W/C of 50/50 is significantly different from the succeeding values.

Fig. 41 shows the WA of the boards was adversely affected by $Al_2(SO_4)_3$. WA values that were obtained from boards with $CaCl_2$ slightly improved but depending on the

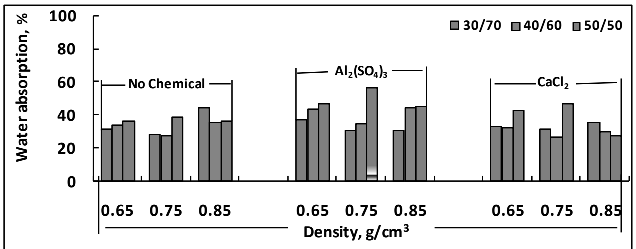


Fig. 41. WA of 19-mm *A. macrophylla* G. Don WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

material ratio and density. The highest value obtained was 56.55% with $Al_2(SO_4)_3$ while the lowest was 27.85% with no chemical. ANACOVA on Table 6 indicated that all sources of variation significantly affected WA. DMRT of the WA (Table 6c) showed a value similar to TS wherein boards with Al2$(SO_4)_3$ and W/C of 50/50 is significantly different from the succeeding values.

Table 46. ANACOVA on the MOR, MOE, NHPT, TS and WA of <u>*A. macrophylla*</u> WWCB with a thickness of 19-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	195.91	14.33**	53887460.30	23. 68**	5548.26	9.46**	4.73	11.61**	534.75	5.53**
Chemical	2	240.79	17.61**	55382540.40	24.33**	5959.57	10.16**	4.56	11.20**	624.21	6.45**
W/C	2	243.38	17.80**	4727809.70	2.08ns	9496.94	16.20**	11.86	29.13**	745.03	7.70**
Chem*W/C	4	3.00	0.22ns	5446580.00	2.30ns	1614.91	2.75*	2.01	4.96**	262.28	2.71*
Den	1	665.13	48.65**	132939953.10	58.41**	18539.84	31.62**	0.01	0.04ns	413.74	4.28*

CV = 22.391 (MOR) 23.109 (MOE) 27.882 (NHPT) 29.286 (TS) 26.812 (WA)
R^2 = 0.507 (MOR) 0.630 (MOE) 0.405 (NHPT) 0.455 (TS) 0.284 (WA)

Table 46a. DMRT of the NHPT of *A. macrophylla* WWCB with a thickness of 19-mm

Treatment		NHPT
Chemical	Wo/Ce	
None	50/50	119.520a
$Al_2(SO_4)_3$	50/50	119.225a
None	40/60	95.881 b
$Al_2(SO_4)_3$	40/60	90.923 b
$CaCl_2$	50/50	86.862 bc
$Al_2(SO_4)_3$	30/70	69.748 cd
$CaCl_2$	30/70	68.359 cd
None	40/60	65.705 cd
$CaCl_2$	40/60	65.405 d

Table 46b. DMRT of the TS of *A. macrophylla* WWCB with a thickness of 19-mm

Treatment		TS
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	3.395a
$Al_2(SO_4)_3$	40/60	2.668 b
$CaCl_2$	50/50	2.511 bc
None	50/50	2.159 cd
None	40/60	2.070 cd
$CaCl_2$	40/60	1.944 de
None	30/70	1.778 de
$Al_2(SO_4)_3$	30/70	1.580 e
$CaCl_2$	30/70	1.508 e

Table 46c. DMRT of the WA of *A. macrophylla* WWCB with a thickness of 19-mm

Treatment		WA
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	49.100a
$Al_2(SO_4)_3$	40/60	40.847 b
$CaCl_2$	50/50	38.705 bc
None	50/50	36.714 bcd
None	30/70	34.644 bcd
$CaCl_2$	30/70	34.422 bcd
$Al_2(SO_4)_3$	30/70	33.022 cd
None	30/70	32.615 cd
$CaCl_2$	40/60	30.040 d

Eucalyptus urophylla

Properties of 8-mm WWCB

The MOR, MOE, NHPT, TS and WA of *E. urophylla* WWCB with a thickness of 8-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 42, 43, 44, 45 and 46 respectively. Fig 42 and Fig. 43 shows that $Al_2(SO_4)_3$ adversely affected the MOR and MOE of the boards while $CaCl_2$ imparted an improved MOR and MOE. For boards with $CaCl_2$, results show that MOR increased as the amount of wood is increased at densities of 0.65 and 0.75 g/cm^3. It can be surmised that $Al_2(SO_4)_3$ disturbed the behavior of the boards in terms of MOR as there is no definite trend observed as to the effect of density and W/C ratio. For boards with $CaCl_2$, MOE increased as density is increased at 30/70 W/C ratio but a reverse trend was observed on boards with 50/50 W/C ratio. For boards with $Al_2(SO_4)_3$, MOE decreased as the density and the amount of wood are increased. The highest MOR of 24.30 kgf/cm^2 was obtained from boards with $CaCl_2$ and W/C of 50/50 at 0.75 g/cm^3 while 8,544 kgf/cm^2 for MOE with $CaCl_2$ and 30/70 W/C at 0.85 g/cm^3 density. ANACOVA in Table 47 shows that all sources of variation significantly affected MOR and MOE except for the interaction between chem*W/C. Results indicated that $CaCl_2$ imparted better MOE compared to those with no chemicals and with $Al_2(SO_4)_3$.

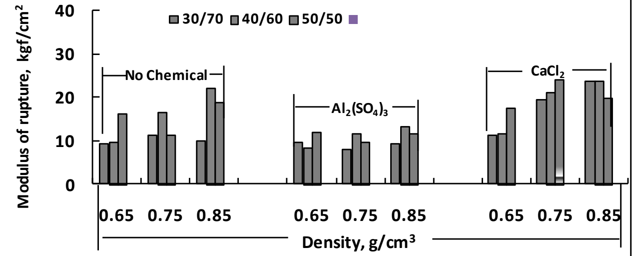


Fig. 42. MOR of 8-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

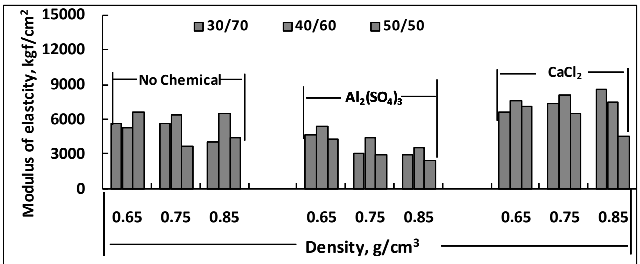


Fig. 43. MOE of 8-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

NHPT of the boards, like MOR and MOE, was favorably affected by $CaCl_2$ as shown in Fig. 44. The highest value of 50 kgf was obtained from boards with $CaCl_2$ and W/C of 50/50 at 0.85 g/cm^3 density. For boards with $CaCl_2$, it implies that NHPT is not only a function of density but of W/C which improved fiber to fiber contact. ANACOVA on Table 47 shows that all sources of variation have significant effect on NHPT. DMRT on Table 47a showed that NHPT values are not significantly different at treatment combinations of $CaCl_2$ * 50/50 WC; No chem * 50/50 W/C; and $CaCl_2$ * 40/60 W/C.

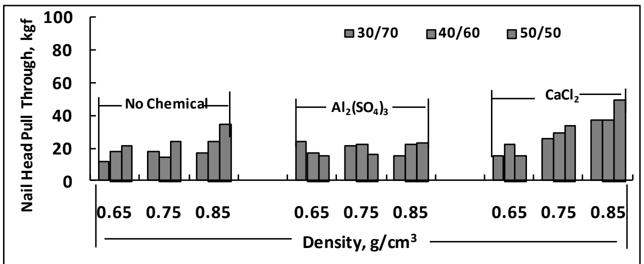


Fig. 44. Nail head pull through strength of 8-mm *E. Urophylla* as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) at three density levels.

Results of TS and WA (Figs. 45 and 46) show that $CaCl_2$ imparted better fiber-to-cement contact considering lowest values compared to boards with no chemicals. A slight improvement in TS was observed when $Al_2(SO_4)_2$ was added and there is an increasing trend as the amount of wood is increased for each density level. Boards with chemicals exhibited an increasing trend as the amount of wood is increased at each density level. There is no definite trend that WA would improve as the density is increased. Boards with $CaCl_2$ and 30/70 W/C at 0.85 g/cm^3 exhibited TS and WA of 1.28% and 23.41%, respectively. ANACOVA on Table 7 showed that TS and WA were significantly affected by the sources of variation except for the interaction of chem*W/C of TS. DMRT of the WA on Table 7b revealed that the value under treatment combination of $Al_2(SO_{4)3}$ and W/C of 50/50 is significantly different from other values with different treatment combinations.

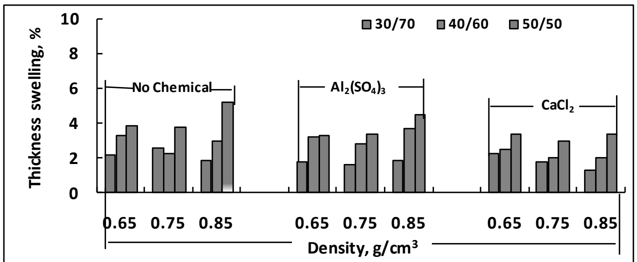


Fig. 45. TS of 8-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

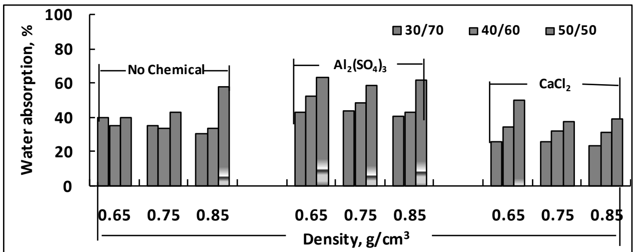


Fig. 46. WA of 8-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Table 47. ANACOVA on the MOR, MOE, NHPT, TS and WA of *E. urophylla* WWCB with a thickness of 8-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	391.75	15.55**	42609111.10	15.85**	854.44	11.03**	11.03	10.60**	1961.73	69.51**
Chemical	2	237.71	9.44**	39169038.70	14.57**	382.29	4.93**	5.25	5.05**	525.85	18.63**
W/C	2	455.31	18.08**	8145982.25	3.03*	1332.56	17.20**	29.18	28.05**	843.51	29.89**
Chem*W/C	4	38.01	1.51ns	1098463.25	0.41ns	319.78	4.13**	1.77	1.71ns	91.70	3.25*
Den	1	1312.14	52.09**	82754215.37	30.79**	3584.66	46.26**	0.64	0.62ns	3762.26	133.31**

CV = 34.485 (MOR) 30.203 (MOE) 37.738 (NHPT) 36.360 (TS) 12.977 (WA)
R^2 = 0.528 (MOR) 0.533 (MOE) 0.442 (NHPT) 0.432 (TS) 0.833 (WA)

Table 47a. DMRT of the NHPT of *E. urophylla* WWCB with a thickness of 8-mm

Treatment		NHPT
Chemical	Wo/Ce	
$CaCl_2$	50/50	33.696a
None	50/50	30.442ab
$CaCl_2$	40/60	27.485abc
$Al_2(SO_4)_3$	50/50	25.626 bc
$Al_2(SO_4)_3$	30/70	23.156 cd
$Al_2(SO_4)_3$	40/60	22.819 cd
None	40/60	16.849 de
$CaCl_2$	30/70	16.723 de
None	30/70	13.132 e

Table 47b. DMRT of the WA of *E. urophylla* WWCB with a thickness of 8-mm

Treatment		WA
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	51.805a
None	50/50	46.124 b
$Al_2(SO_4)_3$	40/60	44.036 bc
$CaCl_2$	50/50	40.895 cd
None	30/70	40.016 cde
None	40/60	39.008 de
$Al_2(SO_4)_3$	30/70	37.512 de
$CaCl_2$	40/60	36.814 e
$CaCl_2$	30/70	32.209 f

Properties of 12-mm WWCB

The MOR, MOE, NHPT, TS and WA of *E. urophylla* WWCB with a thickness of 12-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 47, 48, 49, 50 and 51, respectively. The MOR and MOE as shown in Figs. 47 and 48, respectively, remarkably improved when $CaCl_2$ was added compared to boards without chemicals. For each W/C ratio, MOR increased as density is increased. For each density level, all boards with W/C of 40/60 exhibited high MOR. $Al_2(SO_4)_3$ adversely affected MOR to the extent that some values are lower compared to boards with no chemicals. The maximum MOR value of 29.21 kgf/cm^2 was obtained from boards with $CaCl_2$ and W/C of 40/60 at 0.85 g/cm^3 density. The MOE of boards with no chemicals and with $CaCl_2$ shows a decreasing trend as the density is increased at all W/C ratios. This trend was not observed on boards with $Al_2(SO_4)_3$. ANACOVA on Table 8 shows that all sources of variation significantly affected MOR and MOE. DMRT on Table 8a revealed that treatment combinations of $CaCl_2$ with 40/60 W/C and $CaCl_2$ with 50/50 W/C resulted to MOR values that are not significantly different. The succeeding MOR values of the different treatment combinations are significantly different from the above as shown in Table 8a. DMRT of the MOE showed different results wherein all treatment combinations with $CaCl_2$ at three W/C ratios, and treatment combination of no chemical with 50/50 W/C resulted to values of no significant differences.

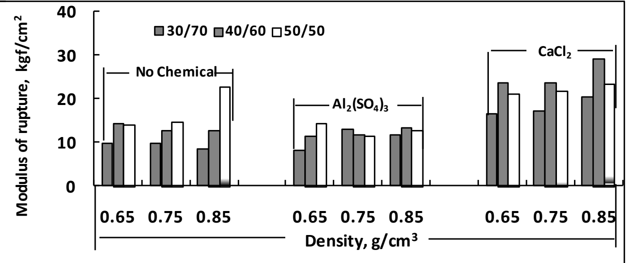


Fig. 47. MOR of 12-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

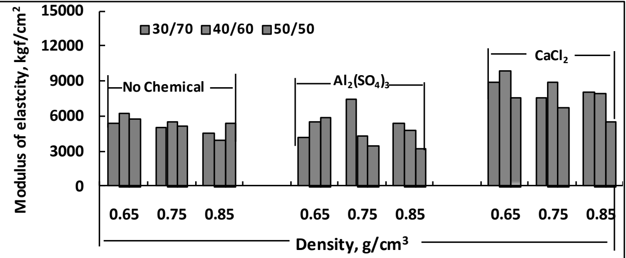


Fig. 48. MOE of 12-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

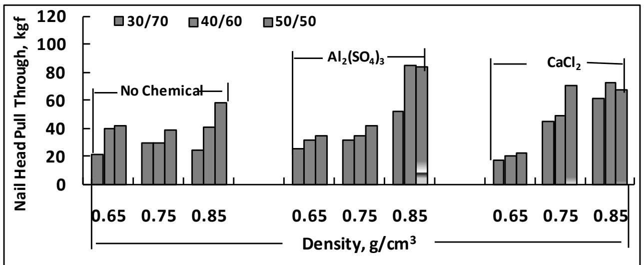


Fig. 49. Nail head pull through strength of 12-mm *E. Urophylla* as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) at three density levels.

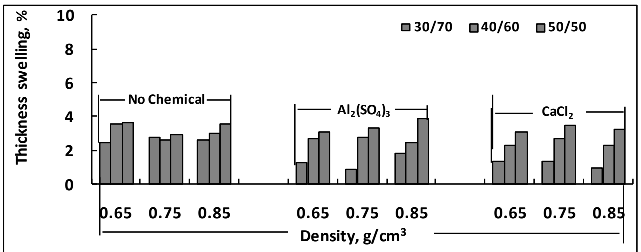


Fig. 50. TS of 12-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

NHPT in Fig. 49 showed that boards with $Al_2(SO_4)_3$ and W/C of 40/60 at 0.85 g/cm^3 density has the highest value of 72.50 kgf. NHPT of boards with chemicals increased as density is increased for all W/C ratios. Unexpectedly, the low NHPT values were obtained from boards with $CaCl_2$ at 0.65 g/cm^3 compared to boards with no chemicals and to boards with $Al_2(SO_4)_3$. ANACOVA on Table 48 revealed that except for the interaction between chem*W/C, all sources of variation had significant effect on NHPT. TS of the boards in Fig. 50 had encouraging result due to the very low values implying that the boards are dimensionally stable even when immersed in water for 24 hours. The highest value of 4.90% was exhibited by boards with $Al_2(SO_4)_3$ and W/C of 50/50 at 0.85 g/cm^3 density. All sources of variation had significant effect on TS as shown in Table 48 except for the density which is a covariate. DMRT of the TS (Table 48c) shows that all boards with 50/50 W/C had TS that are not significantly different including boards without chemical at 40/60 W/C.

Fig. 51 shows that WA of boards with $CaCl_2$ exhibited lower values compared to boards with $Al_2(SO_4)_3$ and boards with no chemicals. Boards that had the lowest WA value was produced with $CaCl_2$ and & 30/70 W/C at 0.65 g/cm^3 density. The highest value of 61.70% was from boards with $Al_2(SO_4)_3$ and W/C of 50/50 at 0.75 g/cm^3 density. All sources of variation had significant effect on WA as manifested in Table 8 (ANACOVA). WA values of boards with 50/50 W/C and $Al_2(SO_4)_3$ also with no chemical had no significant difference.

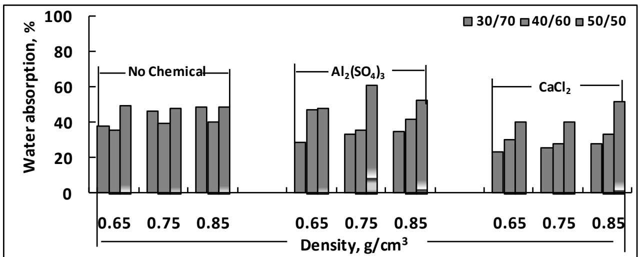


Fig. 51. WA of 12-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Table 48. ANACOVA on the MOR, MOE, NHPT, TS and WA of *E. urophylla* WWCB with a thickness of 12-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	509.22	33.85**	61171985.30	43.14**	1532.91	3.98**	9.47	11.37**	1679.57	167.20**
Chemical	2	648.57	43.11**	38220703.80	26.95**	1970.11	5.11**	6.27	7.53**	547.42	54.50**
W/C	2	678.03	45.07**	12911925.20	9.11**	4805.61	12.47**	24.34	29.20**	257.00	25.58**
Chem*W/C	4	47.40	3.15*	7683987.20	5.42**	146.29	0.38ns	2.14	2.57*	55.23	5.50**
Den	1	1048.70	69.70**	253955723.90	179.10**	2525.2	6.55*	0.17	0.21ns	5007.90	498.53**

CV = 24.636 (MOR) 19.697 (MOE) 45.172 (NHPT) 35.036 (TS) 7.906 (WA)
R^2 = 0.709 (MOR) 0.757 (MOE) 0.222 (NHPT) 0.450 (TS) 0.923 (WA)

Table 48a. DMRT of the MOR of *E. urophylla* WWCB with a thickness of 12-mm

Treatment		MOR
Chemical	Wo/Ce	
$CaCl_2$	40/60	22.957a
$CaCl_2$	50/50	22.364ab
None	50/50	19.684 bc
$Al_2(SO_4)_3$	50/50	17.049 cd
$CaCl_2$	30/70	15.876 de
None	40/60	13.645 e
$Al_2(SO_4)_3$	40/60	13.057 e
$Al_2(SO_4)_3$	30/70	8.594 f
None	30/70	8.467 f

Table 48b. DMRT of the MOE of *E. urophylla* WWCB with a thickness of 12-mm

Treatment		MOE
Chemical	Wo/Ce	
$CaCl_2$	40/60	7646.43a
$CaCl_2$	30/70	7058.56ab
$CaCl_2$	50/50	6769.23ab
None	50/50	6750.24ab
$Al_2(SO_4)_3$	50/50	6249.25 bc
None	40/60	5463.25 cd
$Al_2(SO_4)_3$	40/60	5343.89 d
None	30/70	4657.82 de
$Al_2(SO_4)_3$	30/70	4357.40 e

Table 48c. DMRT of the TS of *E. urophylla* WWCB with a thickness of 12-mm

Treatment		TS
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	3.484a
None	50/50	3.440a
$CaCl_2$	50/50	3.332a
None	40/60	3.057ab
$Al_2(SO_4)_3$	40/60	2.663 b
None	30/70	2.604 b
$CaCl_2$	40/60	2.425 b
$Al_2(SO_4)_3$	30/70	1.277 c
$CaCl_2$	30/70	1.170 c

Table 48d. DMRT of the WA of *E. urophylla* WWCB with a thickness of 12-mm

Treatment		WA
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	46.062a
None	50/50	43.851ab
None	30/70	43.343 b
None	40/60	40.944 c
$CaCl_2$	50/50	40.260 c
$Al_2(SO_4)_3$	40/60	39.731 c
$Al_2(SO_4)_3$	30/70	38.970 c
$CaCl_2$	40/60	34.814 d
$CaCl_2$	30/70	32.818 d

Properties of 19-mm WWCB

The MOR, MOE, NHPT, TS and WA of *E. urophylla* WWCB with a thickness of 19-mm as affected by chemical accelerator at W/C ratio of 30/70, 40/60, 50/50 and with densities of 0.65, 0.75, 0.85 g/cm^3 are presented in Figs. 52, 53, 54, 55 and 56 respectively.

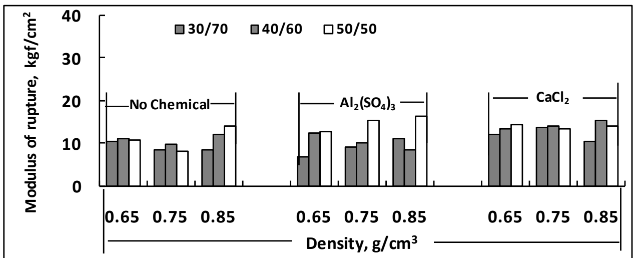


Fig. 52. MOR of 19-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

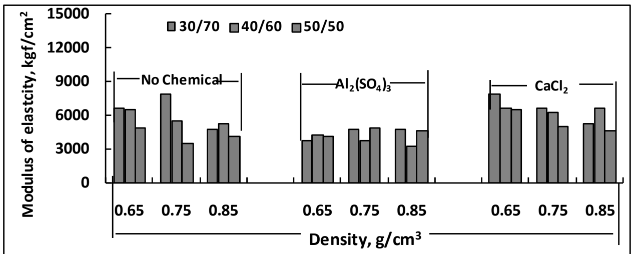


Fig. 53. MOE of 19-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

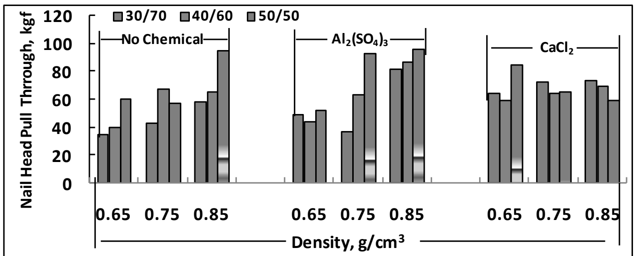


Fig 54. Nail head pull through strength of 19-mm *E. Urophylla* as affected by chemical accelerator and wood/cement ratio (30/70, 40/60, 50/50) at three density levels.

MOR in Fig. 52 slightly improved at 0.65 and 0.75 densities as affected by $Al_2(SO_4)_3$ whereas $CaCl_2$ imparted a favorable effect on MOR compared to boards with no chemicals. There is however no definite trend that MOR would increase as density is increased or as the amount of wood is increased. All MOR values obtained from this set of boards (19mm) are relatively low compared to MOR of boards with a thickness of 12mm implying that thickness is not factor in increasing MOR. Boards with $Al_2(SO_4)_3$ and 50/50 W/C had high values of 15.55 and 16.71 kgf/cm^2 at 0.75 and 0.85

g/cm^3 densities, respectively. All sources of variation had significant effect on MOR as manifested in Table 9 except for the interactions between chem*W/C. Fig. 53 indicated that the addition of $Al_2(SO_4)_3$ adversely affected the MOE compared to boards with no chemicals particularly at 0.65 and 0.75 g/cm^3 densities with 30/70 and 40/60 W/C ratios. On the other hand, $CaCl_2$ favorably affected the boards at all density levels and W/C ratios but with a decreasing trend as density and amount of wood are increased. ANACOVA in Table 9 indicated that all sources of variation, except for the W/C, had significant effect on MOE. The values of MOE on all boards with $CaCl_2$ and with three W/C had no significant difference as manifested in Table 49a.

The results of NHPT which are presented in Fig. 54 imply that better nail head resistance can be obtained from boards with W/C of 50/50 and $Al_2(SO_4)_3$ at 0.75 and 0.85 g/cm^3 densities as well as on boards with no chemicals at 50/50 W/C with 0.85 g/cm^3. All sources of variation had significant effect on NHPT as shown in Table 49. All boards with 50/50 W/C and with $Al_2(SO_4)_3$, $CaCl_2$ and with no chemicals had values that are not significantly different.

There is no definite trend that TS would increase or decrease with increasing density as shown in Fig. 55 but as manifested by the results, values are high on all boards with 50/50 W/C and with $Al_2(SO_4)_3$. Interestingly, $CaCl_2$ favorably affected TS with values as low as 0.63%, 0.82% and 0.86% at 0.65, 0.75 and 0.85 g/cm^3, respectively with 30/70 W/C. Almost the same values were obtained from boards with no chemicals at the same W/C ratios and densities. ANACOVA in Table 49 shows that all sources of variation had significant effect on TS except for the interaction between chem*W/C. Addition of chemical although significant was an adverse due to increase in TS.

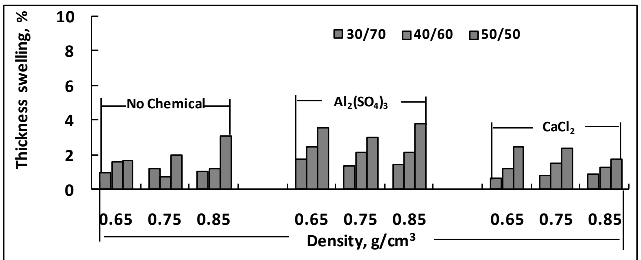


Fig. 55. TS of 19-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

As shown in Fig. 56., all boards with W/C of 50/50 exhibited high WA including some with 40/50 W/C indicating that *E. urophylla* absorbs much water even when used in cement bonded board. The same trend was obtained from the previous figures for 8-mm and 12-mm boards. The addition of chemicals did not improve WA as manifested in the figure. ANACOVA in Table 49 revealed that all sources of variation significantly affected WA except for the interaction between chem*W/C. Although the role of $Al_2(SO_4)_3$ and $CaCl_2$ are as cement accelerators, their effect is significant as manifested in Table 49.

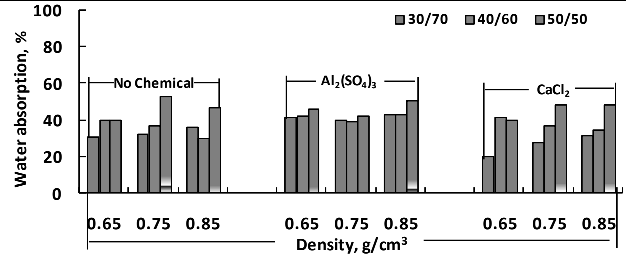


Fig. 56. WA of 19-mm *E. Urophylla* WWCB as affected by chemical accelerator at various wood/cement ratio (30/70, 40/60, 50/50) and at three density levels.

Table 49. ANACOVA on the MOR, MOE, NHPT, TS and WA of *E. urophylla* WWCB with a thickness of 19-mm

Source of variation	dF	MOR		MOE		NHPT		TS		WA	
		MS	F-value	MS	F-value	MS	F-value	MS	F-value	MS	F-value
Treatments	9	104.64	13.25**	29217649.50	29.88**	2139.11	6.97**	10.16	17.80**	1346.68	53.31**
Chemical	2	118.73	15.03**	39921352.60	40.82**	3071.04	10.01**	11.58	20.30**	354.60	14.04**
W/C	2	256.18	32.44**	1431796.40	1.46ns	6444.43	21.01**	16.62	29.12**	229.80	9.10**
Chem*W/C	4	17.30	2.19ns	2909303.80	2.98*	751.01	2.45*	1.21	2.13ns	15.67	0.62ns
Den	1	335.16	42.44**	120802586.60	123.53**	6154.27	20.07**	5.70	9.99**	6202.58	245.55**

CV = 23.687 (MOR) 18.642 (MOE) 27.108 (NHPT) 41.980 (TS) 12.742 (WA)
R^2 = 0.488 (MOR) 0.682 (MOE) 0.334 (NHPT) 0.561 (TS) 0.793 (WA)

Table 49a. DMRT of the MOE of *E. urophylla* WWCB with a thickness of 19-mm

Treatment		MOE
Chemical	Wo/Ce	
$CaCl_2$	40/60	6510.37a
$CaCl_2$	30/70	6124.95ab
$CaCl_2$	50/50	5949.06ab
None	40/60	5681.32 bc
None	30/70	5544.53 bcd
None	50/50	4977.52 cde
$Al_2(SO_4)_3$	50/50	4837.00 de
$Al_2(SO_4)_3$	40/60	4328.80 ef
$Al_2(SO_4)_3$	30/70	3787.45 f

Table 49b. DMRT of the NHPT of *E. urophylla* WWCB with a thickness of 19-mm

Treatment		NHPT
Chemical	Wo/Ce	
$Al_2(SO_4)_3$	50/50	88.371a
$CaCl_2$	50/50	76.365ab
None	50/50	75.386 bc
$CaCl_2$	40/60	67.754 bcd
$Al_2(SO_4)_3$	40/60	66.061 bcde
$CaCl_2$	30/70	62.425 cde
$Al_2(SO_4)_3$	30/70	57.551 de
None	40/60	53.243 e
None	30/70	34.274 f

4.5. Output 2.2. Determine equipment needs for production and manufacturing constraints.

-Activity 2.2.1. Review equipment availability.

Based on the products selected for use of SDL, this activity will focus on needs of the industry for handling and processing SDL with minimal impact on current operations. This was done with the cooperation and input of operating mills.

The urbanization reflect of society and the parallel trend from detached residential housing to more compact townhouses and condominium, the demand for sawn timber is increasing only slowly. Consumption is further depressed by substitution: the use of wood panels rather than timber. Improved construction methods have reduced the volume of timber. Whereas, there is a natural progression from solid wood through panel products, such as plywood, LVL, Glulam, particleboard, and fiberboard.

Research conducted by Simangunsong (2010) revealed that during the period 2002-2009, world's plywood production increased from 59.25 million m^3 in year 2002 to 78.20 million m^3 in year 2009, a 32% increase. In addition, world's plywood export quantity, import quantity, and price increased by 16%, 1%, and 41% over the period 2002-2009, respectively. World's veneer sheets production increased from 8.49 million m^3 in year 2002 to 12.06 million m^3 in year 2009, a 42% increase. World's veneer sheets export and import quantities decreased by 36% and 39%, respectively, whereas price sharply increased by 76% during the period 2002-2009. World's particleboard production significantly increased from

85.81 million m^3 in year 2002 to 93.95 million m^3 in year 2009, a 9% increase. Furthermore, World's fiberboard production increased from 41.00 million m^3 in year 2002 to 71.20 million m^3 in year 2009, a 74% increase. World's fiberboard export quantity, import quantity, and price increased by 31%, 9%, and 56% over the period 2002-2009, respectively.

The increasing in panel products world's demand accompanied with technological site, including the preparation of compatible equipment. In general, the wood industries in Indonesia had adequate equipment for producing panel products. However, 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 wood industries should adjust the equipment required.

Review on equipment availability of wood industries was done through field visit to plywood factories (PT. Andatu Lestari Plywood in Lampung, PT. SGS in Tanggerang, PT. Kayu Lapis Indonesia in Probolinggo, PT. Erna Djuliawati in West Kalimantan, PT Wijaya Tri Utami in South Kalimantan, and PT Sumalindo in East Kalimantan), Glulam and LVL factories (PT. Mayora Inkas Sukabumi, PT SGS in Tanggerang) , particleboard industry (PT. Paparti Pertama in Sukabumi), and MDF factories (PT. Sumalindo in East Kalimantan, PT. Masari Dwisepakat in Karawang).

1. Equipment for plywood production

Plywood is a structural panel that which have revolutionized the nature of light wood-frame construction. During the last sixty years, use of these panels has grown from limited applications to full domination of many building-material commodity markets such as sub-flooring, roof and wall sheathing, corner bracing, concrete forming, and others.

Plywood is manufactured by gluing together one or more veneers to both sides of a veneer or solid wood core (Walker 1993, Bowyer 2003, Maloney 1993). The grain of alternate layers is arranged to cross at right angles and the structure must be symmetric about the mid-point. Plywood production can be divided into three manufacturing staged; 1) veneer manufacture, 2) veneer drying and upgrading, and 3) panel lay-up and finishing.

a. Veneer manufacture

Logs delivered to panel mills are either processed immediately or inventoried for future use. To begin production, all logs are debarked (Fig. 97). Debarkers are utilized to remove the bark from logs or stems prior to peeling. There are basically two types of log debarkers: ring debarker, and drum debarker, but mostly debarking activity is done manually using a special tool (Fig. 98).

Figure 97. Log debarker activity in PT. Andatu Lestari

(a) (b)

Figure 98. Log debarker

(a) Conventional

(b) Machinery

a.1. Peeling Veneer.

Virtually all veneer in structural products is peeled on lathe. Rotary lathes are designed to produce continuous ribbons of green veneer that is subsequently clipped to recover usable veneer width (Bowyer 2003). The process is essentially one of cutting perpendicular to the grain with the knife lying parallel to the grain. The bolt is centered between two chucks on a lathe using lathe charger. Lathe charger is described having an improved charger spindle positioning system which is less vulnerable to damage, is of simpler construction and is of faster operation. The charger spindle positioning system includes spindle support and adjustment means for moving the spindles both horizontally and vertically by linear movement in one direction of linear positioning means at the opposite ends of the log (Fig. 99).

The linear positioning means are located above the log so as not to be damaged by a falling log. Each linear positioning means includes a pair of cylinders whose piston rods are pivotally attached to a spindle support plate on opposite sides of the spindle. A log support and centering means receives logs at a pick up position and transports such logs to a scan position after rough centering and clamping the logs with their longitudinal axis in such a scan position. The charger spindles engage the log in the scan position and rotate the log while it is scanned with a light beam to determine the optimum yield axis of the log for the greatest production of wood veneer. The charger spindles are then moved automatically by the linear positioner to move the log from the scan position until its optimum axis is aligned with a transfer position located at a predetermined position relative to the lathe axis. Transfer arms engage the log to move the log from the transfer position to the lathe where the optimum axis of the log is in alignment with the lathe spindle axis.

Figure 99. Rotary lathe

a.2. Veneer reeling and unreeling.

The unit comprises a rotatable reeling roll disposed in parallel to the grain of veneer sheet to be wound thereon, thread storage member which contains a winding of thread of a required length for supplying thread during reeling operation and re-collecting thread after operation, and thread guiding member which is adapted to guide thread supplied from the storage member so that the thread may be wound together with the veneer round the periphery of reeling roll in such a way that the former may guide and support the latter. The use of this unit in reeling device can make possible smooth reeling of veneer sheets of various shapes and widths.

a.3. Automatic stacker.

Both machines offer great speed and flexibility used in conjunction with the chain conveyor and chain take-off (Fig. 100).

Figure 100. Veneer stacker

a.4. Veneer Clipper.

Veneer Clipper machine is possible to cuts veneer sheets to specified size and cuts out defective sections. The ribbon of veneer passes from the lathe through manual or automated clipping machines which cut or 'clip' the veneer to size, or into smaller strips if defective material has been removed (Fig. 101).

Figure 101. Veneer clipper

a.5. Veneer Drying.

After peeling the veneer is far too wet to glue and needs to be dried. Historically veneer was dried down to 2-5% moisture content, but today target moisture contents have been raised to 6-12% and even 15% (Walker 1993). Many types of dryer have been used in structural veneer mills: forced air roller-restraint; platen heated by steam; and radio frequency (Sellers 1985 in Bowyer 2003). Continous dryer is mostly used for long continous veneer which is reeled from veneer cutting (Fig 102).

Figure 102. Continous dryer

a.6. Conveyor to veneer dryer.

Dryers used in manufacturing boards and panels such as veneer dryers employ roller conveyors to carry raw material through the dryer while it is exposed to forced hot air (Fig. 103). In a veneer dryer, for example, the powered rollers carrying the materials being dried is paired, one overlying the other so as to create a nip through which the material is conveyed. In conventional designs of veneer dryers and similar equipment, the rollers, shafts, bearings and sprockets are located in confined spaces. Sprocket driven roller shafts are ordinarily carried in carbon bearings and these bearings are in-board of the sprockets and roller chain.

Figure 103. Veneer conveyor

a.7. Veneer jointer.

This machine is used for jointing and gluing both veneer edges of single veneer strips, in one operation, continuously, clean and fast working (Fig. 104). Advantageous for rotary-cut veneer. 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.

Figure 104. Veneer jointer

a.8. Veneer splicer.

Veneer Splicer is designed to splice long length veneers, custom veneers or high end veneers which require no visible joint line. Traditional splicing requires taping or stitching joints which is more labor intensive and requires more sanding. Veneers with pre-glued edges are fed into the splicer which accurately carries them through upper and lower heating bars, firmly bonding the edges, to form a perfect seamless joint.

a.9. Sorting and Stacking.

Veneer sorting is done to separate the face/back veneer and core/crossband veneer. Sorting the veneer from the chain in a squence that matches normal veneer development makes the job easier and more efficient.

b. Panel Lay-up, Pressing, and Finishing

b.1. Resin application.

When the appropriate sections of veneer are assembled for a particular run of plywood, the process of gluing begins. This may be done manually or semi-automatically with machines (Fig. 105). In the simplest case of three-ply sheets, the back veneer is laid flat and is run through a glue spreader, which applies a layer of glue to the upper surface. The process of applying adhesives to veneer, assembling veneer into a plywood panel, and moving the panels in and out of the press often involved the most labor-intensive step in manufacture.

Figure 105. Glue spreader

b.2. Veneer assembly.

Veneer assembly is possible to achieve certain visual effects by the manner in which the leaves are arranged. Since rotary cut veneers are difficult to match, most matching is done with sliced veneer.

b.3. Cold press or pre-press.

Most plywood mills prepress batches of layed-up panels in a cold press (Fig. 10) prior to final pressing in the hot press. The purposes are to allow the wet adhesive to tack the veneer layer together.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.

Figure 106. Cold press

b.4. Hot press.

Hot pressing (Fig. 107) to cure the plywood glue lines are done in hydraulically powered and in the multiopening presses. The purpose of the press is to bring the layers of veneer tightly together and to heat the adhesive to the temperature required. 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.

Figure 107. Hot press

b.5. Finishing.

Finishing equipments are including: double sizer (Fig. 108), trimmer (Fig. 13), and double-belt sander (Fig. 14).

Figure 108. Double sizer

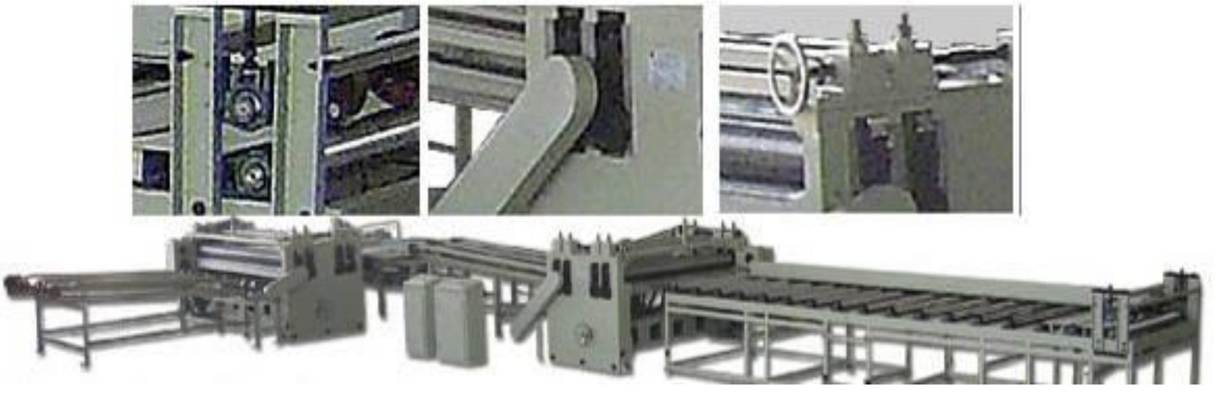


Figure 109. Trimmer

Figure 110. Double-belt sander

c. Special Consideration Related to Small Diameter Logs Processing

c.1. Veneer repairing

Veneer that resulted from small diameter logs are usually very low quality and small size. Therfore, veneer repairing is become importance division in plywood manufacturing.

There are various problems that can arise when working with wood veneer. It is very common to have to repair veneer at various stages of doing veneer work. Most of this repair is somewhat easy to fix however. Usually all it takes is some detailed hand work and patience.

c.2. Veneer defects prior to lamination

Veneer repairs that need to be performed before the veneer has been glued down to the substrate are easier to solve than after they have been glued down. A little preparation in each case will solve the problem.

c.3. Veneer defects after lamination

Veneer problems that arise after glue up can sometimes be very difficult to fix without going unnoticed. Most of the time the damage is due to exposure of water or extreme dryness, or physical impact.

2. Equipment for particleboard production

Particleboard offered a means to do so because it is so tolerant of wood quality and a wide variety of species. Moreover, the quality of lumber and plywood trend downward as we enter the era of small log, short-rotation forest management, the opportunity is open for particle-based products.

a. Particle preparation.

Most pulp and wood-panel mills debark their round wood in drum debarker. Breaker plates projecting slightly from the cylinder wall create turbulence and help to keep the bolt sliding against one another. The bark falling through the slots in the drum wall, it is collected and used as fuel.

A newer chipper design employs a steel disk with knives mounted upon it as the chipping mechanism. In this design, reversible hydraulically powered wheels draw the material from the hopper towards the disk, which is mounted on a perpendicular angle to the incoming material. As the disk spins, the knives cut the material into chips. They are thrown out the chute by flanges on the drum. This design is not as energy-efficient as the drum-style design, but produces chips of more uniform shape and size.

The equipments require for particle preparation are belt conveyor, drum-type chipper, flake silo, ring-type flakers, wet flake silo, air system for flake conveying.

b. Drying Section:

The equipment for particle drying are: Belt Conveyor, Rotor Dryer, Oscillating Screen, Belt Conveyor, Ring-type Mill, Air System for Flake Conveying, Silo for Core Flake, and Silo for Surface Flake.

Several different types of dryer are available. These include single and multiple-pass rotary drum, stationary drum, and tube-flash dryer. When there is a wide mixture of raw material as far as moisture content is concerned, it is advisable to treat the wet materials separately from the dry (Maloney 1993).

c. Glue Blending Section:

The next step is blending resin and wax with the furnish. Catalyst can be added with the resin or immediately after blending. The equipment needed for resin blending are: Surface Glue Blender, Core Glue Blender, Glue Regulating & Supplying System, Belt Conveyor, Swing Belt Conveyor.

d. Forming and Pre-pressing Section:

Classy-former, Continuous Pre-press Machine, Cross-cutting Saw, Longitudinal Saw, Synchronous Conveyor, Accelerating Conveyor, Pre-loading Machine.

e. Hot Pressing Section:

Loader, Hot press, Un-loader, Dry Board Belt Conveyor

f. Edge Sawing Section:

Feeding Roller Conveyor, Panel Turnover Machine, Discharging Roller Conveyor, Alongside Roller Conveyor, Longitudinal Edge Saw, Cross-feeding Conveyor, Transverse Edge saw, Roller Discharging Machine

g. Sanding Line:

Feeding & Discharging Roller Conveyor , Hydraulic Lift, Board Moving System, Sander, Air Conveying Dedusting System for Sanding Line.

3. Equipment for Glulam

Glued laminated timber, also called Glulam, is a type of structural timber product composed of several layers of dimensioned timber bonded together with durable, moisture-resistant adhesive. By laminating several smaller pieces of timber, a single large, strong, structural member is manufactured from smaller pieces. These structural members are used as vertical columns or horizontal beams, as well as curved, arched shapes. Individual lamina are generally between 19-38 mm thick.

Typically, glulam production is manually intense. First, lumber is machine stress rated and stored according to bending stiffness ad stress. Next, individual boards are end-jointed to form continuous, full length lamina. Following finger jointing, the individual lamina are proof tested and then face planed to remove any adhesive squeeze-out from the finger jointing process. Laminations are pressed together in moveable clamps anchored to a working floor (Bowyer 2003).

Typical equipments for glulam production are:

a. Band saw.

Band saw is a power tool which uses a blade consisting of a continuous band of metal with teeth along one edge to cut various work pieces. The band usually rides on two wheels rotating in the same plane, although some small bandsaws have three wheels. The saw is powered by electrical motor.

b. Circular saw.

Circular saw is a metal disc or blade sometimes with saw teeth on the edge as well as the machine that causes the disk to spin. It is a tool for cutting wood or other materials.

c. Lumber dryer.

Lumber dryer is to take moisture out of the air of an enclosed space containing lumber to be dried, thereby allowing the air to absorb more moisture from the lumber and subsequently speeding up the whole drying process.

d. Sander.

Sander is a power tool used to smooth wood and automotive or wood finishes by abrasion with sandpaper. Sanders have a means to attach the sandpaper and a mechanism to move it rapidly contained within a housing with means to hand-hold it or fix it to a workbench.Woodworking sanders are usually powered electrically, and those used in auto-body repair work by compressed air. There are many different types of sanders for different purposes. Multi-purpose power tools and electric drills may have sander attachments.

e. End jointer.

A jointer, also known as a planer or surface planer, and sometimes also as a buzzer or flat top, is a woodworking machine used to produce a flat surface along a board's length. End jointer is joining strip-end to strip-end.

f. Glue spreader.

A glue spreader can speed up production, improve quality and reduce adhesive consumption.

g. Clamping beds.

The laminations are then assembled into the required layup; after the adhesive is given the proper open assembly tie, pressure is applied. The most common method for applying pressure is with clamping beds; the pressure is applied with either a mechanical or hydraulic system.

4. Equipment for MDF production line

MDF is a panel product made primarily from wood fiber, and bonded with synthetic resin to a density of 500-800 kg/m^3. The technology for producing MDF has increased greatly in recent years. There are two main manufacturing processes; wet process and dry process MDF.

The first step in making MDF are similar to those employed in manufacturing hardboard. Logs and other raw materials such as plywood and furniture trims or sawmill cut-off blocks are initially reduced to chips. The chips are then refined as in thermo mechanical pulping. Thereafter, the process closely resembles particleboard manufacturing (Bowyer 2003, Walker 1993, and Maloney 1993)

a. Flakes processing production line

1. Chipper
2. Belt conveyor
3. Silo

b. Fiber processing production line

4. Heat milling machine
5. Pre-boiling vat
6. Fiber feeding machine
7. Gluing machine with weighting
8. Water-proof weighting device
9. Fiber outlet valve

c. Fiber drying production line

10. Hot wind generator
11. Main blower and motor
12. Drying pipe
13. Whirlwind separator
14. Dry wind control system
15. Fiber silo

d. Paving and shaping production line

16. Paving machine
17. Boards conveyor

18. Pre-presser
19. Plain machine
20. Board sawer
21. Edge trimming machine
22. Fiber recycle system
23. Support board callback system

e. Paving and shaping production line Board feeding machine

24. Hot presser
25. Board unloading machine
26. Board outlet machine

f. Surface processing production line

27. Horizontal sawer
28. Vertical sawer
29. Sander
30. Sands recycle system

-Activity 2.2.2. **Identify source and costs for equipment.**

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 anticipation of suitable equipment is needed. From all panel production process mentioned above, veneer production only has affected by this new raw material characteristics.

Identify sources and cost for equipment of wood industries was done by internet searching and field visit to plywood factories (PT. Andatu Lestari Plywood in Lampung, PT. SGS in Tanggerang, PT. Kayu Lapis Indonesia in Probolinggo, PT. Erna Djuliawati in West Kalimantan, PT. Wijaya Tri Utama in South Kalimantan, and PT Sumalindo in East Kalimantan), Glulam and LVL factories: PT. Mayora Inkas in Sukabumi, PT. SGS in Tangerang, particleboard industry: PT. Paparti Pertama in Sukabumi and MDF factories (PT. Sumalindo East Kalimantan, PT. Masari Dwisepakat in Karawang).

Spindle-less Lathe. This machine (Fig. 111) is one of the main equipments for plywood producer, It is mainly used to peel the round small wood or the remainder wood core which after being peeled by the machinery single-clamp-shaft veneer lathe, It can peel the wood core with the diameter less than 250 mm into the logs with different thickness, which raises the using wood efficiencies, It adopts advanced numerical frequently conversion technology, making its peeling precision almost equal to the machinery single-clamp-shaft veneer lathe.

Technological development to conventional veneer lathes have made the peeling of small logs economically viable. They include: automatic lathe chargers, and the use of telescopic.

Figure 111. Spindle-less lathe

Hot press dryer.(Figure 112) Veneer produced from small diameter log is dried by using hot press dryer. Drying systems have been considered which heat the surface of the veneer directly by using heated platen (Pease 1980 *in* Walker 2003). These consist of multiple daylight presses in which single veneers are placed on the lower plate of each daylight and the platen closed to keep the veneer flat during drying.

Figure 112. Hot-press dryer

The complete sources and cost for equipments are listed in Table 50.

Table 50. Sources and cost for equipment

No.	Equipment	Type	Country	Price (USD)
1	Log charger	Hongsing LG 9ft Hongsing LG 5ft	Taiwan Taiwan	34,600 32,800
2	Rotary lathe 9ft	BQK 1226/8E1 Uroko RB-9	China Japan	57,800 543,000
3	Rotary lathe 5ft	BXQS 1813A Uroko RB-5	China Japan	13,000 450,000
4	Auto clipper 9ft	BJ1326A	China	18,125
5	Auto clipper 5ft	BJG1313	China	52,000
6	Press dryer	BJG48-40-12	China	46,875
7	Roll dryer	BG1932 roll	China	125,076
8	Continuous dryer	BG1932 net	China	125,076
9	Longcore composser	HS-TVCW8	Taiwan	60,000
10	Back composser	HS-BVCW	Taiwan	63,000
11	Core composser	CL-CB4	Taiwan	55,800
12	Glue spreade	SDJ2700	China	16,989
13	Cold press	BY814X8/4c	China	30,625
14	Hot press	BY214X8/6-15	China	66,000
15	Sizer	DD.SAW ZHJ4	China	36,750
16	Sander	BSGR-R-P13	China	85,000
17	Spendle-less Rotary Lathe 9', consist of : - input conveyor - Lathe - output conveyor Lathe 9'	9HL-W-3-350	China Taiwan	 4,162 49,210 4,995 90,000

18	Spendle-less Rotary Lathe 5', consist of : - input conveyor - Lathe - output conveyor Lathe 5'	5HL-W-3-350	China Taiwan	 4,162 22,800 4,995 60,000

The production process of particleboard and MDF are not affected by the changing of wood characteristics as their raw material; 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. However, the wood industries that use veneer as their raw material, such as plywood and LVL, are affected by the changing of wood characteristics. Special equipment is needed for convert small diameter log to veneer. Spindle less lathe is a compatible machine for producing plywood or LVL from small diameter log. Furthermore, veneer produced from SDL is dried by using discontinue hot-press dryer and veneer repairing is more intensive because short veneer is more produced.

4.6. Output 2.3. **Address production coordination issues.**

-Activity 2.3.1. **Work with mills to identify issues when incorporating SDL into the production process.**

This activity will focus the issues with operational mills to products using material from SDL. This will help to identify how to handle incoming SDL, how to incorporate new equipment into the production stream and the issues that may limit use of SDL into current production.

Utilization of Small Diameter Logs (SDL) in composite industry becomes popular nowadays due to the very limited supply of large diameter logs from natural forest. In the previous technical reports it was written that several composite industries, especially plywood industries have spent a huge amount of money to prepare and adjust their machinery to process SDL. In the future, it was predicted that most of the composite industry raw materials coming from plantation forest, community forests and replanting of estates, will be classified as small diameter logs. Thus, in the future, SDL will become the basis of tomorrow's resource supply and the bio-composite industry must accommodate this kind of raw material. In this case, anticipating the potential problems which will arise if SDL are incorporated into production process is very important. The logs properties and quality should be considered are wood density, spiral and interlocked grains, knots, juvenile wood, decay and extractive content. Other aspects must be considered are technical aspect related to veneer and plywood production, especially in terms of logs storage, logs cutting, logs debarking, logs peeling or veneer production, veneer storage, veneer drying, veneer repairing, veneer joining, veneer arrangement or veneer composing, glue spreading, prepress, and other related aspects.

This study paid attention to SDL fulfilling log quality performance, and SDL for processing to produce veneer and plywood. The surveys were done in several plymills such as PT. Andatu Plywood Industry in Lampung – Sumatra, PT. Kutai Timber Indonesia in Ponorogo - East Java, PT. Erna Djuliawati in Sanggau - West Kalimantan, PT. Wijaya Tri Utama in Banjarmasin – South Kalimantan, PT. Sumalindo Lestari Jaya in Samarinda – East Kalimantan, PT. Paparti Pertama in Sukabumi – West Java, PT SGS in Balaraja Tangerang – West Java, and PT. Majora Inkas in Sukabumi – West Java.

Critical Issues When Incorporating SDL into the Production Process

The issues raised by plywood industries when incorporating SDL into the production process are related with log pond, log cutting (bucking), log debarking, rotary peeling, veneer drying, hot pressing, veneer jointing and the quality of the produced plywood. Detailed descriptions of the strategic issues are as follows.

1. Log pond; SDL need more space in log pond as compared to those of large diameter logs. (LDL) need more space for the same volume of wood. Simple calculation for this phenomenon is described in Figure 113.

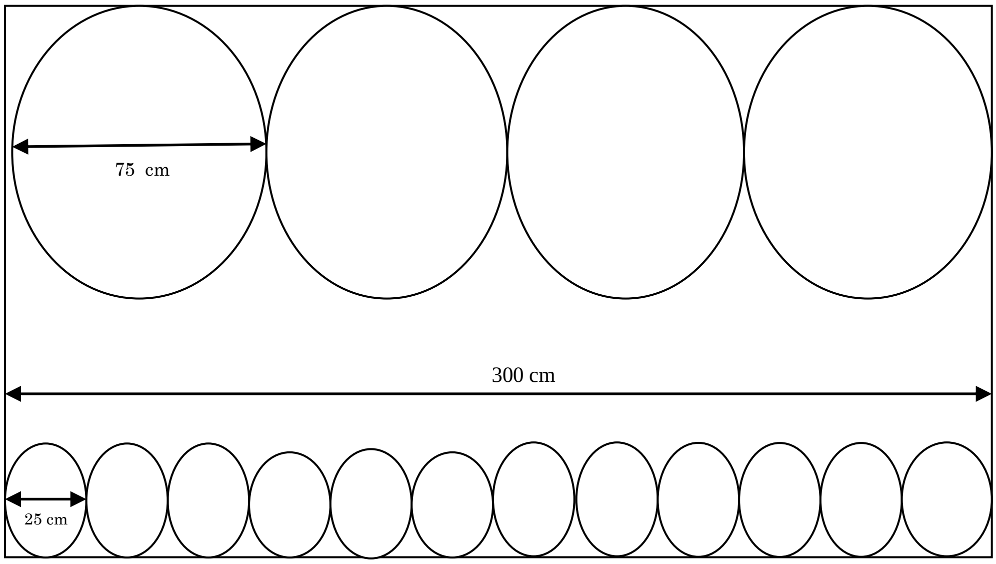


Figure 113. Comparison of space requirement between those of SDL and LDL

Calculation of SDL as compared to LDL based on the data described as shown in Figure 1 indicates that the ratio of SDL volume compared to those of LDL is 33.33%. The value varies based on the difference in diameter between SDL and LDL.

Beside the requirement of larger log pond space, SDL also creates difficult problem in log marking. SDL requires longer time in average for this work as compared to those of LDL because the person position should be in the water.

2. Log cutting (bucking) ; the total number of SDL is higher as compared to LDL for the same volume of wood. This make the productivity of log cutting (bucking) is lower when SDL are incorporated into plywood production, as compared to those of LDL. The productivity decrease by 35% as compared to those of LDL.
3. Log debarking; SDL debarking should use manual process, because the minimum log diameter for debarker machine is 55 cm. This means that incorporating SDL into plywood production needs more human resources for log debarking. This would not be a big problem for plywood industries in Indonesia, since there are so many qualified human resources available and ready to do the job.
4. Veneer production; SDL cannot be round up in the conventional rotary because the minimum diameter to be processed in conventional rotary is 40

cm. In plywood industries, SDL were round up in spindle-less rotary. The consequence is that processing of SDL needs more man power, time, transportation and new machinery such as spindle-less rotary. The veneer yield of SDL was lower, namely about 2.0% as compared to those of LDL. This was because the log core percentage, quantity of narrow veneer, knot content, and thin veneer portion were higher in SDL as compared to that of LDL. Moreover, at the same volume, the total number of SDL was higher as compared to those of LDL. This lead to decreasing rotary capacity by approximately 26%.

In some cases, combination of young wood (harvested from young tree) and low density of wood, needs extra handling process because the SDL tend to check or split if the moisture content decrease sharply, and they are easily attacked by blue stain. Utilization of plastic S nail proved to effectively control light check at log end. Other problems raised during the processing of SDL in plywood industry, are as follows:

a. Utilization of chuck spindle is ineffective if the SDL density is very low because the chuck spindle is boring and cannot spin the log.
b. The knife should be very sharp and knife changing frequency is doubled for certain species as compared to LDL.
c. Veneer thickness target is higher because the veneer shrinkage is higher. The impact of this is the diminishing veneer yield.
d. There are difficulties in producing veneers of less than 1.00 mm, because they tend to tear, and to be soft and fragile. If the production is successful, the veneers are difficult to be reeled and should be cut in wet condition.
e. In some species it is difficult to predict the density difference between sapwood and heartwood so the thickness variation of the product is higher.
f. They are easy to be attacked by mold. In some cases the wet veneer will be attacked by mold in 14 days. The veneer will decay, stick to each other and are easily broken. This phenomenon was found in veneer made from SDL of akasia, dadap, kemiri and karet (rubber) wood species.

g. Veneer quality resulting from SDL was lower as compared to those of LDL. This is because the knot content and narrow veneer portion are much higher as compared to those of LDL.
h. Plywood made from randu wood is not feasible for light construction because the density is very low and the Indonesian consumer refused the randu plywood.
i. Plywood produced from SDL is relatively lighter compared to those made from LDL.

5. Veneer drying; veneer resulted from SDL cannot be dried using conventional dryer because it tends to be wavy and the portion of narrow veneer was very high. The veneer resulted from SDL should use hot press dryer. This type of dryer needs more manpower and the risk of veneer being broken is higher as compared to those of conventional dryer. Moreover, the productivity of hot press dryer (0.45 m^3/hour) is very low as compared to those of roller dryer (11 m^3/hour). Several plywood industries reported that the veneer produced from SDL absorb moisture faster compared to those from LDL, and this phenomenon prevent veneer from SDL to be stocked after drying process.
6. Veneer Storage; In some cases, if the veneer production mush higher compared to those of use in plywood production process, veneer storage could be a problem because dried veneer easily attacked by mold due to the minimum extractive contain.
7. Veneer repairing; veneer resulted from SDL need repairing process with much more time and skilled human resources as compared to those of LDL veneer.
8. Veneer jointing; the capacity of veneer jointer decreased sharply when incorporating SDL into the production process because the portion of narrow veneer was very high as compared to those of LDL.
9. Veneer arrangement or veneer composing; veneer arrangement or veneer composing needs more time because so many jointing in one sheet veneer; moreover arrangement of face and back veneer should be conducted more carefully.

10. Glue spreading; glue spreading needs more time when incorporating SDL into the production process as compared to those of LDL, because glue spreading process need two times process for avoiding veneer being overlapped and detached and for avoiding core gap. The average number of veneer joints in one sheet veneer was 11 joints if the veneer was resulted from SDL, compared to 4 joints if the veneer was resulted from LDL.
11. Prepress; prepress should be arrange very carefully to adjust glue penetration and veneer overlap.
12. Materials requirement on the plywood industry increased sharply, especially glue tread, hot melt, gummed tape, cutter and knife. This is because the total number of jointer increased by about 300 %.

Table 51. Comparison of SDL and LDL as plywood raw materials

Description	Log Diameter			
	22.2	26.6	33.2	72.1
Yield (Log of 4 feet length)				
a. Log to green veneer	77%	79%	82%	86%
b. Log to dry veneer	72%	75%	78%	82%
c. Log to plywood	37%	40%	43%	55%
Capacity				
a. Rotary (m3/hour)				
b. Dryer (m3/hour)				
c. Jointer (pieces/hour)	62	90	130	200
d. Repair (pieces/hour)	40	50	67	80
Other				
Number of joint (8 feet length)	14	10	7	4

Source : Gani Sulaksono, 2010.

13. Human Resources Development; In several plywood industries which were use small diameter logs as plywood raw material classified as more labor intensive compared to those of using large diameter logs. Moreover, their productivity were lower, repairing and composing veneers were very intensive, requires special treatment in several production process especially in logs management (storage, grouping, debarking), veneering, drying, veneer

repairing, cold and hot pressing. In a cruel process such as veneer production and veneer drying it requires skill improvement on plywood industry human resources.

4.7. Output 2.4. **Mitigate potential trade barriers.**

***-Activity 2.4.1 and 2.4.2.* Identify standards for selected products and markets, to ensure compliance and appropriate test were conducted.**

No products can compete on the global market unless they adhere to establish, accepted regional or international standards. This is particularly true of bio-composite products. Depending on the products and markets identified, appropriate standards will be identified for purposes of ensuring compliance with the standards. Standards may include quality control on the manufactures product or performance requirements for the products.

Trade barriers should not be imposed on the SDL that are manufactured from lesser used species or thinning of forest plantation species. In fact, the use of these discarded species is considered as environmentally process and should be encouraged. To ensure acceptance of the products will be coordinated with physical and mechanical test of the prototype products. Obviously numerous test can be conducted on a product. This step will ensure that only the relevant test will be conducted; i.e. those test which are necessary to demonstrate compliance with regional or international standards.

In international trade, there are several standards known for bio-composite products such as plywood, LVL, glulam, particleboard and MDF. Among the international standard being used by Indonesian bio-composite industries are Japan Standard (JPIC/JAS), British Standard (BS), United States Standard (IHPA), German Standard (DIN), etc. Each country has different measurement, water content, veneer condition, etc Generally, Indonesian produces and exports the bio-composite products according to standard determined by the buyer (importing country).

1. Plywood

Plywood is a type of engineered board made from thin sheets of wood, called plies or wood veneers. The layers are glued together, each with its grain at right angles to adjacent layers for greater strength. There are usually an odd number of plies, as the symmetry makes the board less prone to warp, and the grain on the outside surfaces runs in the same direction. The plies are bonded under heat and pressure with strong adhesives, usually phenol formaldehyde resin, making plywood a type of composite material. Plywood is sometimes called the original engineered wood.

A common reason for using plywood instead of plain wood is the resistance of cracking, shrinkage, twisting, warping, and its general high degree of strength. In addition, plywood can be manufactured in sheets far wider than the trees from which it was made. It has replaced many dimensional lumbers on construction applications for these reasons.

A vast number of varieties of plywood exist for different applications. Softwood plywood is usually made either of pine or fir, and typically used for construction and industrial purposes. Hardwood is used for some demand end use. Hardwood plywood is characterized by its excellent strength, stiffness and resistance to creep. It has a high planar shear strength and impact resistance, which make it especially suitable for heavy-duty floor and wall structures. Oriented plywood construction has a high wheel carrying capacity. Hardwood has excellent surface hardness, damage and wear resistance.

Decorative plywood is usually faced with hardwood, including red oak, birch, maple, lauan, meranti, mahogany, and a large number of other hardwoods. Plywood for indoor furniture generally uses the less expensive urea-formaldehyde glue which has limited water resistance, while outdoor and marine grade plywood are designed to withstand rot, and use a water resistant phenol-formaldehyde glue to prevent delamination and to retain strength in high humidity.

The most common varieties of plywood come in three, five or seven plies with a metric dimension of 1.2 m x 2.4 m or the slightly larger imperial dimension of 4 feet x 8 feet. Plies vary in thickness from 1/10” through 1/6” depending on the panel thickness. Roofing can use the thinner 5/8 inch plywood. Sub-floors are at least ¾ inch depends on the distance between floor joists. Plywood for flooring applications is often longer and grooved. High-strength plywood, known as aircraft plywood, is made from mahogany and/or birch, and uses adhesives with increased resistance to heat and humidity. Marine plywood is specially treated to resist rotting in high moisture environment. Marine plywood is frequently used in the construction of docks and boats. Other types of plywood are fire retardant, moisture resistant, sign grade, pressure treated, and of course that hardwood and softwood plywood. Each of these products are designed to fill a need in industry.

Advantages of plywood are, among others high uniform strength; freedom from shrinking, swelling, and warping; non-splitting qualities; availability of relatively large sizes; economical and effective utilization of figured wood; ease of fabrication of curved surfaces; reduction of waste, and weight reduction.

In international trade, there are several standards known for plywood, among others: Japan Standard (JPIC/JAS), British Standard (BS), United States Standard (IHPA), German Standard (DIN), etc. Each country has different measurement, water content, veneer condition, etc. Generally, Indonesian produces and exports the plywood according to standard determined by the buyer (importing country). According to field survey results, all of the visited plywood industries have been using JAS 233 for plywood to control their plywood quality.

Most of plywood industry in Indonesia very familiar with Japanese Standard for plywood because all of plywood exported to Japan should fulfill JAS (Japanese Agricultural Standard) No 232, 2003 for plywood. JAS was developed by Japan's Ministry of Agriculture, Forestries, and Fisheries (MAFF). According to JAS, plywood is divided into four broad categories, and products of each category passing the standards are accompanied by a JAS label:

- A. "Structural plywood" : Used in applications where innate strength and resistance to environmental conditions are crucial.

A JAS Structural Plywood Stamp

- B. "Ordinary plywood" : used in applications which may be subjected to some, but not continuous, moisture; normally found used for interior underlayments.

A JAS Ordinary Plywood Label

- C. "Concrete-form plywood" : designed for use (obviously) in making concrete formwork

A JAS Coated Concrete Form Stamp

- D. "Cosmetic veneers" and "special-process veneers" : plywood with attractive surfaces, for use in finish applications where water resistance isn't normally a critical issue.

JAS Special Process Cosmetic Plywood Stamp

The stamps for these plywood types are similar, although there are subtle differences, such as the diamond-shaped outline for "ordinary plywood," and the different circle styles. Structural plywood often has a circular JAS imprint accompanied by a rectangular box holding detailed information about the product. In addition, there is considerable leeway in the amount of information that manufacturers include in their stamps—and the style in which they display that data. For example, here is a sampling of labels for concrete-form plywood, provided by the Japan Plywood Manufacturers Association:

1.a. Structural plywood

As noted above, "structural plywood" is designed for applications where inherent strength and glue longevity are foremost concerns, namely places like load-bearing walls and underlayments for floors and roofs. Standard thicknesses available include 9 mm, 12 mm, 15 mm, 24 mm and 28 mm. The latter two thicknesses are said to be increasingly used in "rigid floor" designs that help reduce the number of floor joists required.

The three important qualities noted on the JAS stamp include Bonding Properties (water-resistance), Strength, and Surface Quality.

Bonding or Adhesive Properties (water-resistance): Superior, Type 1.

Structural plywood is meant for use in architectural applications where structural integrity is paramount, so the glues used are directly related to the longevity of the overall structure and require greater adhesive (bonding) performance than those for other plywood. At JAS, the bonding properties of structural plywood are rated either as "Superior type" or "Type 1", may be abbreviated as T1).

Structural plywood rated as "Superior type" is designed for use outdoors or in other environments exposed to constant moisture, and typically uses phenol resin or better glues. Plywood rated as "Type 1" is designed to withstand intermittent exposure to moisture, and typically uses melamine-modified urea formaldehyde resin (MUF) or better glues. It's important to note, however, that in actual use, even "superior"-rated structural plywood must be finished with some kind of preservative stain or paint if they are to be exposed to continuous sun and rain. While the glue itself may not fail, the wood plies can and will decompose without proper finishing.

Strength: Class 1, Class 2

While the adhesive properties of plywood give a good indication of its performance in response to environmental conditions, structural plywood is also classified for innate strength as either "Class 1" or "Class 2".

"Class 1" structural plywood is subjected to rigorous performance tests for qualities like flexure and in-plane shear, while "Class 2" plywood simply isn't subjected to those tests. Several online sources emphasize, however, that even Class 2 structural plywood has innately superior characteristics in these performance areas compared to ordinary plywood (generally better glue and more plies), so Class 2 is typically found used in applications like exterior wall sheathing, subflooring, and roof underlayment, while Class 1 is reserved for other more critical applications.

Surface Quality: Grades A, B, C, D

In addition to bonding properties and innate strength, Structural Plywood is rated for surface quality, utilizing alphabetical designations Grade A to D. Grade "A" plywood should be smooth without knots, while Grade "D" may have substantial and large knots, gaps, and an overall rougher finish appearance. The JAS stamp normally displays two alphabetical designations (e.g., "C-D"), in which case the first refers to the "front" (better) surface, and the second refers to the obverse side. On reflection, however, architectural substructure materials (subfloor, wall sheathing, roof sheathing) don't depend on a nice exterior appearance for their performance, so Grade C-D is said to be most commonly used in these applications. Some examples of stamps found on structural plywood as describe by next figure.

JAS Structural Plywood 12mm

JAS Structural Plywood 24mm

JAS Class 1 Structural Plywood 12mm

1.b. Ordinary Plywood

Ordinary plywood is constructed in the same way as other plywood in the sense that it is composed of multiple layers of veneers (plies) glued together in alternating orientations, but it is not designed to demonstrate the same strength as structural plywood. According to JAS definitions, "ordinary" plywood is what you have left over when you take away concrete-form plywood, structural plywood, natural wood cosmetic veneers, and special-process cosmetic veneers. As a result, it is not subject to JAS regulations for "structural plywood" or "concrete form plywood."

Bonding Properties (water-resistance): Type 1 (T1) or Type 2 (T2)

Since ordinary plywood isn't designed to be used outdoors or in other conditions exposed to constant moisture, no "Superior type" rating is available.

Type 1 is meant mainly for use in concrete form plywood and other plywood to be used in intermittently wet places (environments). I've read that melamine-modified urea formaldehyde resin (MUF) or better glues are ordinarily used.

Type 2 can be used in places (environments) exposed to occasional moisture, but this basically means indoors—and not in bathrooms or kitchens.

Surface Quality: Grade A, B, C, D, or Grade 1, 2

Similar to structural plywood, ordinary plywood is rated for surface quality, but there is a difference in the designations. While all structural plywood is graded as A, B, C, or D, ordinary plywood uses two grading notations, depending on whether the plywood is made from softwood (coniferous) or hardwood (broadleaf) trees. Coniferous plywood is graded as A, B, C, or D, but hardwood plywood is graded as Grade 1 or Grade 2. Plywood made from coniferous softwoods will normally have a dual rating, such as "B-C" which indicates the surface quality of the two sides. This difference from structural plywood is once again likely due to the assumed roles the plywood is to play: structural plywood is meant for applications where the function, not the form, is important. In contrast, ordinary plywood may be used for applications where visual surface quality is more important.

JAS Ordinary Plywood 3mm

JAS Ordinary Plywood 4.8 mm

1. c. Concrete-form plywood

As the name suggests, "concrete form plywood" is a category of plywood designed for use in making concrete formwork. Most of this kind of plywood is made from one of the so-called "lauan" tropical hardwood, radiata pine and other coniferous woods. Aside from its availability, a reason for prefering lauan is because it has few knots, making for plywood with naturally smoother finish.

Important ratings for concrete form plywood include surface quality, bond strength, and flexure strength (not discussed here). Concrete form plywood can be made in various standard thicknesses (numbers I've seen include 12, 15, 18, 21, and 24 mm), but I think all the actual *konpane* I've seen in home centers and lumber yards has been 12 mm.

Bonding or Adhesive Properties (water-resistance) : Type 1 (T1)

All JAS concrete form plywood is rated for bonding qualities equivalent to Type 1 ordinary plywood. Due to this uniform standard, it is considered unnecessary to display the specific adhesive type, and that information is normally omitted in the stamp. Although not as strong as the "superior" type available with "structural plywood", the glues (melamine-modified urea formaldehyde resin [MUF] or better) used in concrete form plywood are still considered strong, outdoor grade and should last many years under adverse conditions, particularly if the plywood is painted or finished with a preservative stain.

Surface Quality: Grades A, B, C, D

The surface quality of concrete form plywood is rated in descending order as A, B, C, or D, often—but not always—with a two-letter designation (e.g., "B-C") indicating the front and rear sides of the panel.

Examples of stamps:

JAS Concrete Form Plywood 12mm

JAS Coated Concrete Form Plywood 12 mm

1.d. Natural-Wood Cosmetic Veneer and Special-Process Cosmetic Veneer

These are basically sheets of "ordinary plywood" a few millimeters in thickness, factory applied with a variety of attractive surface veneers or coatings for use in finish applications. Natural-wood cosmetic veneers have a surface ply (or plies) of attractively grained natural wood, while special-process plywoods (also called secondary-process plywood) is ordinary plywood with a factory-applied artificial cosmetic finish coating, either paint, imprinting, or overlay.

Bond Properties (water-resistance): Type 1 (T1) or Type 2 (T2)

These ratings are the same as for ordinary plywood, namely, Type 1 or Type 2. Those commonly found in home centers are typically the cheaper Type 2 (T2).

Sub-Ratings for Surface Quality:

F Type ("Flat"): special-process cosmetic-veneer plywood supplied mainly for uses in tabletops and counters.

FW Type ("Flat, Wall"): special-process cosmetic veneer plywood supplied mainly for uses in architectural structures as surfaces for load-bearing walls, and also for furniture.

W Type (Wall): special-process cosmetic veneer plywood supplied mainly for uses in architectural structures as surfaces for ordinary walls

SW Type ("Special Wall"): special-process cosmetic veneer plywood supplied mainly for uses in architectural structures as surfaces for "special walls".

Formaldehyde Emissions

In relation to plywood, the current standards utilize a four-star system of ratings (F☆☆☆☆ to F☆ in ascending levels of formaldehyde emissions) that make it easy to see at a glance what the level of emissions are (in terms of safety, the more stars the better). This star system is included in the JAS plywood rating stamp, and is interpreted as follows:

Formaldehyde Emission Values (mg/L)

Rating category	Average Value	Max. Value
F☆☆☆☆	0.3 mg/L	0.4 mg/L
F☆☆☆	0.5 mg/L	0.7 mg/L
F☆☆	1.5 mg/L	2.1 mg/L
F☆	5.0mg/L	7.0 mg/L

NOTES:

1. Restrictions are now placed on the amount of products with F☆☆☆ or higher formaldehyde emissions that can be used indoors.
2. Concrete form plywood is available only with formaldehyde emission ratings of F☆☆☆, F☆☆, or F☆. No four-star rating is available, since concrete-form plywood is not meant for interior use.

Standard Dimension

Standard dimension of the plywood shall be as follows in the Table 52.

Table 52. Standard dimension of plywood according to JAS 233, 2003.

Plywood type	Thickness (mm)	Width (mm)	Length (mm)
Plywood for general use	2.3, 2.5, 2.7, 3.0, 3.5, 4.0, 6.0, 9.0, 12.0, 15.0, 18.0, 21.0, 24.0	910	910; 1,820; 2,130; 2,430; 2,730; 3,030
		610, 760, 1,220	1,820
		850, 1,000	2,000
		1,220	2,430
Concrete forming plywood	12.0, 15.0, 18.0, 21.0, 24.0	500	2,000
		600	1,800, 2,400
		900	1,800
		1,000	2,000
		1,200	2,400
Structural plywood	5.0, 5.5, 6.0, 7.5, 9.0, 12.0, 15.0, 18.0, 21.0, 24.0, 28.0, 30.0, 35.0	900	2,000
		910	1,800, 2,400
		955	1,800
		1,000	2,000
		1,220	2,440, 2,730
Natural wood decorative plywood	3.2	910	1,820
	4.2, 6.0	610, 1,220	2,430
		910	1,820, 2,130
Specially processed plywood	2.3, 2.4, 2.5, 2.7, 3.0, 3.2, 3.5, 3.7, 3.8, 4.0, 4.2, 4.8, 5.0, 5.2, 5.5, 6.0, 8.5, 9.0	606, 610	2,420, 2,425, 2,430, 2,440, 2,730, 2,740
		910, 915, 920	1,820, 1,825, 1,830, 2,120, 2,130, 2,140, 2,420, 2,430, 2,440
		1,000, 1,010	2,000, 2,010
		1,070	1,820
		1,210	2,420
		1,220, 1,230	1,820, 1,825, 1,830, 2,120, 2,135, 2,150, 2,420, 2,430, 2,440, 2,740
		2,130	2,440

2. Laminated Veneer Lumber

Laminated veneer lumber is engineered lumber, a heat and pressure laminate composed of wood veneers, wood particles, moisture-resistant resins and glues. Because they are a manufactured item, unlike standard lumber, it is possible to calculate the load factors for each size and to produce a consistent product.

Standard Sizes

The size of LVL depends upon the manufacturer. Available thickness, for instance, include 1 ¾ inches and 3 ½ inches. Standard depths are 9 ¼ inches, 9 ½ inches, 11 ¼ inches, 11 7/8 inches, 14 inches, 16 inches and 18 inches. Standard lengths are 24 feet, 28 feet, 32 feet, 36 feet, 40 feet, 44 feet and 48 feet.

Qualities of LVL

Laminated veneer lumber is stiff, stable, has a high strength-to-weight ratio and resists warping, shrinking, checking and splitting. The resin used in the manufacturer of LVL instills a moisture-resistant barrier. Unlike standard lumber, LVL has no knots or other defects that need to be cut out, resulting in less wasted material.

Uses for LVL

Compared to standard lumber, LVL has a higher tensile strength, allowing it to handle more weight along its length without bowing. Therefore, it is often used in areas where weight needs to be supported by long beams such as roof supports and garages. It is also used for window and door headers, ridge beams, stair stringers and other areas where weight-carrying beams are required.

Storage and Handling

LVL should be stored on a raised platform, laid flat and in a weather protected area. Keep LVL in its wrapped bundles until ready to use. Designed to be used in dry, covered locations, LVL should also be kept protected at the job site.

The quality of LVL can be tested using ASTM Standard D 5456 – 05 Standard Specification for Evaluation of Structural Composite Lumber Products. LVL is intended for use as an engineering material for a variety of end-use applications. The composition of the lumber varies by wood species, adhesive composition, wood element size, shape and arrangement. To provide the intended performance, LVL require: (1) an evaluation of the mechanical and physical properties and their response to end-use environments, and (2) establishment of and conformance to standard performance specifications for quality.

Procedure contain in ASTM Standard D 5456 – 05 are also to be used for establishing the design properties and for checking the effectiveness of property assignment and quality assurance procedures. The quality assurance sections in this specification are intended to serve as a basis for designing quality-control programs specific to each product. The objective is to ensure that design values established in the qualification process are maintained.

3. Glued Laminated Timber (Glulam)

The quality of glulam can be tested using Designation: D 3737 – 04 Standard Practice for

Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam). This practice covers the procedures for establishing allowable properties for structural glued laminated timber. Properties considered include bending, tension and compression parallel to the grain, modulus of elasticity, horizontal shear, compression perpendicular to the grain, and radial stresses in curved members. This practice is limited to the calculation of allowable properties subject to the given procedures for the selection and arrangement of grades of lumber of the species considered. Requirements for production, inspection, and certification are not included, but in order to justify the allowable properties developed using procedures in this practice, manufacturers must conform to recognized manufacturing standards. Refer to ANSI/AITC AI90.1 and CSA 0122. Allowable properties established by use of this practice are based on dry conditions of use (less than 16 % moisture content). The values stated in inch-pound units are to be regarded as standard.

This standard does not purpose to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Individual laminations shall not exceed 2 in. (51 mm) in net thickness. Lumber may be end-jointed to form any length of lamination or placed edge-to-edge to form any width, or both. When the member is subjected to loads parallel to the wide face of the laminations or when the member is subjected to torsion stresses, edge gluing of the laminations may be required to develop the required shear strength at the edge to edge joints.

All lumber shall be graded as either visually graded or E-rated lumber prior to laminating the member and suitably marked or segregated to identify its grade. When pieces are ripped, each piece shall conform to applicable grade requirements. E-rated lumber shall be re-graded for E after ripping except that re-grading may be waived if both the E and tensile strength are monitored by quality control procedures referenced in ANSI A190.1, section 4.3.5.

If lumber is to be qualified by test as equivalent to visually graded or E-rated lumber, the procedures of Annex A shall be followed. E-rated lumber shall have special visual provisions applied to those portions not subjected to mechanical test to assure piece quality.

The effect of decay or compression failures upon strength cannot be readily determined, thus these defects shall be prohibited from laminating grades insofar as existing inspection and grading technology permit. Firm white speck or light white pocket is permissible in grades of lumber that permit knots to occupy up to one third or more of the cross section provided their extent in combination with knots does not exceed that of the largest edge knot permitted. The exception is that firm white speck and light white pocket shall be excluded from end joints in tension members and the outer 10 % of the total depth on the tension side of bending members.

Compression wood in readily identifiable and damaging form shall be limited in accordance with for dry service condition (4.4.1) and for wet service condition (4.4.2). For dry service conditions, grades permitting knots up to one half of the cross section may contain streaks of compression wood occupying as much as 20 % of the cross section. Streaks of compression wood up to one eighth of the cross section may be permitted in other grades. For wet service conditions, or for pressure-treated members, the conditions of 4.4.1 apply except that compression wood is limited to 5 % of the cross section of the laminations in tension members and in the outer 10 % of the total depth on the tension side of bending members.

Lumber shall be free of shakes and splits that make an angle of less than 45° with the wide face of the piece. Pitch pockets shall be limited in size to the area of the largest knot permitted, and pitch streaks shall be limited to one sixth of the width of the lumber. For wet service conditions, wane is limited to that which will be removed upon final surfacing of the member. For dry service conditions, wane up to one sixth the width of the lumber is permitted at each edge provided the allowable shear strength is adjusted to consider this un-bonded region.

The range of moisture content of lumber for assembly into a single member shall not exceed five percentage points, except when all the lumber is 12 % or lower. The maximum moisture content of individual laminations is 16 %, unless the in-service conditions are wet service and in this case the maximum is 20 %.

4. Particleboard

Particleboard is a composite panel product consisting of cellulosic particles of various sizes that are bonded together with a synthetic resin or binder under heat and pressure. Particle geometry, resin levels, board density and manufacturing processes may be modified to produce products suitable for specific end uses. At the time of manufacture, additives can be incorporated to impart specific performance enhancements including greater dimensional stability, increased fire retardancy and moisture resistance.

Today's particleboard gives industrial users the consistent quality and design flexibility needed for fast, efficient production lines and quality consumer products. Particleboard panels are manufactured in a variety of dimensions and with a wide range of physical properties that provides maximum design flexibility for specifiers and end users.

Common Uses

- Countertops
- Door Core
- Floor Underlayment
- Kitchen Cabinets
- Manufactured Home Decking
- Office and Residential Furniture
- Shelving
- Stair Treads
- Store Fixtures

Product Standards and Certification

The American National Standard for Particleboard (ANSI A208.1) is the North American industry voluntary standard. It classifies particleboard by density and strength and covers physical, mechanical and dimensional characteristics as well as formaldehyde levels. The Standard was developed through the sponsorship of the Composite Panel Association (CPA) in conjunction with producers, users and general interest groups.

Third-party certification to ANSI Standards is required for many applications of composite panels. For example, the US Department of Housing and Urban Development (HUD) requires the physical properties of manufactured home decking to be third-party certified. In addition, many building code jurisdictions require the physical properties of particleboard underlayment and stair treads to be third-party certified. HUD and the states of California and Minnesota also require third-party certification of formaldehyde emissions for nearly all particleboard and MDF under their jurisdiction.

Formaldehyde Emission Limits

The standard has a tiered system of emission levels allowing either a maximum of 0.18 ppm or 0.09 ppm for industrial grades or 0.20 ppm for manufactured home decking. To meet the needs of the market many particleboard manufacturers have voluntarily developed ultra low-emitting and no added urea-formaldehyde (NAUF) products, so there are a wide variety of products available today with reduced formaldehyde levels, as well as a growing number of non-formaldehyde alternatives.

Standard Particleboard

Appearance	Thickness	Length x Width (mm)	Applications
 Description Standard grade raw Particleboard is a high density, strongly bonded economical general purpose board made of large wood particles in the core and finer particles on sanded surfaces. It is an ideal substrate for laminating and veneering. Other uses include making furniture and shelving.	12 mm	1800 x 450/600/900/1200 2400 x 450/600/900/1200 3600 x 450/600/1200/1800	Shelving Furniture Table lamination substrate Storage containers
	16 mm	1800 x 450/600/900/1200 2400 x 450/600/900/1200 3600 x 450/600/1200	
	18 mm	1800 x 450/600/900/1200 2400 x 600/900/1200 2700 x 900/1200 3600 x 600/1200/1800	

Particleboard MR

Appearance	Thickness	Length x Width (mm)	Applications
 Description MR or Moisture Resistant Particleboard is a type of particleboard with a special water-resistant resin added to the panel to ensure moisture resistance properties. MR Particleboard is specifically produced for use in areas subject to high humidity or occasional wetness.	16 mm	1800 x 300/450/600/900/1200 2400 x 300/600/1200 3600 x 600/1200/1800	Substrate for laminating kitchen cupboards Bathroom tables Dishwasher bench cavity lining Furniture for tropical areas
	18 mm	1800 x 450/600/900/1200 2400 x 450/600/900/1200 3600 x 450/600/1200	
	33 mm	3600 x 605/610/755 3600 x 900/1200/1800	
	33mm	180° profile 3600 x 604/900	

Timber Edged Particleboard

Appearance	Thickness	Length x Width (mm)	Applications
 Description Particleboard edge-lipped with timber edging.	16 mm	1800 x 300/450/600 2400 x 300/450/600 3600 x 300/450/600	Shelving for: Laundries Wardrobes Storage units

5. Medium Density Fiberboard

Testing MDF quality can be conducted according to ASTM D 1037 – 99 Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials. The test methods presented herein have been developed and are presented to serve two distinct purposes. They are divided into two parts, Parts A and B, depending on the purpose for which they are intended. The choice between a particular test method and its alternative should be made with a full understanding of the intended purpose of each, because values obtained from tests may, in some cases, differ. Of the test methods presented in both parts, some have been in generally accepted use for many years, some are modifications and refinements of previously developed test methods, and some are more recent developments. Where test methods are suitable for more than one of the purposes, they are delineated in Part A, but not repeated in Part B. It is the intent that reference to the appropriate section of the test method shall suffice in specifications developed for the different materials.

Part A. General Test Methods for Evaluating the Basic Properties of Wood-Base Fiber and Particle. Part A is for use in obtaining basic properties suitable for comparison studies with other materials of construction. These refined test methods are applicable for this purpose to all materials covered by Definitions D 1554.

Part B. Acceptance and Specification Test Methods for Hardboard. Part B is for specific use in specifications for procurement and acceptance testing of hardboard. These test methods are generally employed for those purposes in the industry. By confining their intended use as indicated, it has been possible to achieve adequate precision of results combined with economy and speed in testing, which are desirable for specification use.

These test methods cover the determination of the properties of wood-base fiber and particle panel materials as follows: Size and Appearance of Boards, Strength Properties: Static Bending, Tensile Strength Parallel to Surface, Tensile Strength Perpendicular to Surface, Compression Strength Parallel to Surface, Fastener Holding Tests (Lateral Nail Resistance Test, Nail Withdrawal Test, Nail-Head Pull-Through Test, Direct Screw Withdrawal Test), Hardness Test, Hardness Modulus Test, Shear Strength in the Plane of the Board, Glue-Line Shear Test (Block Type), Falling Ball Impact Test, Abrasion Resistance by the U.S. Navy Wear Tester, Moisture Tests (Water Absorption and Thickness Swelling, Linear Variation with Change in Moisture Content, Accelerated Aging, Cupping and Twisting, Moisture Content) and Specific Gravity, Inter-laminar Shear and Edgewise Shear.

Testing the properties of bio-composite products should be conducted proper according to the standard used for testing. This meant that the condition of the bio-composite products sample and the procedure of testing should be adjusted following the standard. Field research results regarding the quality of the bio-composite products using small diameter logs as raw material shown that most of the bio-composite products fulfill the minimum required to fulfill the standard. In case, the bio-composite products fail to fulfill the international standard, and then it will be sale in the domestic market. Following is the testing results of MDF produced by MDF industry in Indonesia which use small diameter logs as its raw material.

Table 53. Performance of MDF made of small diameter logs from community forest

Properties	Unit	Thickness				
		2.5 mm	2.7 mm	3.0 mm	3.6 mm	4.75 mm
Thickness tolerance	Mm	0.20	0.20	0.20	0.20	0.20
Density	Kg/m^3	780 - 840	780 - 840	780 - 830	780 - 820	780 - 810
Modulus of Rupture	N/mm^2	37 - 40	37 - 40	37 - 40	37 - 40	37 - 40
Modulus of Elasticity	N/mm^2	2,800 – 3,000	2,800 – 3,000	2,800 – 3,000	2,500 – 2,800	2,500 – 2,800
Internal Bond	N/mm^2	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0
Moisture content	%	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0
Thickness swelling	%	20 - 25	20 - 25	18 - 23	15 - 20	10 - 15
Water absorption (24 hours)	%	30 - 35	30 - 35	25 - 30	20 - 25	15 – 20
Surface absoption	mm	150	150	150	150	150
Board weight/Pcs (1220 x 2440 mm)	kg	6.25	6.75	7.40	8.75	11.50
Quantity pieces/m^3	Pcs	134	124	112	93	71
Quantity m3/40' container	M^3	28.58	28.29	28.57	28.29	28.27

-Activity 2.4.3. **Establish quality control procedures.**

Quality control is a process employed to ensure a certain level of quality in a products. It may include whatever actions a business deems necessary to provide for the control and verification of certain characteristics of a product. The basic goal of quality control is to ensure that the products, or processes provided meet specific requirements and are dependable, satisfactory, and fiscally sound.

Quality control program should:

- Maximize the value of raw material through all phases of the manufacturing process.
- Provide quality assurance in the products produced.

Value maximization provides the greatest benefit to a wood industries dollar return. Retaining raw material through the manufacturing process means less waste, and optimum productivity. To maximize value, each step of the manufacturing process must be included in the quality control program.

The quality control procedures was established by literature review and field visit to Plywood factories (PT. Andatu Lestari in Lampung, PT. SGS in Tanggerang, PT. Kayu Lapis Indonesia in Probolinggo, PT. Erna Djuliawati in West Kalimantan, Glulam and LVL factories (PT. Mayora Inkas in Sukabumi, and PT SGS in Tanggerang), Particleboard industry (PT. Paparti Pertama in Sukabumi) and MDF factory (PT. Sumalindo in East Kalimantan, PT. Masari Dwi Sepakat in Karawang)**.**

1. Quality Control Procedure in Plywood Manufacturing

There are several keys point as a management action of proses control cycle measurement and assessment at each processing point (Baldwin 1995), those point are:

A. Block sawing and barking
   a. Degree of accuracy in cutting of the saw kerf
   b. Method of bark removal
   c. Handling damage
B. Block selection: matching the block to the order
C. Block conditioning; steaming, hot-water treating, or cold-peeling
D. Block charging
   a. Method of block centering
   b. Mechanical condition of equipment
E. Lathe
   a. Operator skill, knowledge, and experience

b. Management operating strategy
c. Equipment design
d. maintenance

F. Tipple and tray system
a. Basic design of the unit
b. Electrical and mechanical operation

G. Veneer clipping
a. Operator skill, knowledge, and experience
b. Management clipping strategy
c. Clipper control design and operation
d. Mechanical functioning

H. Green veneer sorting

Log Selection

The character and availability of wood supply is rapidly changing; the diameter of available log is diminishes, driving technology to design more versatile and yield-efficient equipment.

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.
c. 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).

d. Pricipal requirement:
- avalable in sufficient quantity
- sufficient size
- adequate form

Peeler Block Preconditioning

- The peeler blocks must be heated and soaked to soften the wood.
- The blocks may be steamed or immersed in hot water. Heated blocks result in a higher yield, lower variation, and higher veneer grade (Bowyer 2003). This process takes 12-40 hours depending on the type of wood, the diameter of the block, and other factors.
- In general, dense hardwoods are heated to higher temperature (80-100^{o}C)

Principles of Rotary Veneer Cutting

- The process is essentially one of cutting perpendicular to the grain with the knife parallel to the grain.
- The bolt is centred between two chucks on a lathe and turned against the knife.
- Veneer is peeled off through the gap between the nose bar and the face of the knife as a long continuous ribbon.
- The peeling speed is between 2.5 and 6.0 m/s

Lathe Equipment Setting

Table 54. Lathe equipment setting

Bevel angle (degree)	Width of knife face (inches)	
	5/8" thick knife	¾"-thick knife
17	2 1/8	2 9/16
18	2	2 7/16
19	1 15/16	2 5/16
20	1 13/16	2 3/16
21	1 ¾	2 1/8
22	1 11/16	2
23	1 5/8	1 7/8

There are several steps involved in an effective knife setting method:

- The lathe knife is placed in the knife holder and temporarily secured. The lathe carriage is brougth forward within 10 to 12 in from the spindles.
- Both spindles are extended beyond the ends of the knife.
- The knife clamps on the end of the lathe carriage are tightened, allowing enough slack for final adjusment.
- Determine the knife height from the fixed point.

Setting the Pressure bar

- Setting the horizontal pressure bar exactly parallel to the cutting edge of the knife
- Visually inspects the veneer
- The vertical pressure bar adjusment; measure the distance from the knife tip to the upper roler bar lip.
- The pressure bar then is adjusted up or down until the selected setting is reached.

Veneer Drying

- The wet veneer is fed through a drier to reduce its moisture content to about 8%.
- High temperatures (150-200^{o}C) can be utilized in the first few sections of the dryer where the veneer is very wet.
- The optimum moisture content for gluing depends on the species and density of the veneer, the adhesive and gluing procedures being used.

- The drying time is regulated by adjusting the speed of the conveyors and/or the temperature of the hot air.
- Veneer produced from small diameter log is dried by using hot press dryer. Drying systems have been considered which heat the surface of the veneer directly by using heated platen (Pease 1980 *in* Walker 2003). These consist of multiple daylight presses in which single veneers are placed on the lower plate of each daylight, and the platen closed to keep the veneer flat during drying.

Jointing or Veneer Repair

- Finnish veneer made from small diameter logs necessitates much repair work, e.g. patching and jointing.
- Small strips of veneer are jointed into full size sheets by edge gluing, stitching or using perforated tape.
- Open defects may be repaired by using plugs to upgrade the veneer.

Crossbands

- The core veneers that run across the panels at right angles to the face veneers are termed 'crossbands'.
- In a 2400 mm x 1200 mm panel the crossbands can be produced by a smaller lathe, or by cutting full sheets of veneer into two.

Plywood Fabrication

Lay-up

- The dried, graded veneers are assembled in two bundles in preparation for the spreading operation.
- In one bundle the graded faces and long bands are assembled and the other consists of the crossbands or in the case of three ply, the cores.
- It is these crossbands or cores which are run through the glue spreader.
- Different grades of plywood are made from various grades of faces, backs, crossbands and cores. In a three ply construction only the centre veneer passes through the glue spreader.

Glue Mixing

When the appropriate sections of veneer are assembled for a particular run of plywood, the process of gluing begins. This may be done manually or semi-automatically with machines.

- In the simplest case of three-ply sheets, the back veneer is laid flat and is run through a glue spreader, which applies a layer of glue to the upper surface.
- The short sections of core veneer are then laid crossways on top of the glued back, and the whole sheet is run through the glue spreader a second time.
- Finally, the face veneer is laid on top of the glued core, and the sheet is stacked with other sheets waiting to go into the press.

In the conventional roll coater, the amount of adhesive that is spread on the veneer is regulated by adjusting the gap between the steel doctor roll and the rubber applicator roll. Resin cost can be contained by adding filler and extenders which both bulk and contribute to adhesion. They modify many resin characteristics such as viscosity and cure rate and can contribute up to 50% of the resin volume.

Pressing

- Stacks of panels are pre-pressed cold for 3-5 minutes before being loaded into the hot press. The cold press ensures that the adhesive which is applied to one face of each veneer is transferred to the veneer on the other side of the glue lines.
- The glued sheets are loaded into a multiple-opening hot press. Presses can handle 20-40 sheets at a time, with each sheet loaded in a separate slot.
- The press squeezes them together under a pressure of about 110-200 psi (7.6-13.8 bar), while at the same time heating them to a temperature of about 230-315° F (109.9-157.2° C). The pressure assures good contact between the layers of veneer, and the heat causes the glue to cure properly for maximum strength.
- After a period of 2-7 minutes, the press is opened and the sheets are unloaded.

Finishing

- The rough sheets then pass through a set of saws, which trim them to their final width and length.
- Higher grade sheets pass through a set of 4 ft (1.2 m) wide belt sanders, which sand both the face and back.
- Intermediate grade sheets are manually spot sanded to clean up rough areas. Some sheets are run through a set of circular saw blades, which cut shallow grooves in the face to give the plywood a textured appearance.
- After a final inspection, any remaining defects are repaired.

Testing

The plywood is tested according to Japanese Agricultural Standard (JAS) for plywood N0. 232-2003. The properties tested were moisture content and shear strength. The cutting pattern of plywood samples can be seen in Figure 114.

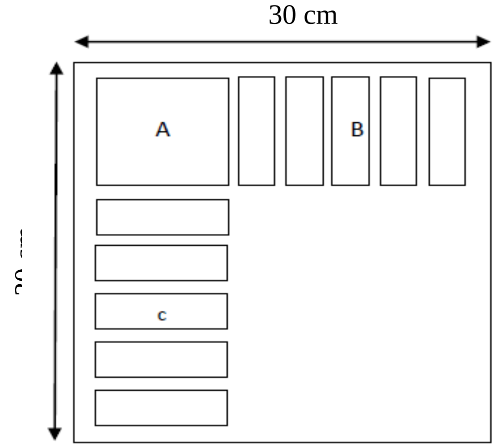


Figure 114. Cutting pattern of plywood sample

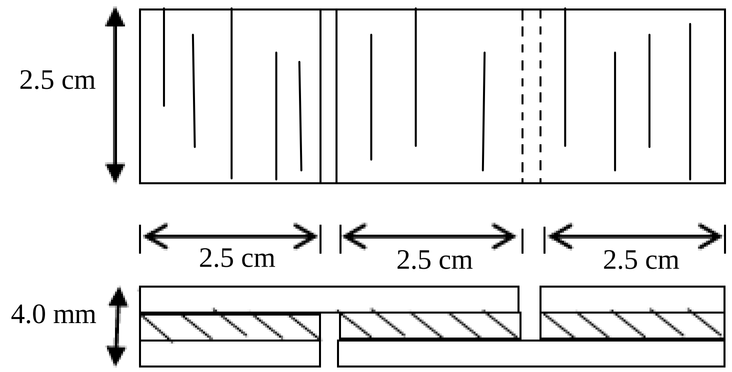
Note :

A = moisture content sample.

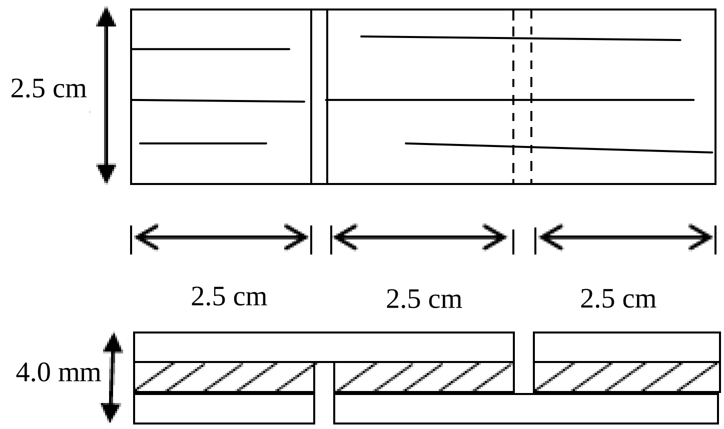
B = Shear strength perpendicular to the face/back veneer grain.

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 115.



Shear strength perpendicular to grain



Shear strength parallel to grain

Figure 115. Shear strength samples

2. Quality Control Procedure in Glulam Manufacturing

Manufacture

- The laminates are arranged so that all grain is generally parallel, and the ends of the laminations are usually connected by either glued scarf or glued finger-joints to produce continuous lengths, the same length as the glulam member.
- After application of a high quality permanent, rigid adhesive, the laminates are clamped together with a predetermined pressure, and allowed to cure.

Finger Joints

Glued "finger joints" are often used to give continuity to the laminations. The geometry of the finger joints enable a large surface area of glue to transmit the force across the discontinuity at the end of one portion of the lamination to the next portion. The shallow angle of the finger joints means that the glue transmits load in shear across the glue line. This is much more effective than direct tension across a glued butt joint. Good quality glued finger joints give performance that is comparable with the design tension strength of the lamination material.

Specification

The following should be included in the specification of glue laminated timber:

- Size
- Stress grade (or manufacturers grade)
- Service class
- Surface finish (Appearance class)
- Preservative treatment
- Pre-finishing or protection
- Handling and storage

Curved and tapered beams

Tapered beams are beams where the upper surface is sloped to provide roof drainage and architectural effect. They are made by stepping the laminates so that there are more laminates (and hence greater depth) at one end than the other.Beams can be produced with a single taper or a double taper. Double tapered beams have the highest point near the center of the beam.

- Curved beams are made by curving the manufacturing jig.
- After gluing, the laminates are pressed up into a curved shape.
- The shape is held by the clamps, and after the glue has hardened, the shape is held by the beam.

There are limits on the tightness of the curve that can be made without damaging to the wood, and curves and tapers also affect the stiffness and strength performance of the finished member.

Handling and storage

- Care should be taken in the handling and storage of glued laminated products to ensure their visual and structural integrity.
- The use of fabric slings is recommended when lifting by crane, and the use of chains avoided to prevent bruising of the surface, especially corners.
- Glulam products should be stacked vertically on closely spaced, level bearers at least 150mm clear of the ground, and protected from the weather by tarpaulins or polythene sheeting around and under the stack.
- Where not specifically manufactured for exposed applications, glued laminated timber should continue to be protected until the roof is in place.
- Some manufacturers wrap their products in thin plastic wrap. This should stay on as long as possible, and certainly until the roof is installed.

Testing

a. Density

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

$$\text{Density, gr/cm}^3 = \frac{B}{pxlxt}$$

Where :

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. Scheme of loading on the flexural static strength tests are presented as in Figure 116.

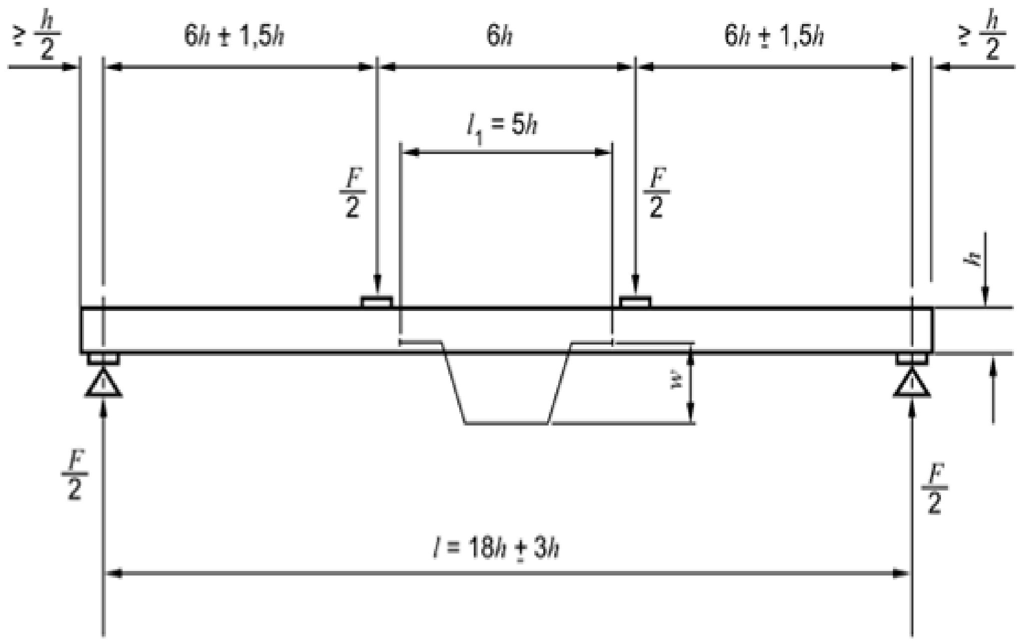


Figure 116. Scheme of loading on the static bending

Where :

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

Tests is made after the objects were condition for oneweek. 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. Testing is done until the objects is damage (failure). 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.

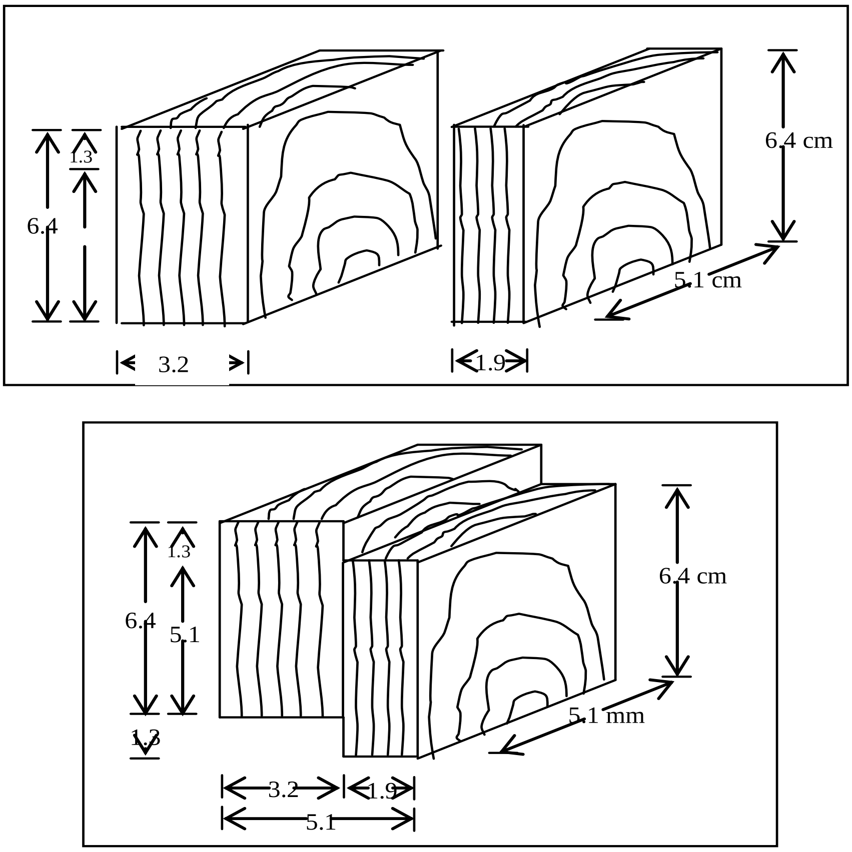


Figure 117. The shape and size of the object of wood sticking

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

3. Quality Control Procedure in Particleboard manufacturing

Raw material

Wood

- Low density wood
- Wood waste (wood industry waste, harvesting waste)
- Lesser use species, low quality wood, fast growing species
- Lignocellulosematerials (bagasse, bamboo, rice husks, straws, and other agricultural residues)
- Barkwood (≤ 5%)

More than 90% of the raw materialis wood with the recovery factor about 75-90%.

Adhesive

- Liquid adhesive usually used with solid content of 40-65%
- Usually thermosetting resins, thermoplastic resins sometimes used for specified type
- Interior (UF/MF/MUF), Exterior (PF)
- Amount of adhesiv eadded depend up on strength of board:
- Single layer : 6-10%
- Three layers: SL: 8 – 12 %; CL: 6 – 8%

≈ based on solid content.

Additives

To obtain certain properties of particleboard

- Water repellent:
- To reduce water absorption and thickness swelling, cupping, and twisting, added to the glue about 1% parafin (based on wood particle weight)
- Resistant to fungi and insect:
- Fungicide, insecticide (NaPCP, BFCA)
- Fireretandant (phosphates) etc.

Board Manufacturing

- The wood particles are dried, then milled sorted to eliminate overly large or small pieces.
- Once this mechanical sorting has been completed, the acceptable wood particles move by conveyance to a blending hopper. Along the way, several overhead nozzles spray the wood particles with a strong liquid resin or glue. Several different forms of formaldehyde-based resins used, depending on the specific quality of particleboard desired.
- The resin-soaked wood is then blended to form a consistent paste. This combination is piped into a forming machine, which presses out a sheet of uncured particleboard.
- The formed panels of particleboard are then pressed down for easier transportation to the final curing ovens.
- Individual sheets of particleboard are held under pressure as the air around them is superheated. This allows the resin to harden and form a very strong bond with the wood particles.

  There are several factors affecting the quality of particleboard, i.e.:

  - wood species,
  - type and amount of resin,
  - board density,
  - additives,
  - resin distribution,
  - pressing variables, and
  - particle orientation.

Testing

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

a. Density

The board density is calculated using formula:

$$\rho = \frac{m}{v}$$

Where:

ρ = density (g/cm^3)

m = air-dry weight (g)

v = volume (cm^3)

b. Moisture Content (MC)

The MC is calculated using formula:

$$MC = \frac{W1 - W2}{W2} \text{ x } 100\ \%$$

Where:

MC = moisture content (%)

W1 = initial weight (g)

W2 = oven-dry weight (g)

c. Water Absorption (WA)

The WA is calculated using formula:

$$WA = \frac{W2 - W1}{W1} \text{ x } 100\ \%$$

Where :

WA = Water Absorption (%)

W1 = Initial weight (g)

W2 = Soaked weight (g)

d. Thickness Swelling (TS)

The TS is calculated using formula:

$$TS = \frac{T2 - T1}{T1} \text{ x } 100\ \%$$

Where :

TS = Thickness swelling (%)

T1 = Initial thickness (cm)

T2 = Soaked thickness (cm)

e. Modulus of Elasticity (MOE)

The MOE is calculated using formula:

$$MOE = \frac{\Delta PL^3}{4\Delta ybh^3}$$

Where :

MOE= modulusof elasticity (kg/cm^2)

Δp = loading difference (kg)

L = span (cm)

Δy = deflection difference (cm)

b = width of sample (cm)

h = thickness of sample (cm)

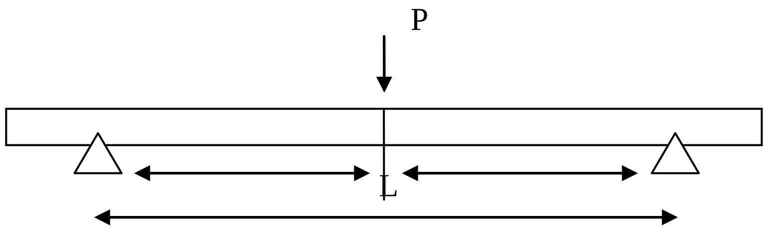


Figure 118. Schema of MOE and MOR

f. Modulus of Rupture (MOR)

The MOR is calculated using formula:

$$\mathrm{MOR} = \frac{3PL}{2bh^2}$$

Where :

MOR = modulus of rupture (kg/cm^2)

P = maximum load (kg)

L = span(cm)

b = width of sample (cm)

h = thickness of sample (cm)

g. Internal Bond (IB)

The IB is calculated using formula:

$$\mathrm{IB} = \frac{P}{A}$$

Where :

IB = internal bond (kg/cm2)

P = maximum load (kg)

A = area of sample (cm^2)

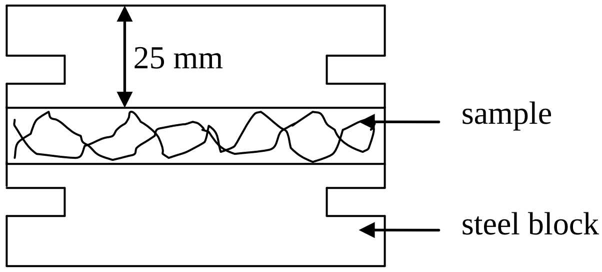


Figure 119. The internal bond test.

4. Quality Control Procedure in MDF Manufacturing

Raw material

Wood and other lingo-cellulosic materials are main raw material for producing MDF. Some importance factors to consider are as follows:

- Species (source, continuity)
- Low density
- Moisture content
- pH
- Age

Resin (urea formaldehyde), hardener (NH_4Cl), and wax are supporting raw material in the production of MDF.

Debarking

- Once the MDF plant has obtained suitable logs, the first process is debarking. The logs could be used with the bark, as could any fibrous material, but for optimization of the final product the bark is removed to;
  - ➢ decrease equipment damaging grit,
  - ➢ allow faster drainage of water during mat formation,
  - ➢ decrease organic waste load by 10-15 %,
  - ➢ stabilize pH levels (reduces corrosion of tools) and increase surface finish.
- Most pulp and wood-panel mills debark their roundwood in drum debarkers which can be 4 m in diameter and 25 m long (Walker 2003).
- The bolts are fed in at one and of the large, gently inclined, slowly rotating drum and bark is sheared off by friction during the rubbing and tumbling action.

Several importance factors which are support the success of debarking are as follow: log shape, age, and the thickness of bark.

Chipping

- 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.
- The chips are then screened and those that are oversized/rechipped, 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.

In order to optimize the performance of chipper, there are several factors to consider: log species, feed speed, gap between chipper knife and counter knife, knife sharpness, and screener size.

Pulping

- The chips are compacted using a screw feeder into small plugs which are heated for 30 to 120 seconds (this softens the wood),
- Then fed into the defibrator. The defibrator consists of two counter wise 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 groves are finer.
- The feeding devices at the entrance and exit to the defibrator maintain suitably high pressure and temperature (about 150 ^{o}C).
- The steam is then separated from the pulp, the total time in the defibrator is about one minute.
- The pulp may pass through a secondary refiner to ensure the fibers meet pre-determined levels of `freeness'.

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 fibers 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.
- The agitation of fibers in the blow-line helps disperse resin consistently.
- The fibers 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 this is considered a dry process.

Mat Forming

In order to form a continuous and consistent mat the following problems must be overcome: the fact that considerable air velocities must be maintained to suspend fibers, fiber/air suspension does not flow laterally on a horizontal support and fiber form lumps. One way of overcoming this is a Pendistor.

Impulses of air act on the fiber as it falls down the shaft to a vacuum box at the start of the conveyor belt that carries the mat. The oscillatory action on the fibers spreads them uniformly into a mat and they begin their run on the conveyor belt at between 230-610 mm thick.

Pressing

The pressure may reach 3500 MPa and be heated to over 200 ^{o}C. Thicker boards may require up to 750 MPa and additional steam or radio frequency heating. Press sizes can be from 1.5-2 m wide by 5-20 m long.

- 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 top

and bottom 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 acting at impacted pressure initially and then slower pressure application. As an example for a 16 mm board:

- Press closed 20 seconds to bring mat to 28 mm.
- 28 seconds at 26 mm.
- 23 seconds at 25 mm.
- 125 seconds at 18.3
- Total time of 330 seconds to bring board to 16mm, then decompression time.

Some important parameters in the operation of continuous-hot press are as follows:

- Pressure; to determine the thickness and density of MDF.
- Temperature; effect the curing time and moisture content.
- Pressure time
- Gap between drum

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 colored melamine laminate, though natural wood veneers and raw MDF are common.

Testing

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

4.8. Output 2.5. **Comply with relevant standards.**

-Activity 2.5.1. **Coordinate with international standards bodies.**

ISO is an international organization that handling standardization, with name International Organization for Standardization. Some of ISO standard directed to one standard, one testing, can be accepted in everywhere and unite, binds, and connects the world. In ISO organization is known MTB (Management

Technical Board) as director, TC (Technical Committee) and SC (Sub Technical Committee) as the regulator and WG (Working Group) as the executor of TC which in general area could form SC. Each unit has its own secretariat.

The membership of ISO is a country and in each country, there is berau, which connected with ISO. In handling a certain standard, the membership of a country in ISO is divided into participant (P-member) or observer (O-member). The P-member has a vote's right in decision-making, and O-member has none. The duty of P-member is giving comments for standard suggestion which proposed by ISO. If there is no comment in three times, the position as participant member could be return to observer member. This position could be return after the country proposes an application to ISO.

ISO TC 165 is handling two groups of wood for structure needs, which is complete wood and incomplete wood. In complete wood includes round, pole, and saw wood. In incomplete wood includes lamina wood and panel wood. Secretariat of TC 165 is lead by Canada. TC 165 hands preservation problem.

Indonesia is a member of ISO and the agency who is in charge to handle is BSN (National Standardization Agency). In its membership, Indonesia is a participant member (P-member) in ISO TC 89 (panel wood) and ISO TC 165 (Structural wood).

A. ISO TC 165 (Timber structure)

In ISO activity, BSN forms Mirror Committee (MC), which is shadow committee of Technical Committee (TC) ISE/IEC and Codex Committee (CC) CAC in national level that the member is consists of expert in certain subjects and represents stakeholders, who has duty for supports Indonesia's participation in international standard formulation.

Secretariat membership is fixed by Decision Letter from Head of BSN, which executes this duty of MC's secretariat, on top of routine activity, according to its duty and its function, that is giving comments to draft of international standard (and another standard documents that need to be commented) which given by activity coordinator MC ISO/IEC or CCP Secretariat through the Secretariat of MC.

Comments of ISO standard draft is according with local importance, such as wood species that used, terms of glulam internal bond, in ISO it is too high if it compared to the results of research which has been done or ability of the factory in producing glulam with that terms (example of comments are attached). In the terms of wood species in ISO is directed to wood species that not exist in Indonesia or Southeast Asia, so it is suggested to add wood species, which found in the mentioned area and accepted by ISO.

Contribution of USDL team goes to improvement of the following ISO standards :

1. ISO/DIS 20152-1: 2009. Timber structures – Bond performance of adhesives- Part 1: Basic requirements.
2. ISO CD 20152-2: 2008. Timber structure – Bond performance of adhesives – Part 2 : Additional requirements
3. ISO 9709-2005. Timber structure – Visual strength grading – Basic principles
4. ISO 16670-2003. Timber structure – Joints made with mechanical properties – Quasi – static reserved- cyclic test method.
5. ISO CD 22389 Timber structure – Bending application of I-Beam. Part 1: Structural testing, evaluation and characterization.
6. ISO 13912 – 2005: Timber structure – Machine strength grading Basic principles
7. ISO FDIS 8375
8. ISO/FDIS 8375: 2008 Timber structures – Glued laminated timber – Tests methods for determination of physical and mechanical properties
9. ISO/FDIS 12578: 2008 (E). Timber structures – Glued laminated timber – Component performance and production requirements.
10. ISO/DIS 22390-1. Timber structures – Laminated veneer lumber (LVL) – Part 1: Structural properties (2009)
11. ISO/DIS 22452 (2009). Timber structures – Structural insulated panel wall - Test methods.

12. ISO/TR 22157-2. Bamboo – Determination of physical and mechanical properties – Part 2: Laboratory manual
13. ISO/FDIS 21581. Timber structures – Static and cyclic lateral load test methods for shear walls.
14. ISO/Technical Report. Light frame timber construction – Comparison of four national design documents.
15. ISI/FDIS 15206. Timber poles – Basic requirements and test methods.
16. ISO/FDIS 22380: Timber structures – Laminated veneer lumber – Structural properties (2010)

B. ISO TC 89 (Wood-based Panels)

The contribution of the USDL team member goes to ISO standards for improvement as follows :

1. ISO/FDIS 12460-3. Wood-based Panels – Determination of formaldehyde release- Part 3 : Gas analysis method
2. ISO/FDIS 12460-4. Wood-based Panels – Determination of formaldehyde release – Part 3: Desiccators method
3. ISO 3340 Wood-based Panels – Fiberboards sand content (suggested to be abolished)
4. ISO 3729 Wood-based Panels – Fiberboards surface stability (suggested to be abolished)
5. ISO/CD 27567 Laminated veneer lumber – Measurement of dimensions and shape – Methods of rest.

Indonesian USDL team have been actively involved to contribute for ISO standards improvement through the Ministry of Forestry Republic of Indonesia based on the USDL research results, experiences and their expertise in bio-composite products.

4.9. Output 2.6. **Conduct regional workshop.**

-Activities 2.6.1 - 2.6.5. **Coordinate workshop activities with project findings, solicit suitable attendes, produce workshop materials, conduct the workshop and evaluate the useful of the wokshop.**

After the project completion, the project findings will be presented in the workshop. The workshop materials consist of papers, samples of bio-composite products made of SDL, stationary, etc.Suitable attendees of the workshop were selected from the scientists involved in the projects, prominent scientists working on bio-composite, bio-composite industries representative, as well as the students working on wood-based technology to present their research findings on bio-composite. The workshop materials were produced in sufficient quality according to the number of participants. Execution of the workshop was assisted intensively by ITTO and CFC. Evaluation of the workshop was conducted in order to know the usefulness of the workshop and research on bio-composite from different perspectives.

Description of the workshop execution are as follows :

A. Workshop Agenda

Thursday, 9 December 2010:

Item 1. Opening of the workshop

08.30-09.20 Registration and coffee morning

09.20-09.30 Announcement from Master of Ceremony

09.30-10.30 Remarks from:

- The Director General of Forest Utilization, the Ministry of Forestry, Indonesia. Dr Ir R. Iman Santoso, MSc
- Vice Dean of Faculty of Forestry, Prof Dr Fauzi Febrianto
- ITTO, Mr Ramon Carrillo
- CFC, Ms Yukiko Tomihisa

10.30-11.00 Introduction of the Participants by Dr. Supriyanto, Secretary and Treasurer of the Project

- Government officials
- Project Executing Agency Staff
- Entrepreneurs from Companies Involved in the Project (SBK & SLJ)
- Collaborative Institutions from Malaysia and Philippines
- Other participants, from agencies.
- Photo session

Item 2. Presentation and discussion related to the wood raw material

11.00-12.00 Moderator : Dr. Supriyanto

- The Use of Small Scale Diameter Logs for Bio-Composite by Director General Forest Utilization, Ministry of Forestry, Republic of Indonesia, Dr Ir R Iman Santoso, MSc
- Export of Indonesian Wood Industry Products (Panel and Wood Working) and Timber Legality Assurance System by Forestry Industry Revitalization Body, Dr Ir Zulfikar Adil, MBM.

Item 3. Presentation and discussion related to the technical aspect

13.00-14.30 Moderator : Prof. Dr. Muh. Yusram Massijaya

Technical aspect performance of bio-composite produced from small diameter logs

a. Small Diameter Logs for Producing Bio-Composite Products by Prof. Dr. Yusuf Sudo Hadi (Bogor Agricultural University, Indonesia)
b. Utilization of small diameter lesser used species for producing bio-composite products by Prof. Dr. Mohd. Hamami Sahri (University Putra Malaysia).
c. Performance of cement board made of small diameter logs by Dr. Dwight Eusebio (Forest Products Research and Development Institute, Philippines).

14.30-15.00 Coffee Break

15.00-16.30 Comment and Discussion according to the experience on producing and marketing biocomposite products:

a. Plywood and LVL industry (PT. Andatu Plywood, PT. Kutai Timber Indonesia)
b. Particleboard industry (PT. Paparti Pertama).
c. MDF industry (PT. Masari Dwisepakat Fiber)
d. Glulam industry (PT. PAL)
e. Wood Industry, Malaysia.
f. Wood Industry, Philippine
g. Other participants

Item 4. Conclusion and recommendation

16.30-16.50

Item 5. Closing remarks from ITTO and CFC representatives

16.50-17.00 (thank to CFC, ITTO, participants)

Friday, 10 December 2010:

Excursion : 06.30 – 21.00: Field Trip to Cianjur to see Woody Home Industry and stand of Mahogany and Teak of Perum Perhutani, and Community Forest.

Presentation and Discussion

A. The Use of Small Scale Diameter Logs for Bio – Composite Products
By Dr. Ir. R. Iman Santoso, M.Sc
Director General of Forest Utilization, Ministry of Forestry

Ladies and Gentlemen,

As we are aware of the complexity of the problems faced by forestry sector in Indonesia and other developing countries, the Ministry of Forestry Indonesia has set 8 priorities in the 5 – year forestry sector development plan, namely : 1) strengthening of the legal status of permanent forest, 2) rehabilitation of critical watersheds, 3) forest protection and fire control. 4) bio diversity conservation, 5) forest community development 6) climate change mitigation and adaptation. 7) strengthening forest institution, 8) revitalization of the forest industries.

Through the revitalization of forest industries, we are going to strive for the growth of the forest sector by expanding plantation on degraded production forest and increasing the forest products sectors. The second, we are going to improve our government for better investment in real sectors in forestry which creates more jobs for people. And the third, the economy of the forest communities would be improved by granting more access to forest resources through granting concession in community plantation forest, village forest, and other community development schemes, these three programs in revitalizing the industries are in line with the triple – track policy of national development plan which are addressed to target of pro growth, pro job, and pro poor, while keep the environment in sound condition to ensure the sustainability of the resources and the security of the nation.

Ladies and gentlemen,

In revitalizing our wood based in industries, the usage of logs as a raw material has changed from those came from natural forest to those of plantation forest. This trend shown by data of logs supply to industries, especially industries with capacity of 6,000 m^3 per year. In the last 5 years from 2004 to around 2009 the log supply had decreased from 25 million in the 2004 to around 7.4 million m3 in 2008, and only 4.6 million m3 in 2009. On the other side logs supply from the plantation to the industries showed significant increase, from 10.3 million m3 in 2004 to 24.5 million m3 in 2008. The logs mostly comes from the industrial plantation forest (or HTI), community forest (or HR), and those from rubber and coconut estate plantation.

The other trend in industries is the use of small diameter logs. This trend is in anticipating the use of logs from small plantation with small economy of scale. The small plantations, both industrial plantation and community plantation with a shorter cash flow, will produce only small diameter logs from fast growing species with small diameter. This situation in recently anticipated by the industries by renewing their mill and diversing their products. Those are driven by market which now accepting not only wood panel and other wood products from hardwood species, but also accepting products from fast growing species which used to be lesser known species. This trend has encouraged communities, particulary in Java to grow fast growing species such as *Albizia falcataria* and *Athocephalus sp* on their own land, and this have improved the productivity of the land.

Ladies and gentlemen

To ensure the smooth process of wood supply to industries, and keep the continuing changes in raw material uses, the Ministry of Forestry is now implementing policies on the management and distribution of timber by using an on – line system which is aimed at simplifying the legal process using friendly information technology. The system is intended to record and track the timber supply chain from legal sources and control the sustainability of timber supply. The system is also intended to process the legality of the timber supply plan of each industry, which are expected to be faster and cheaper, more accountable and build the better overall forest governance both in government and corporation sides.

Ladies and gentlemen,

In promoting legal timber and other wood products in international markets, the Ministry of Forestry has developed a timber legality assurance system or “sistem verifikasi dan legalitas kayu”. The system was developed through multi – stakeholder process, in formulating verification standard for timber legality, as well as formatting the institution which will operate the system. This system is built on the spirit in improving our governance, through improvement our commitment in allowing participation of all stakeholder in the management of forest and timber. The system has complied with the international market expectation, particularly with a “do care “ of lacey act of the United States of America, Green Konyuho Japan, Fleigt – VPA European Union, and the other global markets.

Ladies and gentlemen,

With the context of revitalization forest industries, the role of the researchers and academicians in developing more technologies in the use of any wood material for industries, and in building the appropriate system in assuring the legality and sustainability of forest and industry are essential. We appreciate the support from research institutions and universities which have contributed many support on those improvement. With the context of this workshop, we do hope that we could identify challenges and problems we are facing now in the use of small scale diameter logs in bio composites, and find solution for better achievement in the future. The contribution from this workshop will be of the important contribution to the pulling out of the Indonesia timber industry from the sunset condition to the sunrise.

With the bless of Allah, I declare the workshop on the use of small diameter logs for bio composites products, officially opened.

Point of Discussion:

- There’s concern with the prevailing condition of wood industry in Indonesia. Wood industry experience difficulties in obtaining fund from bank.

Recommendations from related-stakeholders are needed to improve the furniture industry, including the use of raw materials.

- Community forests have high potential to supply wood industry. Ciamis regency has the potential of about 5 million m^3 of timber from community forest. There should be a strong policy to ensure community development and welfare.
- There are much inputs from the aspects of supply and raw materials. Nowadays, products seem to be more diverse. East Java's wood industry seems to improve. A lot of products made from various kinds of materials, even products made from very minimum wood material, can be found in East Java.
- It seems that minimal regulation had encouraged optimum product diversification. On the contrary, the more regulation seems to complicate wood supply and increasing the production cost.
- However, high-cost economy mostly caused by non-forestry regulation which were beyond the autonomy of the Ministry of Forestry (MoF). There is a lot of homework to be done.
- Governance should be improved, both on the side of the government and the community.
- There has never been any regulation, which bans the use of oil palm stem/trunk. Perhaps the problem is lack of promotion. Promotion of the use of oil palm, bamboo, and other potential wood should be strengthened.
- Actors who involved in the industry should know the problems better than the government, since the government essentially only conduct problems identification.
- There seems to be improper promotion of products. For example, a certain wood products promoted as if the products can be used for all purposes, while in fact the products are ideal only for furniture. There should be a proper promotion of the use of different kinds of woods.
- Whenever possible, organize seminar to address specific problems. Such seminar would provide valuable inputs and recommendation for the government to improve the regulation.

B. Export of Indonesian Wood Industry Products (Panel and Woodworking) and Timber Legality Assurance System.

By Dr. Ir. Zulfikar Adil, MBM

Forestry Industry Revitalization Body

Point of Presentation :

- Wood products certification has been an emerging trend in the export trading of wood industry. There's increasing number of countries which require certified wood products.
- Timber Legality Assurance System (TLAS) or Sistem Verifikasi Legalitas Kayu (SVLK) was launched on 1 September 2009
- BRIK: established on 13 December 2002 based on joint decree of Ministry of Industry (MoI) and Ministry of Forestry.
- Endorsement system is one of BRIK operational activities on timber origin. Ensure export of timber from legal sources→ ETPIK (registered exporter) certificate issued by Director General of Foreign Trade.
- There are 11 harmonized systems (HS) categories of wood panel and woodworking export endorsed by BRIK. The HS category is divided into wood panel and wood working.
- Data of wood panel and wood working 2004 – 2010 show that export decrease significantly. There had been shortage of logs inputs or supply.
- Around 40% of wood working inputs come from community forest.
- Main export destination: Taiwan, China, Japan, Australia. Taiwan and China imported more wood working product in terms of volume. However, in terms of value, Japan and Australia imported more.
- TLAS is a new policy in Indonesia. Development of TLAS was based on 3 regulations, involving multi-stakeholder, such as government, NGO, private sectors, communities, and academician.
- TLAS as the Indonesian standard for the international consumer, build on governance, representativeness and credibility.
- National Commission on Accreditation (KAN) awarded certification to wood products certification bodies.

- BRIK had been certified as the Timber Legality Certification Body on 1 September 2009. KAN extended BRK's certificate up to 1 September 2014 based on gap analysis and audit-witness.
- Up to 30 Nov 2010, BRIK had carried out TLAS for 10 companies: 3 had been awarded TLAS, 3 in decision-making process, 2 audits had been reported, 2 more were being prepared. TLAS was carried out by the Legality Division of BRIK.
- Saw Mills at Bintuni were going to be accredited by the legality division of BRIK.
- There will be 40 companies accredited based on TLAS by the end of this year. Far lower than the 700 companies targeted in the first stage of TLAS implementation.
- Constrain is limited number of auditor to do the TLAS. There is opportunity for fresh graduates to join TLAS training.
- Surviving wood products exporter companies are those which relying their products on engineered wood products. Companies which relying their products on solid wood are experiencing difficulties in obtaining supply.
- The use of SDL had become significantly increasing. The SDL had been seen as a potential replacement for wood products inputs. Sengon and rubber wood has high potential contribution for wood materials. The price of sengon wood had never decreased that the companies using them had very small margins.
- Margins of SDL, including rubber wood, is also small. Industry who uses SDL should be cost-focused, which means increasing their production number to lower the average fixed cost per m^3.
- Increasing number of species had been used for timber products.

Point of Discussion :

- Exploring SDL from natural forest would not be economics. Should consider sources from the community forest.
- There should be also harmonization of the regulation.
- TLAS is very important to ensure sustainability of sources.
- TLAS and Export Destination Countries:

  - The EU and many other countries will ban export which is not accompanied with certification. Indonesian government is in the process of negotiation with the EU regarding TLAS acceptance in EU. Hopefully that EU will accept TLAS as the Indonesian standard used internationally. EU had sent two expert missions to verify the compatibility of TLAS with the system in EU.
  - MoF had sent team to the US to promote TLAS and discuss the acceptability of TLAS in the US. The US will accept TLAS since it was stipulated by the decree of formal regulation.
  - Japan had also accepted TLAS.
- TLAS and wood Industry:
  - Based on the regulation, Pulp and Paper, and Furniture industry are excluded from TLAS. It does not necessarily mean that those industries would not be benefited by the TLAS. Furniture products were mostly exported to the European countries, which require certification for wood products. Products which are not certified would have to undergo customs inspection which take time and would also be costly.
  - However, the first stage of TLAS implementation would be limited to wood working and panel industry, which means about 700 companies. The process of certification for a company takes time, about 1.5-2 months. Certification for 700 companied will take 1 or even 2 years time. There is need of more auditors. Certification bodies should be developed.
  - Furniture industries had not formally included in the first phase of certification. However, considering that furniture industries might face market problems, particularly in exporting products to European countries, the industries are welcome to enroll their companies to get certification. In the mean time, furniture industries should register their companies to the MoI. The furniture and pulp and paper industry are the domain of MoI.

- Bio-composite products:
  - Wood pellets had big market in Europe and Korea. Wood pellets are used as wood energy.
  - Wood pellets are bio-composite products, based on the definition of bio-composite: any kind of composites consist of cellulose.
  - There's an increasing trend of wood pellets use. Basically, density of the composites is increased several times greater. Wood pellets' density can be higher than coal's density. Wood pellets had been registered to the Ministry of Research and Technology (RISTEK).
- Three main issues in the world: Human rights, democracy, and environment. Environment leads to certification. Certification leads to competition.
- Difference of TLAS and the current system:
  - When voluntary certification is introduced in Indonesia in 1990s, the progress is very slow, because it's not established based on the country's specification. While TLAS was developed based on Indonesia specific conditions and regulations.
  - Can not tell whether TLAS would cost less than other certification or not. However, TLAS would benefit the companies in terms of: increasing export demand, particularly from the countries which required certified wood products, and raise the price of the products. There are countries which would even raise the price of certified products, such as Australia.
  - Since TLAS is mandatory certification, it's not a replacement for other certification systems.
  - TLAS ensures all mandatory regulations, such as UKL/UPL, industry license, etc., are met by the companies.
  - TLAS as a harmonization of the prevailing regulation. Specific for Indonesia, but developed to meet international standard.
- Math analyses of Indonesian wood products market:
  - The situation is different nowadays. Building an association with great power such those exist in the new era (Orde Baru) is not possible. Indonesia is no longer the top player of international wood trading. Malaysia had overtaken Indonesia position. Indonesian industries are facing various problems: lack of labor force, raw material inputs, etc.

    - Japan is still the main export destination. Total volume exported to Middle East countries, including the Arab Emirates Union almost is equal the volume exported to Japan. However, the price is lower than Japan.
    - Most of plywood industries is still relying their timber supply on natural forest, which makes them uncompetitive in the international trade. Only several industries in Java had shifted their products to engineered wood. Those who uses engineered wood, such as from sengon wood, are the competitive industry in the international trade.
    - EU countries are self-sufficient countries, which survive even without imported products. Japan, on the contrary, relies on imported products. It would take different approach for EU and Japan. EU is strict with their requirements of certified products, while Japan is not so strict with its certification regulation.
    - There are various problems which cause high-cost economy. For example, license which should be obtain from 2 institutions, instead of just 1 integrated ones. The more abundance the regulation, the more restriction for the industries.
    - Rubber wood plantation were mostly (87%) owned by small stakeholders (farmers), while the remaining 13% were owned by private sectors and PTPN (state owned enterprise).
    - There is also study on market trends and market analyses on wood industries. There is also projection for the next 10 years.
    - The price of bio-composite products is better with TLAS, particularly in Australia and Italy.
    - Still more companies to be certified.
- TLAS and harmonized system category:
    - Veneer is covered in harmonized system (HS) 4408. Trade of veneer is regulated based on MoI regulation. Veneer included in panel category: 4408 veneer, 4411 plywood, 4412 particleboard.
    - Harmonization is needed to develop similar perception.
    - Category of HS is based on national customs system.

    - TLAS enables stronger bargaining position in the international trade.
    - Harmonization should be done, particularly between regulations in one country and other country.
- TLAS and products of community forest:
    - TLAS will cover not only the industry, but also the raw material. Raw material should be the first to get certification from TLAS. Uncertified raw material would led to problems in destination countries. However, since there is time limitation, TLAS is implemented concurrently for the products and the raw material.
    - SFM and legal wood should be singled out. SFM requires cutting cycle. Legal wood from community forest does not require cutting cycle. Regarding community forest, the regulation is related to ownership. When there is legal ownership, 1 requirement is met. Other requirements are related to license for cutting the tree and certificate of origin.
    - Certification for community forest is applied to groups which own the land, not to individual owner or farmer.
- Companies which own voluntary certification had bigger opportunity to market their products. However there is no difference between the price of certified and uncertified products. That is the reason why voluntary certification developed slowly. Problem is wood export to countries which has originality regulation, such as EU, requires certification for the exported products.
- TLAS ensures the fulfillment of the prevailing regulation by the companies being certified. Study on TLAS shows compatibility with the destination countries regulation or requirements.
- Certification is the requirement of export destination countries.
- There is a lot of industry in need of assistance regarding certification. There is opportunity for Faculty of Forestry IPB to assist the farmer or small holder to face the certification.
- Certification is important; it also plays the role of regulation harmonization.
- Support is needed to accelerate the process of socialization and implementation of TLAS.

C. Small-Diameter Logs for Producing Bio-Composite Products.

By Muh. Yusram Massijaya, Yusuf Sudo Hadi, Bedyaman Tambunan, Nurwati Hadjib, Dede Hermawan

Point of Presentation :

- Logs supply: Indonesian log supply before 2000s were dominated by natural forest, and after 2000s the supplies were dominated by plantation forest. There has been a change of source of wood supply.
- Big diameter logs had been increasingly difficult to find. The SDL had been view as the substitute.
- SDL is trees or logs with less than 10” diameter at breast high.
- Study on SDL showed that there are only slight different of the average basic properties of SDL from plantation forest and the natural forest is not.
- SDL research on plywood showed that the properties were in the accepted range standard.
- SDL research on LVL: better medium density of wood.
- SDL research on MDF: species used in the study is suitable for MDF.
- SDL research on Particleboard: species used in the study is suitable for particleboard.
- Changes of logs supply: from big → small diameter logs, dipterocarps → other species
- There should be a new line production
- The weakness of using SDL for veneer: more knots, more short veneer, more space to stack the logs, requires specific debarking, cutting, drying, repairing, composting, and gluing → more time consuming → higher cost →lower productivity
- However, wood mills can meet the required standard of export.
- Particleboard and MDF products: too low SG of wood is not suitable, and light color of wood is preferable.

Non Technical aspects barriers were, related to logs availability, government regulation, trade barrier (CoC, logs certification), bank support and skill training

D. Utilization of Small-Diameter Logs From Sustainable Source for Bio-Composite Products.

By Mohd. Hamami Sahri, Zaidon Ashaari, and Edi Suhaimi Bakar

Point of Presentation :

- Total forested land in Malaysia (55.3%): peninsular 44.7%, sabah 57.5%, Sarawak 65.5%. The area of plantation forest were lower that the natural forest.
- There had been conversion of forest into oil palm plantation.
- Log production in peninsular were decreasing by half from 1995 – 2005, while in the other two area (Sabah and Sarawak) there had been fluctuation of log production.
- There's an increasing of both supply and demand of sawn rubber wood from 1998 – 2003, and the supply still can not fulfill the demand.
- Focus of research: milling issues and appropriate properties of products manufactured from SDL. Potential SDL species had been reported previously.
- Methods: trials at the mills, visit and discussion with mill operator and managers, questionnaire, direct lab test, use of secondary data.
- Species used: rubberwood species, acacia species, sentang, sesenduk, mahang and oil palm.
- Oil palm had been seen as the complementing wood for jungle woods.
- Peeling trials:
    - all acacia logs can be peeled without interruption with consistent thickness, except for the core logs which have knots.
- Board properties from SDL species: potential for bio-composite products
- There had been financial problems in conducting this research, which had cause delays on several activities.

E. Performance of Cement Board Made of Small Diameter Logs.

By Dr. Dwight A. Eusibio and Dr. Francisco G. Lapitan

Point of Presentation :

- Species used: *Polysias nodosa*, *Alstonia macrophylla* G. Don, and *Eucalyptus urophylla*.
- Design: experimental on board size, pressing time, board thickness (8, 12, and 19 mm), board density (650, 750, and 850 kg/m³).
- Total 2025 specimens of wood wool cement board (WWCB).
- Procedure: mixing, mat forming, pressing, curing and conditioning.
- Results: MoR → *P. nodosa* and *E. urophylla* treated with calcium chloride showed increasing MoR, while the *A. macrophylla* treatment decrease the MoR.
- MoE: specimen treated with calcium chloride had higher MoE
- Nail head pull: treatment with CC increase the value compare with control.
- TS: treatment can decrease the TS properties of specimen compare to control.
- Water Absorption: Aluminum sulfate trigger water absorption, increase the WA properties
- Initial findings: MoR WWCB of P *nodosa* > other 2 species

Point of Discussion (C-E) :

- The use of SDL as raw materials for wood products requires new investments, particularly new machinery for production. The positive impact is more labor force employed in the industries.
- There is problem related to supply, from source of supply to products. There is also problem related to marketing aspects. Most consumers did not like white-colored wood, such as randu.
- License has also become problems. In Lampung, obtaining license to cut trees from plantation forest requires the same procedures as obtaining license to log natural forest. There should be differentiation between the two sources of timber.
- The use of SDL had cost investment on new machinery. There had been decrease in production capacity, increase in production cost, which led to decrease in company revenue.
- The price of SDL should be far lower than the big-diameter log, to encourage the use of community forest's timber.

- Regarding Malaysia experience in cutting the cost of production: merging small cooperation into a bigger one, developing mobile saw mill to produce sawn timber. Sawn timber using mobile saw mill increase. Mobile sawn mill uses almost all of the usable part of woods. To promote the utilization of rubber wood use for saw mill, the government designs incentives systems: provide land for farmer and decreasing tax for the cut timber.
- There are visual requirements of plywood which hard to be fulfilled using the SDL, for example SDL has many knots.
- However, the SDL is suitable for MDF. Problems in MDF related to licenses. The cost of timber extraction is high. There should be differentiation between timber from HPH and community forest. Transportation has become problems too. Source of timber is getting farther. Simplifying the legal aspects would encourage people to plant trees, because the biggest problems are caused by legal aspects.
- There is different requirement of wood materials for ships productions. Teak and camphor wood are common species used as ships materials. Ships need durable timber products. SDL had lower durability compare to teak or camphor wood. More research is needed to ensure the suitability of SDL for ships production. However, there is ongoing research on the performance of SDL compare to the original wood.
- Indonesia and Malaysia face the same issue on technical point of view. Production process issue: there are differences in log core products between Malaysia and Indonesia.
- The cost of utilization of SDL for BC is higher by 1.5 times. But the yield decrease by 15%.
- Mr. Bintang Simangunsong had the competence regarding financial analysis. The financial analyses of SDL usage should be discussed with him.
- The uses of Oil Palm fibers:
  - Oil palm is one of species available for analyses in Dr. Eusebio’s study.
  - Oil palm trunk had been used to produce core veneer. Problems with oil palm for veneer: moist, some machine cannot process the stem. In Indonesia there is the use of the outer part of the stem for veneer.

  - In the future, oil palm wood can be use for wood material. →high quality wood from oil palm trunk .
- There should be new path in using the SDL instead of the conventional one. The low result of SDL maybe because we used the conventional way to produce the products. Issue on the suitable technology is important.
- There's an emerging issues of green infrastructure, using reduce, reuse, recycled materials as building materials. Building bungalow using 100% wood would received more than concrete. There is potential to produce high-quality wood from SDL. The LVL had the potential to be used for structural wood. However potential, the use of SDL for BC products had not been able to ensure high-quality or high-strength products for structural uses.
- Chances or opportunity is opened to apply proposal to ITTO to conduct such research. The next deadline for the ITTO application would be January 2011. Proposal should follow the ITTO guidelines available on its website. Maximum of US$10000 fun could be awarded. There is also possibility to apply proposal to CFC. Information is available on both organization websites.
- There is technology using plasma energy to increase wood strength.
- Grading should be taken care of in research. Too high variability of samples being tested might lead to low result.

Conclusions and Recommendations of the Workshop

- There are total 124 participants attending workshop today: 84 participants from the industry and 40 from scientists, government officials, and students.
- The sessions of presentation and discussion on raw material aspects had led us to several conclusions. Minimal regulation seems to improve the diversification of wood products. However, there should be governance improvement both from the government, and the community. Such seminar would provide valuable inputs and recommendation for the government to improve the regulation.
- Nowadays, there is urgent need to have certification of the exported wood products in the international market, particularly in the EU and USA. Timber

Legality Assurance System (TLAS) was developed as the Indonesian standard for the international consumer, which build on governance, representativeness and credibility. TLAS is mandatory, and would benefit companies in terms of acceptance of their products in countries which requires certification, and price rising.

- From the view of technical aspect, SDL has been seen as potentially dominant wood for raw material for bio- composite industries.
- New line to process SDL is absolutely important (veneer based processing), which need Bank support, Skill training, Review of taxes and administration in utilizing SDL.
- The effect of wood/cement ratio and density on cement board properties vary depending on the wood species.

Visit to Forest Management Unit Cianjur

Forest Management Unit, Cianjur

The government organization in Cianjur which has a responsibility in forest management is Perum Perhutani. At the second day of the workshop, we visited it at Cianjur Forest Mnagement Unit. We had a meeting with Mr. Hezlisah Siregar. He explained many things about the forest condition in Cianjur. But, several point that we could get were :

Figure 120. Forest Management Unit, Cianjur

a. Cianjur Forest Management Unit (FMU) is the biggest plantation company in Java island. It has been well managed and success to develop mutual benefit collaboration with community around the forest area to build forest plantation.

b. Cianjur FMU is offering collaboration research to ITTO/CFC and other stakeholders.

c. Cianjur FMU is developing nursery for high quality teak seedling. The nursery is designed to fulfill the teak seedling requirement in West Java Province.

d. Cianjur FMU forest area is a good example for forest plantation in Indonesia. The dominant wood species is teak, mahogany, and pine.

The utilization of land in Cianjur Regency changes in last several year. In 1997 the land was used to dominated by state forest, dry or gardens, and plantations. While in 2002 the land was dominated by dry or gardens, state forests, fields, and plantations. Land utilization as community forests has increased significantly, while the settlements has increased too but not really significant . In the other side, land utilization for state forest is significantly has decreased. Based on the State of Environmental Report (SoE) in 2003 reported that in terms of vegetation cover, wide open land has increased by 22.75% over the last five years. Then in 2006, the state of forest area increased to 61,453 hectares and dominated the utilization of land use Cianjur Regency.

Forest resources in Cianjur regency consists of production forest, protection forest, natural forest and excursion forest. For existing production forest areas located in Cianjur regency are BKPH Cianjur, BKPH North Ciranjang, BKPH South Ciranjang, BKPH East Gede, BKPH North Sukanagara, BKPH South Sukanagara, BKPH Tanggeung, BKPH Cibarengkok and BKPH Sindangbarang, with a total forest area 67589.31 hectares, and for details, can be explained :

Until 2007, the value rate of productive forest damage is 1.9% per year. But at the end of 2006 the critical area has reduced from 22,916.52 hectares to 21,571.52 hectares because of the land rehabilitation program. But in general, it can be said that the forest condition in Cianjur regency is on alarming stage.

Cianjur is one area that susceptible of disaster caused by ground movements. Based on Geophysics and Meteorology Bereau, there are 30 districts in the regency of Cianjur, and 15 of them are putted in high possibility area to get a big disaster caused by ground movement. Ground movement itself caused by several factors, such as geological conditions, slope, rainfall, and miss utilization of land.

Ground movements in Cianjur regency almost happens every year. It can be happened because of high rainfall, topography Cianjur regency is hilly with varying levels of slope and vegetation conditions are not good enough in some places.

Community Forest

Community Forest located in Cipeuyeum, Cianjur. The participants got there after had a meeting in Perhutani. There is a little size of community forest in the middle of the rice fields and the forest is still in young age. The community forest in the location consists of Albizia. But, there was a mistake in planting the Albizia by the people around the forest. They planted the Albizia too near each other, and this condition makes the tree doesn't grow in their optimum size. The other trees, teak tree are grown near the rice field.

Figure 121 Community Forest

There is large of rice field near the area. Some of the workers, perhaps 10 villagers was doing their job when this visit was doing at the time. The area also becomes a planting fields of corn, papaya, coconut and the other plants.

Furniture Industry based on plantation Forest

The third visited place on the second day is small business unit of furniture industry. In the small building, the workers was making many kinds of furniture. They make cupboard, sofa, table and the other furniture. They get their recourses from the community forest near the small factory. They make it all by traditional tools. But, although they doesn't used any modern tools, they could sells their products for export commodity.

Figure 122 Furniture Industry based on plantation Forest

Logs Storage

Logs storage located in Ciranjang. The location was full by small diameter logs of Pine, teak, and the other wood. In the other side of the location, there is medium community forest of pine. In the other field, some workers were trying to moving the small diameter logs into the trucks. There are some of wood which put in group and has been marked by red and blue.

Figure123 Logs Storage

Teak Nursery

Still in Ciranjang, there is teak nursery in the other side of the logs storage location. The teak nursery field is big enough and the teak trees grow well. The staff of the Perum Perhutani said that sometimes there are a few of larva which destroyed the plants. However, the teaks in this place are excellent variation which ever made. That's why, they keep in secret how they could made this plant.

Figure 124 Teak Nursery

Evaluate the Usefullness of the Workshop

Table 55. Evaluate the usefullness of the workshop

No	Question	Score			
		1	2	3	4
1.	Do you get the benefit from this workshop?	0 %	16%	55%	29%
2.	Do you think this workshop was well organized?	0 %	29%	45%	26%
3.	Is the workshop relevant to the wood industry requirement?	2 %	19%	46%	33%

Number of participants : 124 persons

Score :
1 = Fair 2 = Good 3 = Very good 4 = Excellent

Your comment or suggestion :

" Utilization small diameter logs must be continue in the future."

" Workshop should invite participants from more diverse background, such as industry."

5. Project Duration and Schedule

Project CFC/ITTO/62-PD 40/00 Rev. 4 (I) Utilization of Small Diameter Logs from Sustainable Source for Bio-composite Products was planned for three years (36 months) starting 1 December 2007 to 30 November 2011. However, the project execution was 49 months, this was longer than the initial plan due to several communication and administrative barrier among the project collaborators. ITTO and CFC have been agreed to extent the project execution until December 2011 to give a chance for all the project collaborators executing all the project activities. A thirteen months project extention, from 1 December 2010 to 31 December 2011, was granted by ITTO and CFC without additional funds, to complete the remaining activities. Time table of the project execution can be seen in Table 56.

Table 56. Time table of the project execution.

Output/Activities	Yearly Quarter															
	Year 1				Year 2				Year 3				Year 4			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Output 1.1. Assess market needs																
A 1.1.1 Review market data and examine trends to understand what bio-composite products are sold today and where are they sold	■	■	■	■												
A.1.1.2. Determine where the potential for future market growth for bio-composite products exists	■	■	■	■												
Output 2.1. Address technical gaps in producing bio-composite products																
A.2.1.1. Identify suitable wood species and evaluate physical and mechanical properties				■	■	■	■						■			
A.2.1.2. Identify milling issues							■	■	■							

Output/Activities	Yearly Quarter															
	Year 1				Year 2				Year 3				Year 4			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
A.2.1.3. Identify quality control concerns for raw material and how to address them									■	■	■					
A.2.1.4. Evaluate the appropriate properties of products manufactured from SDL									■	■	■	■	■			
Output 2.2 Determine equipment needs for production and manufacturing constraints																
A.2.2.1 Review equipment availability (Such as chuckles lathes for veneer production, saw technology and press technology)										■	■	■				
A.2.2.2 Identify source and cost for equipment											■	■				
Output 2.3. Address production coordination issues																
A.2.3.1. Work with mills to identify the issues when incorporating SDL into the production process											■	■				
Output 2.4. Mitigate potential trade barriers																
A.2.4.1. Identify standards for selected products and markets, to ensure compliance											■	■				
A.2.4.2. Coordinate with output 2.1. to verify that appropriate test are conducted											■	■				
A.2.4.3. Establish quality control procedures											■	■	■	■		
Output 2.5. Comply with relevant standards																
A.2.5.1. Coordinate with international standards bodies					■	■	■	■	■	■	■	■	■	■		

Output/Activities	Yearly Quarter															
	Year 1				Year 2				Year 3				Year 4			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Output 2.6. Conduct regional workshop																
A.2.6.1. Coordinate workshop activities with project findings											■					
A.2.6.2. Solicit suitable attendees								■	■	■						
A.2.6.3. Produce workshop materials											■	■				
A.2.6.4. Conduct the workshop												■				
A.2.6.5. Evaluate the usefulness of the workshop												■				
PROJECT ORGANIZATION																
• Administrative personnel	■	■	■	■	■	■	■	■	■	■	■	■				
• PSC meeting				■				■				■				
• PEA meeting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
• Project monitoring, evaluation and administration by ITTO				■				■				■				

4. PROJECT OUTCOME, TARGET BENEFICIARIES INVOLVEMENT

Project outcome and target beneficiaries involvement of the project are as follows:

1. Collaboration is established between scientist, government officers, businessman, researcher, consultants, and Non Governmental Organization (NGO).
2. Network among the related stakeholders related to the utilization of small diameter logs for bio-composite products is established. Utilization of small diameter logs creates other business related to the bio-composite industries.
3. Students were involved in research activities, nasional seminars, international symposium and publication of scientific articles.
4. Several publications were produced during the project period. Several scientific publications still in process and will be published several months later.

5. ASSESSMENT AND ANALYSIS

Assessment and analysis of the project execution can be seen in Table 57.

Table 57. Summary of achievement and status of the activities

Project Elements	Indicators	Means of Verification	Analysis and Status
Development Objective: The development objective of the project is to contribute to the continuity of timber production, forest resource security, socio-benefit from sustainable sources, determination of SDL wood properties, and technology transfer of utilization of SDL for value-added bio-composite products.	a. Use of SDL in new or existing production operations. b. Increased use of forest resource resulting in production of value-added products. c. Traditionally non-merchantable species will be used in the timber supply stream after RIL methods; transfer of technology to the forest products industry.	a. Mill production records. b. Trade data. c. Products manufactured in compliance with international products standards.	Based on research results it was concluded that : a. Continued access to forest resources for supplies of timber. b. Continued demand for bio-composite products in international markets. c. Pricing of products sufficient to cover harvesting and manufacturing costs. d. Increasing supply of suitable raw material from plantation and community forest. The status of development objective has been accompalished

Project Elements	Indicators	Means of Verification	Analysis and Status
Specific Objective 1: To asses market needs of USDL from the tropical rain forest.	Database on potential for sale and trade of various bio-composites products using SDL.	- Market data from participating countries and ITTO. - Report on SDL species.	a. Market data of important bio-composite products has been available. b. Cooperation with companies and other institutions run well. c. Experts, study site, fund and continued support from GOI have been available. d. Required reports are available. The status of specific objective 1 has been accomplished
Output 1.1. Assess market needs.	Potential for future market growth for bio-composite products is determined.	- Report on potential for future market growth for bio-composite products.	The required report has been produced. The status of out put 1.1 has been accomplished.

Project Elements	Indicators	Means of Verification	Analysis and Status
Specific Objective 2. Determine the wood properties and utilization technology of SDL and transfer this technology for manufacturing of value-added bio-composite products.	Published report on the performance of the bio-composite products verifying compliance with appropriate product standards	- Reports on finding of available equipment for production, transportation, specialized handling of products from SDL. - Reports that identifies the relevant market standards and how they have been addressed.	All the required reports were been avalaible. Several publications in national seminar, international symposium and scientific journal are available. The status of specific objective 2 has been accompalished.
Output 2.1. Address technical gaps in producing bio-composite products.	Samples of SDL will be collected for wood properties determination.	- Report that identifies suitable wood species from native forest or plantation SDL for manufacturing bio-composite products.	a. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks b. Timely payment coinciding with project tasks and achievements. c. All required reports have been produced. The status of out put 2.1 has been accomplished.
Output 2.2 Determine equipment needs for production and manufacturing constraints.	Establishment of equipment requirements for producing the various bio-	- Report summarizing the findings of available equipment for	▪ Involvement of participants to assist with project management

Project Elements	Indicators	Means of Verification	Analysis and Status
	composite products.	producing bio-composite products, the costs of the equipment and gaps in the available technology as it pertains to production of SDL.	and coordination of technical, economic and marketing tasks ▪ All the required reports have been published. The status of out put 2.2 has been accomplished.
Output 2.3. Address production coordination issues.	Issues for incorporating SDL into the production stream is identified.	- Report that identifies how SDL can be incorporated into the transportation and sorting operations, needs for specialized handing equipment in the mill and issues related post-manufacture.	a. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks b. All the required report have been produced. The status of out put 2.3 has been accomplished.
Output 2.4. Mitigate potential trade barriers.	Identification and mitigation potential trade barriers by producing bio-composite products in compliance with internationally recognized standards.	- Report that identifies the relevant market and trade issues and how they have been addressed.	a. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks b. All the required

Project Elements	Indicators	Means of Verification	Analysis and Status
			reports have been produced. The status of the out put 2.4 has been accomplished.
Output 2.5. Comply with relevant standards.	Ensure the acceptance of manufactured bio-composite products.	- Report that identifies the relevant national, regional or international standards and the test and/or quality control procedures that satisfy the standards.	Coordination with International Standards Organization (ISO) has been conducted through Ministry of Forestry Republic of Indonesia. a. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks b. All the required reports have been produced. The status of out put 2.5 has been accomplished.
Output 2.6. Conduct regional workshop.	Transfer the developed technology and knowledge to the industry.	- Completion of a regional workshop for industry personnel.	a. Involvement of participants to assist with project management

Project Elements	Indicators	Means of Verification	Analysis and Status
		- Proceeding of the workshop. - Technical reports and publications.	and coordination of technical, economic and marketing tasks b. Regional workshop has been successfully conducted in IPB International Convention Centre, Bogor. c. All the required reports have been produced. The status of out put 2.6 has been accomplished.

6. LESSONS LEARNED

1. Lesson learned from project identification, design and implementation

The aspects of the project design which contributed remarkably to its success in achieving the development objectives among the others are as follows :

a. Defining the main problems of the utilization of small diameter logs for bio-composite products.

b. The problems were arranged in a problem tree diagram to find the root of the problem.

c. Logical framework as formulated to describe the interlinked among the project objectives, out puts, and activities. Some indicators and assumptions have to be define to measure the successful of project implementation.

2. **Project management :**

a. The project consists of 4 countries (Indonesia, Malaysia, Philippines, and Papua New Guinea) was more difficult in coordination, research execution, administrative, and financial. Furthermore the variation of capabilities among the institutitons was very high.

b. Frequent and drastic organizational structural changes in a collaborator agency which often involve shifting of personnel had resulted a serious problem in the execution of the project, although this phenomena is often unforeseeable and could not be avoided.

c. Project Steering Committee meeting with inviting all collaborators without financial support because not including in the proposal cause utilization of contingency fund.

d. Collaboration research activities among the supporting countries were more complicated compared to those of collaboration of research in one country.

3. Tecnical aspect :

a. There was a huge change of the bio-composite industry raw material, especially from large diameter logs which was harvested from natural forest to small diameter logs which was harvested from timber estate, community forest, and logging waste in natural forest.

b. There was a huge wood supply deficit in Indonesia. In order to overcome the problem, one of the available alternatives is facilitating the utilization of small diameter logs. This was also supported by the project research results which show that most of small diameter logs harvested from plantation forest, community forest and natural forest are suitable for plywood, LVL, glulam, particleboard and MDF production.
c. Nowdays, communities in Indonesia, particularly in Java island are very interesting in plantation forest, community forest and utilization of small diameter logs for bio-composite products and furniture.
d. Several years ago, most of plywood industry, particularly in Indonesia using large diameter logs from natural forest. Nowdays, most of the plywood industry changing or combine their raw material with small diameter logs. This forced them to improve their human resource capability, production technique, providing new machines such as spindleless rotary and hot press dryer.
e. The prospect of bio-composite is very good. Based on the research results the quality of the produced bio-composite products (plywood, LVL, glulam, particleboard, cement board and MDF) made from small diameter logs fulfill international standard.
f. Several small scale plywood industries using small diameter logs from platation and community forest were established in Java island, Indonesia.

7. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Development Lesson

In the period of the project execution, it was learned that project design, human resource capability and network were the most important aspects contributed to the success in achieving the specific objectives and project out puts. In project design, it was very important to define main problems to be addressed precisely, formulated the logicl framework to see the interlink between the project objectives, out put and activities. Some indicators and assumptions have to be defined to measure the successful of the project execution.

2. Operational Lesson

Project Steering Committee is very important and helpful for the project management. All actions in implementing the project activities have followed accordingly as recommended in minutes of meeting developed by the PSC. In case of this project, ITTO representative (Mr. Ramon Carrillo) and CFC representative (Ms. Yukiko Tomihisa) has shown their remarkable contribution and support for the success of the project execution.

3. Market and Technical aspecs Lessons

Veneer sheet production during the period of 2002-2006 by ITTO country member was more than 15 million m^3 and produced by Malaysia, Brazil, Indonesia, Ghana, India, the Philippines, and Côte d'Ivoire. Major tropical veneer sheet importers were The Republic of Korea, Taiwan, French, China and Italy. For plywood production in the same period was more than 84 million m^3 produced by Indonesia, Malaysia, Brazil and India. Major tropical plywood importers were Japan, United States of America, The Republic of Korea, Taiwan, China, and, a few Western European countries. Particleboard production was about 19 million m^3 and produced by Brazil, Thailand, Malaysia, and Indonesia. For fiberboard production in the same period was about 24 million m^3 produced by Brazil, Malaysia, Thailand, Indonesia, Venezuela and India.

Based on current world's demand and its trend, shares of Indonesia's bio composite product imports of total bio composite product imports in each major country destination as reported by importer countries and considering the principal policies and market forces that are likely to affect the global and regional markets, both plywood and medium density fibreboard made from small diameter log would be plausible to be developed for international market (i.e. Japan, China, the Republic of Korea, Taiwan, Saudi Arabia, and United Arab Emirates) as well as for domestic market. Meanwhile, veneer sheets and particleboard made from small diameter log would be plausible to be developed for domestic market.

The second focused of this study was to identify suitable wood species and evaluate physical and mechanical properties of small diameter logs. Research on small diameter logs of 24 species from natural forest and 14 species from plantation or community forest in Indonesia was carried out for physical, mechanical, and chemical properties regarding to biocomposite products feasibility. The results showed that low and medium densities wood were feasible for bicomposite products, and regarding to the result of market analysis, the prospectus products are plywood, laminated veneer lumaber (LVL), particleboard, medium density fiberboard (MDF), and glued laminated lumber (Glulam).

UPM Malaysia considered 9 groups of SDL have the potential as alternative raw materials for the production of bio-composite products, especially for plywood, laminated veneer lumber, oriented strand board (OSB), cement board and medium density fibreboard manufacturing. FPRDI Philippine did research on *Eucalyptus citriodora, Eucalyptus europhylla* and *Alstonia macrophylla* G. Don in terms of basic properties, and these wood species were investigated for cement board feasibility. PNG Forest Research Institute and Bogor Agricultural University did research on basic properties of 6 wood species of PNG, and several SDL species are feasible for bio-composite products (plywood, LVL, glulam, particleboard and MDF), however some of them only feasible for particleboard and MDF.

In order to produce the high quality product, several milling issues and quality control concerns for raw material were identified. Some milling issues regarding to utilize SDL for LVL and plywood are determining on wood fundamental properties, spindle less rotary machine for veneer production, low quality of produced veneer, hot press veneer drying, pay attention to veneer repair and compose, gluing technique, and pressing process. The main problem to be addressed in Glulam production using SDL is in board production, drying lumber (lamella), and gluing process. In particleboard manufacturing reported that there is no technical problem in producing high quality particleboard and MDF using SDL, however low density SDL is avoided due to the economical point of view.

Regarding to the change of logs supply in Indonesia from natural forest to plantation or community forest, monitoring system for quality and quantity of incoming raw material is very important in terms of wood species, grade, moisture content, dimensions, volume, and visual appearance of SDL for checked and documented. The important issues related to the utilization of SDL as raw materials for Bio-composite products (glulam, LVL, plywood, particleboard and MDF) are wood density, spiral and interlocked grain, knots, juvenile wood, decay, and extractive content. The SDL incoming raw material should be processed as soon as possible due to the low natural durability.

The following research was done for fundamental properties of biocomposite products manufactured from SDL. Evaluation of appropriate properties of plywood from SDL can be mentioned that the surface quality of Urea Formaldehyde bonded and Melamine Formaldehyde bonded plywoods was classified as grade 1, and all of the plywood shear strength parallel and perpendicular to the face or back veneer grain in dry and wet condition fulfilled the JAS Standard for plywood No. 232 year 2003. The average rotary veneer yield of SDL from community and plantation forest using spindle-less rotary lathe was 62 % with standard deviation of 9.9%.

Evaluation of appropriate properties of Laminated Veneer Lumber (LVL) from SDL, the moderate specific gravity wood possessed had 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 SDL of moderate specific gravity woods were suitable to be used for structural uses such as for supporting poles, frame in house, roof timbering, floor joint, and other structural uses.

Evaluation of appropriate properties of Glued Laminated Lumber (Glulam) from SDL the some Glulams were classified to the group E10-E11 based on modulus of elasticity properties, but based on the value of modulus of rupture Glulam was classified or grouped as E10-E17, and some the other had lower grade depending on wood species used. As an example Glulam made from mixed species from jabon-mangium and mangium-manii were not eligible for construction (E<E10), but Glulam made from mangium, jabon and mixed pine-mangium met the JAS (2003) can be used for wood construction and quality pertained E10 or more. The recovery of glulam manufacture from SDL plantation timber ranged from 31-53% with an average of 38%.

Evaluation of appropriate properties of particleboard from SDL could be mentioned that wood species used in the experiment could be utilized for particleboard and these species did not much affect particleboard properties, single species and mixture of species were not different regarding to physical and mechanical particleboard properties. Low density particleboard was still lower in terms of performance related to physical and mechanical properties, but medium and high density particleboards exhibited satisfied performance for physical and mechanical properties. Regarding to termite test the results showed that higher wood density had higher resistant to termite attack, and the resistance was related to its constituent wood or in other words more resistant wood species produced more resistant particleboard to termite attack.

Evaluation of appropriate properties of medium density fiberboard (MDF) from SDL could be mentioned that physical properties of MDF made from rubber wood, mangium, and mixture of both species were excellent and was matched to JIS Standard 5905-2003. The MDF modulus of rupture was lower than the JIS Standard 5905-2003 requirements, however the modulus of elasticity (MOE) value fulfilled JIS standard, and the species used had significant effect on MOE of the resulting MDF, where the mixture of rubber wood and mangium wood resulted in a highest MOE values.

The next activities were to determine equipment needs for production and manufacturing constraints, including review equipment availability, and identify source and costs for equipment. Regarding to equipment availability, all the mills have satisfied equipment required and can produce biocomposite products for export marker to varied countries destinations. In conventional plywood mill the raw material uses logs with diameter more than 40 cm, but nowadays and further future the logs supply will be dominated by SDL, in this case the mill has to provide some equipments namely spindle-less rotary lathe and hot press dryer, and also more activity in veneer repairing and veneer composing. But for the other products (not based on veneer products) the available equipment in the mills are still satisfied.

Information of source and costs for equipments of hot press dryer for veneer and spindle-less rotary lathe are mainly produced by China because the price is much cheaper compare to the equipments produced by Taiwan, Japan, Germany, Italy and other countries. As an example, hot press dryer BJG48-40-12 made in China costs USD 46,875, spindle-less rotary lathe 9’ 9HL-W-3-350 consists of input conveyor costs USD 4,162, spndle-less lathe costs USD 49,210, output conveyor USD 4,995, and spindle-less rotary lathe 9’ made in Taiwan costs USD 90,000. Other spindle-less rotary lathe 5’ 5HL-W-3-350 made in China costs USD 22,800, and spindle-less rotary lathe 5’ made in Taiwan costs USD 60,000.

Regarding to implementation of SDL for biocomposite products, work with mills to identify issues when incorporating SDL into the production process was done. Implementation of SDL for plywood mills has to pay attention that the portion of high quality plywood resulted from SDL is very low as compared to that of large diameter log (LDL), however laminated veneer lumber, glulam, medium deinsity fiberboard and particleboard industries did not report any inferior products. Some critical issues in SDL implementation compared to LDL at plywood mill are log pond needs more space for logs storage, debarking and log cutting have more activity, SDL cannot be round up in the conventional rotary lathe because the minimum diameter to be processed in conventional rotary lathe is 40 cm, and plywood produced from SDL is relatively lighter compared to those made from LDL, veneer resulted from SDL cannot be dried using conventional dryer because it tends to be wavy and the portion of narrow veneer was very high and the veneer resulted from SDL should use hot press dryer, veneer storage could be a problem because dried veneer easily attacked by mold due to the minimum extractive content, veneer resulted from SDL need repairing process with much more time and skilled human resources as compared to those of LDL veneer, the capacity of veneer jointer decreased sharply when incorporating SDL into the production process because the portion of narrow veneer was very high as compared to those of LDL.

The next process is assembling veneers to be plywood, and some attention should be intensively done at veneer arrangement or veneer composing which needs more time because so many jointing in one sheet veneer; moreover arrangement of face and back veneer should be conducted more carefully, glue spreading needs more time when incorporating SDL into the production process as compared to those of LDL because glue spreading process need two times process for avoiding veneer being overlapped and detached and for avoiding core gap, prepress should be arrange very carefully to adjust glue penetration and veneer overlap, materials requirement on the plywood industry increased sharply especially glue tread, hot melt, gummed tape, cutter and knife because the total number of jointer increased by about 300 %, other aspect is also important i.e. skill of human resources should be improved to facilitate production of high quality plywood made from SDL.

The other work was done to identify potential trade barriers trough standards for selected products and markets, to ensure compliance and to verify that appropriate test were conducted. Several standards known for bio-composite products such as plywood, LVL, glulam, particleboard and MDF. Among the international standard being used by Indonesian bio-composite industries are Japan Standard (JPIC/JAS), British Standard (BS), United States Standard (IHPA), German Standard (DIN). However, Japan Standard is the most popular used in Indonesian Bio-composite industries. Field research to the various bio-composite (plywood, LVL, glulam, particleboard and MDF) industries in Indonesia shown that most of the bio-composite products quality which was produced from small diameter logs fulfills the international standards.

To ensure quality assurance, establish quality control procedures were conducted ensuring that products are meet with certain standard. Quality control involves the examination of a product or process for certain minimum levels of quality. The goal of a quality control is to identify products that do not meet a company's specified standards of quality. If a problem is identified, the job of a quality control team or professional may involve stopping production temporarily. Depending on the particular product, as well as the type of problem identified, production or implementation may not easy entirely.

The quality characterize of the products depends on the panel being produced. Since the plywood is produced by assembled from layers of veneer, the moisture content and shear strength is the critical quality that shoud be meet with a certain minimum levels. The surface quality of plywood, such as knot, roughness, decay, discolouration, etc. are the additional quality characterize of plywood which will drive the market penetration. In case of glulam and LVL, the bending strength and shear strength are the essential quality that should be fulfilled. The density, internal bond strength, and bending strength are the performance of particleboard and MDF that should be meet with the certain standard.

Concerning coordination with international standard bodies, Indonesian USDL team have actively involved to contribute for ISO standards improvement through the Ministry of Forestry Republic of Indonesia based on the USDL research results, experiences and their expertise in bio-composite products.

To complete the project, regional workshop has been organized and convened in Bogor Indonesia in December 2010 to facilitate the transfer of technology on SDL management and utilization for biocomposite products to regional academicians, the timber industry sectors, and related government officers. Scientists, students, researchers, related industries representatives, birocrate or decision makers, experts, related association or society, and Non-Governmental Groups from Indonesia, and some representatives from Malaysia, Philippines, and Papua New Guinea have been involved the actively. We discused all topics concerning current and future markets of bicomposite products, basic properties of some wood species from Indonesia, Malaysia, Philippine, and Papua New Guinea and the possibility for biocomposite products, biocomposite products properties from SDL utilization, and the issues to implement SDL to the mills production.

B. Recommendations for Future Projects

1. Identification and Design

a. Many bio-composite industries have been shown their interest to use the information, technique and research results from the project. For this reason, there is a need to continue the project focusing in training on utilization of SDL for bio-composite products and dissemination of the project results.

b. Development of homepage and publication of the research results in scientific journals and international fora to support utilization of SDL for bio-composite products is strongly recommended.

c. Project design should be communicated and discussed with related experts for obtaining more advice and recommendation.

2. Implementation

Intensive communication with all of the collaborators should be carried out for smooth and better project implementation. Regular control and monitoring to the project execution progress should be conducted by the Project Executing Agency.

3. Organization and Management

The organization structure and management of this project could be repetitively formet to ensure that all activities in the next project are planned and implemented accordingly.

Responsible for the completion report

Bogor, 15 June 2012

Prof. Dr. Yusuf Sudo Hadi, M.Agr.

Project Coordinator

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Annex 1. Logical Framework

PROJECT ELEMENTS	INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Development Objective: The development objective of the project is to contribute to the continuity of timber production, forest resource security, socio-benefit from sustainable sources, determination of SDL wood properties, and technology transfer of utilization of SDL for value-added bio-composite products.	a. Use of SDL in new or existing production operations. b. Increased use of forest resource resulting in production of value-added products. c. Traditionally non-merchantable species will be used in the timber supply stream after RIL methods; transfer of technology to the forest products industry.	a. Mill production records. b. Trade data. c. Products manufactured in compliance with international products standards.	a. Continued access to forest resources for supplies of timber. b. Continued demand for bio-composite products in international markets. c. Pricing of products sufficient to cover harvesting and manufacturing costs. d. Adequate supply of suitable raw material from natural forest or plantation thinning.
Specific Objective 1: To asses market needs of USDL from the tropical rain forest.	Database on potential for sale and trade of various bio-composites products using SDL.	- Market data from participating countries and ITTO. - Report on SDL species. - Receipt of reports by the Common Fund.	a. Market data is available. Genetically and environmentally, the diameter growth some species is limited. b. Cooperation with companies and other institutions run well. Experts, study site, fund and continued support from GOI are available.
Output 1.1. Assess market needs.	Potential for future market growth for bio-composite products is determined.	- Report on potential for future market growth for bio-composite products. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	Market data is available.

PROJECT ELEMENTS	INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Specific Objective 2. Determine the wood properties and utilization technology of SDL and transfer this technology for manufacturing of value-added bio-composite products.	a. Published report describing harvesting and silvicultural aspects of using SDL b. Published report on the performance of the bio-composite products verifying compliance with appropriate product standards c. Published report on cost analysis for incorporating SDL into production	- Reports on finding of available equipment for production, transportation, specialized handling of products from SDL. - Reports that identifies the relevant market standards and how they have been addressed. - Receipt of reports by the Common Fund	Successful completion of the harvesting and silvicultural studies, performance studies, and cost analysis
Output 2.1. Address technical gaps in producing bio-composite products.	Samples of SDL will be collected for wood properties determination.	- Report that identifies suitable wood species from native forest or plantation SDL for manufacturing bio-composite products. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	d. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks e. Timely payment coinciding with project tasks and achievements
Output 2.2 Determine equipment needs for production and manufacturing constraints.	Establishment of equipment requirements for producing the various bio-composite products.	- Report summarizing the findings of available equipment for producing bio-composite products, the costs of the equipment and gaps in the available technology as it pertains to production of SDL. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	▪ Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks ▪ Timely payment coinciding with project tasks and achievements

PROJECT ELEMENTS	INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Output 2.3. Address production coordination issues.	Issues for incorporating SDL into the production stream is identified.	- Report that identifies how SDL can be incorporated into the transportation and sorting operations, needs for specialized handing equipment in the mill and issues related post-manufacture. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	c. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks d. Timely payment coinciding with project tasks and achievements
Output 2.4. Mitigate potential trade barriers.	Identification and mitigation potential trade barriers by producing bio-composite products in compliance with internationally recognized standards.	- Report that identifies the relevant market and trade issues and how they have been addressed. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	c. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks d. Timely payment coinciding with project tasks and achievements
Output 2.5. Comply with relevant standards.	Ensure the acceptance of manufactured bio-composite products.	- Report that identifies the relevant national, regional or international standards and the test and/or quality control procedures that satisfy the standards. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	Coordination with international standards bodies is well done. d. Involvement of participants to assist with project management and coordination of technical, economic and marketing tasks b. Timely payment coinciding with project tasks and achievements
Output 2.6. Conduct regional workshop.	Transfer the developed technology and knowledge to the industry.	- Completion of a regional workshop for industry personnel. - Proceeding of the	Fund, participants, workshop material are available. a. Involvement of participants to

PROJECT ELEMENTS	INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
		workshop. - Workshop participant number of technical reports, educational reports, and publications. - Progress reports at the completion of output milestones - Advisory committee meetings - Audited financial reports	assist with project management and coordination of technical, economic and marketing tasks e. Timely payment coinciding with project tasks and achievements