ADDRESS TECHNICAL GAPS IN PRODUCING BIO-COMPOSITE PRODUCTS IDENTIFY SUITABLE WOOD SPECIES AND EVALUATE MECHANICAL PROPERTIES

A Technical Report Prepared for CFC/ITTO-USDL

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CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

I. INTRODUCTION

A. BACKGROUND

Natural forest in Indonesia is essentially public lands, managed and protected by the Government of Indonesia. Natural forest utilization in Indonesia was started in the 1970s as a national development program. For the purpose of increasing national revenue to support development programs, a vast utilization program in the natural forest was implemented. Wood was the main product to be utilized. The popular wood species produce in Indonesia are meranti (*Shorea* sp.), keruing (*Dipterocarpus*), mersawa (*Anisoptera* sp), resak (*Vatica rassak*), teak (*Tectona grandis*), sengon (*Paraserianthes falcataria*), Acacia (*Acacia mangium*), pine (*Pinus merkusii*), and many other tropical wood species. The wood species in Indonesia believed more than 3,000 species, and not more than 500 wood species used for commercial purposes.

Log production activity in Indonesia is carried out by Stated-Owned Enterprises (BUMN) in conjunction with the private sector using a Forest Concessionaire System (HPH), under direct control of the Ministry of Forestry. In the early 1970 to 2000 the dominant wood supply came from natural forest. The wood supply came from high quality tree with large diameter log, sound, cylindrical and straight. The wood supply are primarily to support plywood industry and sawmill. However, after 2000 the trend of wood supply from natural forest decreased and on the contrary the wood supply from plantation forest increased, the produced logs between 2000 – 2006 reached 9.0 to 24.2 million m^3 and about 60% were from plantation forest (Ministry of Forestry, 2007). Changing in wood supply from natural forest to plantation forest affects 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, and these matters forced the wood processing industry to investigate the physical and mechanical properties of the wood and improve their processing technology, otherwise they will be facing a serious problem in the future. The most important fundamental properties for bio-composite products, are wood density, radial and tangential shrinkages, static bending strengths (modulus of rupture (MOR) and modulus of elasticity (MOE)), and compression strength (parallel and perpendicular to the grain).

According to the previous study concerning Market Assessment : Determine where the potential for future market growth for bio-composite products exists (Simangunsong and Tambunan, 2008) stated that based on the current world’s demand and its trend, shares of Indonesia’s bio-composite product imports of total bio-composite products 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 fiberboard (MDF) 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.

LVL (Laminated Veneer Lumber) and Glulam (Glued Laminated Lumber) are not yet popular in Indonesia nowadays. However, these kind of composite products are plausible to be developed in Indonesia in the near future. This is due to the limited production of high quality sawn timber and increasing of sawn timber demand for construction purposes.

Based on the above reasons, the selected bio-composite products in this research were plywood, MDF, particleboard, LVL and Glulam.

B. PURPOSE

The objective of this research is to find out the fundamental properties (important physical and mechanical properties) of small diameter logs from natural forest and plantation or community forest which is related to the required properties for bio-composite products production, especially plywood, MDF, particleboard, LVL and Glulam.

II. PRESENT STATUS OF INDONESIAN BIO-COMPOSITE PRODUCTS RAW MATERIAL

Commercial utilization of wood as forest product in Indonesia is activities primarily to utilize wood without destructing or minimizing negative impact the environment and undermining the main functions of the forest area. Those activities could only be executed in forest area with high commercial wood value with license.

The license to commercially utilize wood in natural forest is license to utilize production forest for which the activities consist of harvesting or felling, transporting, planting, tending, protecting, processing and marketing. The license could be granted to individuals, cooperatives, private companies, state-owned enterprises/local government-owned enterprises.

Based on the data as of December 2007, there were 324 licenses/forest concessionaires in Indonesia commanding a total area of operation of 28.27 million ha. Most forest concessionaires operations are located in Kalimantan island 178 companies with a total area of 12.86 million ha, Sumatra island 39 companies with a total area of 2.14 million ha, Sulawesi island 30 companies with a total area of 1.92 million ha, Papua island 49 companies with a total area of 9.59 million ha and the least located in Maluku and North Maluku amounting to 28 concessionaires operated in the area with a total area of 1.76 million ha (Ministry of Forestry, 2008).

The license to run business of industrial timber plantation may define as the permit to develop plantation forest within production forest area for which the activities consist of land preparation, seedling, planting, tending, protecting, felling or harvesting, processing and marketing of wood. The business may consist of planting monoculture or mixed species in forest production area particularly within bare lands, coarse grass and/or bushes of the area. Up to the end of December 2007, there were 143 units of license/industrial plantation companies controlling a total of 7.12 million ha. However, the actual planted in 2007 only 334,838.71 ha (Ministry of Forestry, 2008).

A. STRUCTURE OF INDONESIAN WOOD PROCESSING INDUSTRY

Wood processing industry is one of the country's assets that is important and should be maintained and developed to improve the Indonesian people's welfare. Therefore, the policy of the Government of Indonesia on wood processing industries should be able to provide clear direction, credible, and have clear vision for the future so that the industries can produce superior quality of products that are highly competitive in the market, both domestic and international.

Wood processing industry is an industry that mostly uses wood raw material from natural production forests, however currently some industries, especially pulp and paper industries, several plywood industries, and Medium Density Fiberboard industry have used wood from plantation forest (HTI) in addition to using non-wood materials and raw materials from recycling process.

The development of wood processing industries in Indonesia during 1990 to present was started by speed development of downstream industries of sawmill and plywood, pulp and paper, and Medium Density Fiberboard (MDF) with quite large capacity. It is planned the raw materials for the industries will be supplied from the plantation forest products. Nowadays, lack of supply of raw materials is getting worse along with the decrease in the production of natural forests.

Data from Ministry of Forestry of the Republic of Indonesia regarding the structure of wood processing industries in Indonesia in year 2005 is presented in **Table 1**.

Table 1. Structure of wood processing industries in Indonesia

Type	Unit **)	Permit Capacity/Year	Needs of Raw Materials (m^3)
Sawmill	1,540	10,491,750 m^3	16,922,105
Plywood/*Veneer*/LVL	113	11,066,813 m^3	20,157,842
Chip wood	6	823,802 ton	1,259,082
Pulp	7	5,865,000 ton	27,764,910
MDF	5	625,000 m^3	657,500
Total	1,671		66.760,439

Source: Ministry of Forestry of the Republic of Indonesia, 2007

In the last few years, wood processing industries in Indonesia have been experiencing serious and threatening problems that if government does not have the right policy it can be guaranteed that the wood industry will collapse in the near future. Among the problems are lack of supply of raw materials from natural and plantation forests, illegal logging, low efficiency in the use of raw materials, security and business assurance, environmental issues, labor issues, and the increase of other country's capability in producing processed wood.

The results of last survey documented by the Association of Wood Processing Enterprise (APKINDO) done in 2006 stated that the number of plywood/veneer/MDF that are in operation was only 53 units (44 units plywood, 8 units secondary processing, and 1 unit particleboard). The rest was temporary stopped operating (26 units) and fully stopped (49 units).

The results of monitoring by the Directorate of Forest Products Processing and Marketing Ministry of Forestry Republic of Indonesia in September 2006 show that 82 units of wood processing industries, with a total capacity of 3,613,405 m^3 (consisted of 1,339,200 m^3 sawn timber, 86,650 m^3 veneer, and 2,187,555 m^3 plywood) were not active.

Based on the above data, it can be concluded that plywood, sawmill and veneer industries have experienced shortage of raw materials that have caused them to close, stop the operation or operate under their potential capacities. The condition of wood production within the last ten years (1998 -2007) is presented in **Table 2**.

Table 2 shows that the main wood product of Indonesia in 2005, 2006 and 2007 were plywood (4,533,749 m^3 , 3,811,794 m^3, 3,454,350 m^3 respectively), sawn timber (1,471,614 m^3, 679,247 m^3, 525,209 m^3 respectively), *veneer* (1,012,205 m^3, 255,759 m^3, 299,202 m^3 respectively) and pulp (988,192 ton, 3,370,600 ton, 4,881,966 ton respectively). The data above show clearly that production of plywood, sawn timber, and veneer in the period of 2005 – 2007 decreased sharply. On the contrary pulp production increased sharply at the same period.

In the period of 1998 – 2007 the trend of processed wood production decrease sharply from year to year except pulp production. This is because log production from natural forest decreased sharply on the other hand log production from plantation forest cannot fulfill the log requirement of wood processing industry.

Table 2. Condition of processed wood products in the last ten years

No.	*Years*	*Plywood* (m^3/CuM)	*Sawn timber* (m^3/CuM)	*Wood Working* (m^3/CuM)	*Block Board* (m^3/CuM)	*Veneer* (m^3/CuM)	*Particle Board* (m^3/CuM)	*Chip Wood* (m^3/CuM)	*Pulp* (Ton/Tons)	*Others* (m^3/CuM)	Moulding (m^3/CuM)	Dowel (m^3/CuM)
1.	1998/1999	7,154,729	2,707,221	6,510	661,954	1,314,063	282,347	495,982	1,993,624	795,005	978,038	5,425
2.	1999/2000	4,611,878	2,060,163	10,472	427,096	1,034,999	188,054	203,325	1,194,283	647,854	634,465	3,802
3.	2000	4,442,735	2,789,543	299,412	321,125	668,842	200,034	19,885	658,984	–	160,336	2,640
4.	2001	2,101,485	674,868	278,088	388,004	94,228	296,877	384,803	702,121	37,384	139,134	542
5.	2002 *)	1,694,405	623,495	71,681	121,560	4,361,044	6,731	22,024	280,591	–	161,833	–
6.	2003	6,110,556	762,604	161,814	436,418	289,191	93,642	127,377	4,662,337	726,502	321,653	–
7.	2004	4,514,392	432,967	387,503	277,396	155,374	244,070	316,673	2,593,926	766,401	238,743	–
8.	2005	4,533,749	1,471,614	131,297	403,160	1,012,205	124,768	352,078	988,192	360,298	272,668	3,680
9.	2006	3,811,794	679,247	39,100	189,007	255,759	40,655	556,967	3,370,600	23,060	119,396	152
10.	2007	3,454,350	525,209	-	204,066	299,202	-	1,103,506	4,881,966	-	-	-
Total		**42,430,074**	**12,726,930**	**1,385,877**	**3,429,787**	**9,484,907**	**1,477,177**	**3,582,619**	**21,326,624**	**3,356,504**	**3,026,267**	**16,241**

Source: Forestry Statistics, Ministry of Forestry (Indonesia), 2008.
Notes:
(-) : no data
*) : corrected data

B. WOOD PRODUCTION AND MARKETING

1. Production

In general, logs used as raw materials in wood processing industries originated from natural forest, plantation forest, and community forest. Data on the log production during year 2003-2007 is presented in **Table 3.**

Table 3. Recapitulation of log production based on the source of production in 2003-2007

No.	Year	Source/Origin of Production					Total (m^3/CuM)
		Natural Forest (m^3)		Plantation Forest (m^3)		Community Forest/ Other License (m^3/CuM)	
		AWP	TUC	SOE	IFP		
1.	2003	4,104,914	956,472	976,806	5,325,772	59,538	11,423,501
2.	2004	3,510,752	1,631,885	923,632	7,329,028	153,640	13,548,938
3.	2005	5,720,515	3,614,347	757,993	12,818,199	1,311,584	24,222,638
4.	2006	5,586,722	3,434,181	337,797	11,451,249	982,195	21,792,144
5.	2007	6,437,685	3,063,607	48,034	20,614,209	1,328,050	31,491,584
Total		**25,360,588**	**12,700,492**	**3,044,262**	**57,538,457**	**3,835,007**	**102,478,805**
Total Percentage		**24.75**	**12.39**	**2.97**	**56.15**	**3.74**	**100.00**
Grand Total		**38,061,080**		**60,582,719**		**3,835,007**	**102,478,805**
Grand Total Percentage		**37.14**		**59.12**		**3.74**	**100.00**

Source: Indonesian Forestry Statistics, 2008 (data analyzed)

Note :
AWP : Annual Work Plan.
TUC : Timber Utilization Concession.
IFP : Industrial Forest Plantation.
SOE : State-Owned Enterprise

Table 3 shows that log production from the plantation forest during 2003-2007 is cumulatively higher compared to those from the natural forest. The Indonesian total log production the period of year 2003-2007 is 102,478,805 m^3 which is produced from natural forest for total amount of 38,061,080 m^3 (37.14%) and the rest come from plantation forest and community forest or other license. The log production from plantation forest and community forest or other license at the same period is 60,582,719 m^3 (59.12%), and 3,835,007 m^3 (3.74%), respectively.

The above data show clearly that there is a new trend of wood supply in Indonesia which is relay on the plantation forest and community forest or other license as source of wood supply. This phenomenon is design intentionally by the Government of Indonesia due to the high quantity of forest degradation due to illegal logging and unperformed forest management practices during several years forest concession practices.

2. Wood Marketing

Wood forest products are classified into wood working timber and woods for the raw materials of pulp and paper or chips. Wood working timber requirements include big diameter and long log (7.4 m) and are used in sawmills and plywood plants. Chip wood should have diameter 10 cm and up, with log length usually 2 m.

Market for wood working timber includes sawmill, moulding and joinery plants, and furniture and plywood. Progress in technologies has allowed plywood and laminated veneer wood industries to use wood working timber with smaller diameter produced by HTI (fast growing species) to produce composite products (plywood, LVL, particleboard, Medium Density Fiberboard), pulp, and paper.

The distribution and marketing of logs highly depend on timber species, number and the capacity of existing industries, forest accessibility, and the availability of transporting roads, forest potentials, and timber marketing strategy.

Timber produced from the HTI, both those for woodworking and chips, are managed the HTI concession owner. Usually, the products are marketed into wood processing industries within the same group or outside the group within or between province/inter-insular.

The timber price highly depends on the timber species, diameter, quality and location of the timber. **Table 4** presents data on export volume, foreign income, and average price of logs and processed wood exported and imported to various countries in 2007.

Table 4. Indonesian logs and processed wood export and import in 2007

No.	Type of product	Volume (100 kg)	Value (1000 US$)	Average Price (US$/kg)
	Export			
1.	Log	0	0	0
2.	Sawn timber	63,721,094	55,995,382	0.88
3.	Plywood	1,599,808,022	1,402,018,644	0.88
4.	Pulp	2,437,372,466	1,065,657,119	0.44
5.	Veneer sheet	3,134,035	6,483,007	2.07
6.	Particleboard including OSB	5,616,468	2,426,267	0.43
7.	Fiberboard	214,902,295	70,802,188	0.33

No.	Type of product	Volume (100 kg)	Value (1000 US$)	Average Price (US$/kg)
	Import			
1.	Log	55,326,249	18,995,944	0.34
2.	Sawn timber	35,780,832	22,691,426	0.63
3.	Plywood	54,481,773	23,774,279	0.44
4.	Pulp	892,958,546	590,685,876	0.66
5.	Veneer sheet	7,575,538	7,423,132	0.98
6.	Particleboard including OSB	151,562,933	35,407,122	0.23
7.	Fiberboard	62,511,563	23,612,637	0.38
	Balance (Export – Import)			
1.	Log	-55,326,249	-18,995,944	-0.34
2.	Sawn timber	27,940,262	33,303,956	0.24
3.	Plywood	1,545,326,249	1,378,244,365	0.44
4.	Pulp	1,544,413,920	474,971,243	-0.22
5.	Veneer sheet	-4,441,503	-940,125	1.09
6.	Particleboard including OSB	-145,946,465	-32,980,855	0.20
7.	Fiberboard	152,390,732	47,189,551	-0.05

Source: Indonesian Forestry Statistics, 2008 (data analyzed)

Based on the above data, it is clear that Indonesia is not export log due to the Government ban. Indonesia imported logs for a total amount of 55,326,249 kg (US $ 18,995,944). In case of veneer sheet and particleboard including OSB, the total Indonesian import is higher compared to those of export. However, in case of sawn timber, plywood and pulp, the total Indonesian export is higher compared to those of import. Processed wood products from Indonesia are exported to various countries, especially to Asia, such as Japan, Singapore, Taiwan, Hong Kong, China, and South Korea, while some are exported to European countries and the USA.

Discussion with actors in wood processing industries concluded that the market for plywood, sawn timber, wood working, pulp and paper and other wood products is still wide open, proven by the many wood processing industries that cannot fulfill orders due to lack of raw materials.

C. LOG POTENTIAL FROM NATURAL FOREST

The Ministry of Forestry Republic of Indonesia (2005) reported that based on the results of the latest recalculation on Indonesia forest cover status for 2003, forest cover in Indonesia was estimated at 133.6 million ha or around 71% of Indonesia total land area. Out of the 133.6 million hectares, 60.9 million ha has been designated for natural production forest, either Limited Production Forest or Permanent Production Forest. This recalculation show too that production forests comprised 14.8 million ha of primary natural forest (24.3 %), 21.6 million ha of secondary natural forest (35.5%), 2.4 million ha of forest plantations (3.9 %) and 18.4 million ha of non-forested areas (30.2%), while no data was available related for the remaining 3.7 million ha (6.1%). Further, 88% of total remaining primary forest and 72% of total secondary forest is located in Papua and Kalimantan. The extensive area of non forested zones indicates the current highly degraded state of natural forests. This is apparent from the extremely sharp decline in log production during the period of 1994 – 2005, which fell from 17.3 million m^3 in 1994 to 5.7 million m^3 in 2005. (Manurung, 2007).

According to the Ministry of Forestry Republic of Indonesia (2008), by 2007, the number of HPH (Forest concession)/IUPHHKs (Forest Products Utilization License) were 324 concessions covering an area of 28.27 million ha. The large number of HPH/IUPHHKs not in active operation (154 units with an area of 17.38 million ha) was due to a number of factors that can be categorized into two groups: internal factors covering poor company health, lack of professional human resources, low level of commitment of forest management, and permit holders waiting only for a more conducive situation; and external factors including : inconsistency and lack of integration in central and regional rules, continued illegal logging, excessive claims by local communities and lack of business certainty. (Manurung, 2007).

When compared to the total area of production forests (60.9 million ha), the total area of HPH/IUPHHKs is far smaller. This means there are vast regions of open access production forest, the area of which is reportedly around 16.4 million ha (Manurung, 2007).

Aside from the1.78 million ha of forest plantations managed by stated owned enterprise Perum Perhutani, the government also processed permits for 10.26 million ha of industrial forest plantation (HTI) during the period of 1989 to 2006 for producing pulpwood and lumber. The cumulative number of this developed by 2006, however, was very low at 3.03 million ha or only 30%. Of this number, 60% was planted for producing pulpwood while only 32% are for lumber. Currently, of the 45 IUPHHK pulpwood forest plantation companies, 12 own a total share of 73%. Whereas, of the 166 IUPHHK lumber forest plantation companies, 32 companies, each with forest plantation areas of more than 9000 ha, own a total share of 61%.

D. LOG POTENTIAL FROM PLANTATION FOREST (TIMBER ESTATE, COMMUNITY FOREST, AND ESTATE)

According to Ministry of Forestry data, log production report for the 1977 to 2000 period, the average volume of commercial log produced from production forests was 22.14 m^3 per ha with an annual incremental growth of 1.13 m^3 per ha. This growth in volume is far lower than that observed by Suwarna et al., (2002) in Manurung et al.(2007) which range from 0.53 m^3 per ha annually in Aceh to 3.26 m^3 per ha annually in East Kalimantan, with an average annual incremental growth of 1.82 m^3 per ha. The figure is, however, far higher than growth estimates by Sist, et al., (1998) in Manurung et al. (2007) of 0.3 to 0.5 m3 per ha annually. Some logged-over natural forests can now be harvested as they have reached their rotation age of 35 years.

Lumber production from Perum Perhutani forest plantations declined sharply during the period of 1994 to 2005, from 1.87 million m^3 in 1994 to 0.74 million m^3 in 2005, indicating depletion in forest resources managed by Perum Perhutani. This contrasts markedly with wood production from this, all of which was pulpwood, which continued to rise throughout the same period. Nevertheless, HTI pulpwood production was still insufficient to meet timber industry needs since not enough were planted, and planting times were unsuited to timber industry development. Average HTI per hectare timber production still remains low.

Observations on the ground in several IUPHHK forest plantations showed that pulpwood production (*Acacia spp*, *Eucalyptus spp*) with a rotation period of 6 to 8 years is sufficiently high, ranging from 125 to 200 m^3 per ha. These wood production figure are still far lower than expected because current incremental volume growth for pulpwood is already between 35 to 60 m^3 per ha annually, depending on the species and clone seedling planted.

From 2003 to 2005, around 219,000 ha of community forest were developed through the national movement on forest and land rehabilitation program (GN-RHL/Gerhan) and a further 2,000 ha through government and community partnership schemes. In addition, approximately 7,606 ha of community forest were developed through partnership schemes involving companies and communities. Nevertheless, the total area of community forest developed is in fact far smaller than the area of 1.56 million ha reported by the Central Statistics Agency based on 2003 Agriculture Census. Further, Santoso (2006) pointed out that at least 6 million m^3 of log is produced by community forest each year.

In 2005, the total area of estate crops in Indonesia was estimated at around 18.64 million ha, 13.89 million of which were smallholder estates and 4.74 million ha were large crops estate. Of this figure, 70.8% was made up of only three species of crops, namely : rubber (*Hevea brasiliensis*) covering 3.28 million ha, coconut (*Cocus nucifera*) on 4.32 million ha and oil palm (Elaeis guineensis) on 5.59 million ha.

Unlike Malaysia and Thailand, Indonesia's timber industry used only in a small portion of rubber wood (*Hevea brasiliensis*) and oil palm wood as raw material for bio-composite products because of the abundant supply of log from natural forest in the past. Ironically, this still remains the case despite the drastic decline of log supply from natural forest. This situation must change, rubber wood and oil palm should be considered as alternative sources of raw materials, particularly as so much information is available on their physical and mechanical characteristics in connection with their processing.

E. PHYSICAL AND MECHANICAL OF WOOD PROPERTIES FOR BIO-COMPOSITE

Selection of wood raw material for plywood industry in Indonesia historically, shown that the biggest and best logs and the most desirable species were reserved for veneer. Logs with the most distinctive color and grain characteristics were sliced for fancy veneer. The remainder was rotary peeled in the various thicknesses, usually were rotary peeled in thicknesses of 1 - 3.2 millimeters. Wood characteristics desirable for slicing have remained about the same, although the sections are even thinner. However, the selection process for rotary peeling has changed dramatically. Timber availability, innovations in rotary peeling technology, and changing uses of veneer have resulted in revolutionary differences in log selection and utilization. The most important parameter is matching the log to the desired veneer based products. In general the prerequisites log for plywood in Indonesia is as follows: (1) fresh cut, (2) minimum diameter 45 cm, (3) straight, cylinder, round, and (4) minimum defect. The prerequisite for Glulam, LVL and plywood is quite strict. However, the prerequisite for particleboard and MDF is lower compared to those of plywood, Glulam and LVL.

III. METHODOLOGY

A. SPECIES SELECTION (NATURAL FOREST, HTI, COMMUNITY FOREST, ESTATE)

Small diameter logs define as logs having diameter 30 cm or less (Regulation of the Republic of Indonesia No. 74, 1999) . It comes from natural forest, plantation forest, community forest or estate. Selection of small diameter logs from plantation forest based on the popular wood species planted by timber plantation companies while from natural forest selected based on the potency of SDL species in sample plot. The total of wood sample is 38 species which is consist of 14 species collected from plantation timber and community forest and the rest (24 species) collected from the concession area of PT. Suka Jaya Makmur (the same group with PT. Sari Bumi Kusuma) in Central Kalimantan and natural forest in Jambi area. The condition and wood sample collection activity in sample plot in PT. Suka Jaya Makmur can be seen in figures below.

Figure 1. Condition of sample plot and wood samples collection

The selected SDL species for wood sample can be seen in **Table 5**.

Table 5. List of selected small diameter logs

No.	Local name	Scientific name	Family
A. Wood from Plantation/Community Forest			
1.	Sengon	*Paraserianthes falcataria* (L) Nielsen	Mimosaceae
2.	Kayu afrika	*Maesopsis eminii* Engl.	Rhamnaceae
3.	Tisuk	*Hibiscus macrophyllus*	Malvaceae
4.	Suren	*Toona sureni* Merr.	Meliaceae
5.	Ekaliptus	*Eucalyptus deglupta* Bl.	Myrtaceae
6.	Sengon buto	*Enterolobium cyclocarpum*	Leguminaceae
7.	Mindi	*Melia azedarach*	Meliaceae
8.	Kiseseh	*Cinnamomum purrectum*	Lauraceae
9.	Melina	*Gmelina arborea*	Verbenaceae
10.	Mahoni	*Swietenia macrophylla* King	Meliaceae
11.	Puspa	*Schima wallichii* Korth.	Theaceae
12.	Rubberwood	*Hevea brasiliensis*	Euphorbiaceae
13.	Pinus	*Pinus merkusii*	Pinaceae
14.	Mangium	*Acacia mangium* Willd.	Mimosaceae
B. Wood from Natural Forest			
1.	Benuang	*Octomeles Sumatrana* Miq.	Datycaceae
2.	Segulang	*Evodia* sp.	Rutaceae
3.	Merkubung	*Macaranga gigantea*	Euphorbiaceae
4.	Jabon	*Anthocephalus cadamba*	Rubiaceae
5.	Sungkai	*Peronema canescens*	Verbenaceae
6.	Pisang-pisang	*Mezzetia parvifolia* Becc.	Annonaceae
7.	Cempening	*Querqus* sp.	Fagaceae
8.	Kelampai	*Elaterospermum tapos* Bl.	Euphorbiaceae
9.	Belatik	*Cococeras sumatrana* J.J.S.	Euphorbiaceae
10.	Sampe	*Microsas henrici*	
11.	Ubar	*Eugenia* sp.	Myrtaceae
12.	Ketikal	*Ochanostachys amentacea* Mast.	Olacaceae
13.	Terentang	*Campnosperma* spp.	Bombacaceae
14.	Meranti merah	*Shorea lephrosula* Dyer	Dipterocarpaceae
15.	Macaranga	*Macaranga hypoleuca* Muell. Arg.	Euphorbiaceae
16.	Tengkawang	*Shorea gysbertsiana* Burck.	Dipterocarpaceae
17.	Bayur	*Pterospermum* spp.	Sterculiaceae
18.	Jelutung	*Dyera costulata* Hook. f.	Apocynaceae
19.	Petai hutan	*Parkia* sp.	Mimosaceae
20.	Meranti putih	*Shorea javanica* K. et V	Dipterocarpaceae
21.	Cempaka	*Elmerillia* sp.	Magnoliaceae
22.	Terap putih	*Artocarpus* spp.	Moraceae
23.	Medang	*Alseodaphne cratoxylon* Kosterm.	Lauraceae
24.	Pulai	*Alstonia* sp.	Apocynaceae

B. WOOD SAMPLE PREPARATION

The wood sample preparation for physical and mechanical properties testing of small diameter logs are as follows :

1. Wood samples were cut from tree or logging waste which has diameter 10 - 29 cm. Illustration of wood sample cutting can be seen in **Figure 2.**
2. Wood samples were cut from three section points of tree (bottom, centre and top part of stem).
3. Each section of wood sample was cut to one meter length.
4. Wood samples were sent to Forest Products Research Institute Department of Forestry in Bogor and tested according to ASTM Standard D 143-94. Selected fundamental properties of wood related to bio-composite products are : density, moisture content, static bending (MPL, MOE, and MOR), compression parallel to the grain, hardness (end and side). Wood testing was conducting in green and air dried condition.

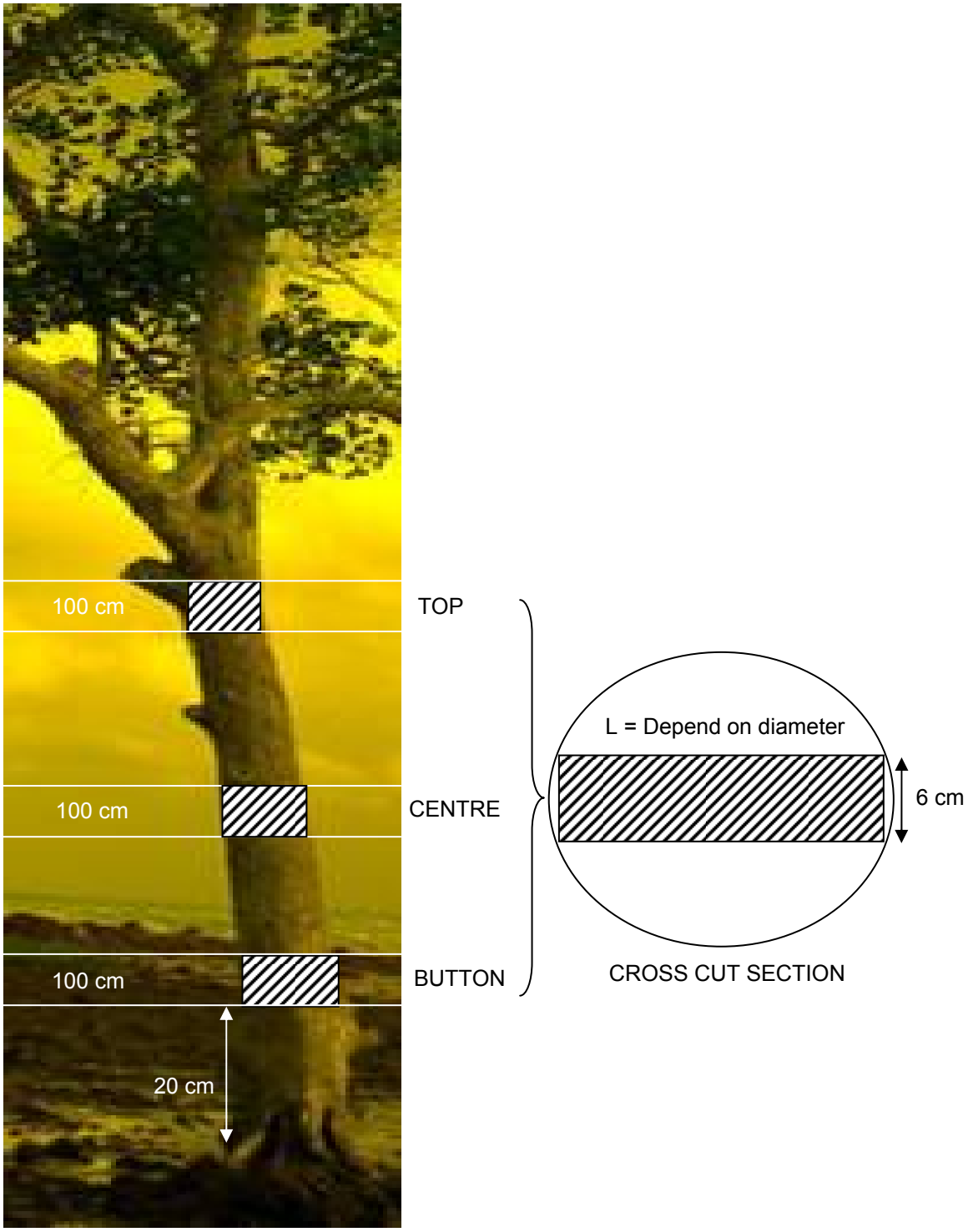


Figure 2. Wood sample preparation

IV. PERFORMANCE OF SMALL DIAMETER LOGS (SDL)

A. FUNDAMENTAL PROPERTIES OF SELECTED 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 6, 7 and 8**.

Table 6. 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	

Table 6. (*continue*)

No.	Wood Species	MC	Sg	Static bending (kg/cm²)			Compression // (kg/cm²)	Hardness(kg/cm²)		Strength class*
				MPL	MOE x1000	MOR		End	Side	
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 6**, 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 7. 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 gigantea	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	

Table 7. (*continue*)

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	
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 7 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.)

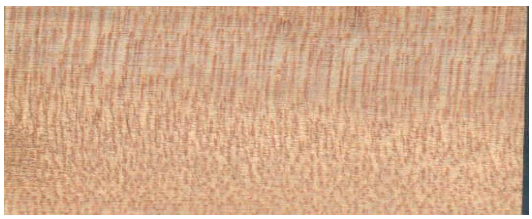
Kelampai (*Elaterospermum tapos* Bl.)

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

Sampe *(Microsas henrici)*

Ubar (*Eugenia* sp.)

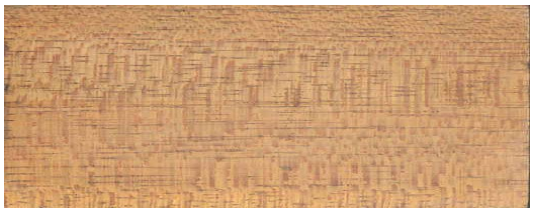
Ketikal (*Ochanostachys amentacea* Mast.)



Terentang *(Campnosperma* spp.)

Meranti merah *(Shorea leprosula* Dyer)

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



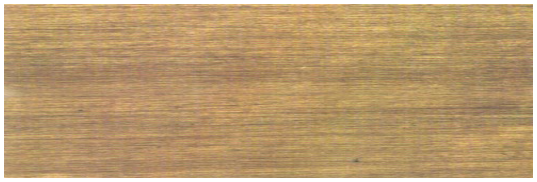
Tengkawang *(Shorea gysbertsiana* Burck.)

Bayur *(Pterospermum* spp.*)*

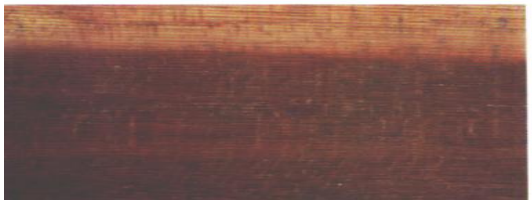
Jelutung *(Dyera costulata* Hook. f.)

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.)

B. SDL for Bio-composite Products : Theoretical Approach

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 8.**

Table 8. 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					
2.	Kayu afrika					
3.	Tisuk					
4.	Suren					
5.	Ekaliptus					
6.	Sengon buto					
7.	Mindi					
8.	Kiseseh					
9.	Mangium					
10.	Mahoni					
11.	Rubberwood					
12.	Puspa					
13.	Gmelina					
14.	Pinus					

Table 8. (*continue*)

No.	Wood species	Glulam	Plywood	LVL	Particle board	MDF
B.	**Natural Forest**					
1.	Benuang					
2.	Segulang					
3.	Merkubung					
4.	Jabon					
5.	Sungkai					
6.	Pisang-pisang					
7.	Cempening					
8.	Kelampai					
9.	Belatik					
10.	Sampe					
11.	Ubar					
12.	Ketikal					
13.	Terentang					
14.	Meranti merah					
15.	Macaranga					
16.	Tengkawang					
17.	Bayur					
18.	Jelutung					
19.	Petai hutan					
20.	Meranti putih					
21.	Cempaka					
22.	Terap putih					
23.	Medang					
24.	Pulai					

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.

V. CONCLUSION AND RECOMMENDATION

1. Wood of small diameter logs has very high potency and feasible in terms of physical and mechanical properties to support wood processing industry in Indonesia.

2. Fresh wood moisture content of SDL from natural forest range from 33.00-153.81%, with averange 67.20%. Air dried moisture content range from 12.00-17.48%, with averange 15.23%. Wet specific grafity range from 0.21-0.79, with average 0.43 gram/cm^3. Air dried specific gravity range from 0.26-0.98, average 0.51.

3. Ketikal Wood classified very heavy, cempening wood, kelampai, belatik, sampe and ubar classified heavywood. While pisang-pisang wood classified as medium and the rest classified as light wood. SDL from natural forest such as meranti merah, macaranga, meranti putih, cempaka, kelampai, belatik, sampe, ubar and ketikal classified as strength class II-III which is feasible for construction material. The rest can be used for light construction and bio-composite raw materials or handycraft raw material.

4. Fresh moisture content SDL from plantation/community forest range from 36.50 - 143.75%, average 75.56%, air dried moisture content range from 11.46-17.30% average 14.30%. Spesific gravity range from 0.28-0.73, with averange 0.52 gram/cm^3. Based on the wood weigth rubberwood, puspa, gmelina and pine classified as medium, and the rest classified as ligthwood. Rubber Wood, puspa, mindi, kiseseh, mahoni and mangium are feasible for construction or light construction. The rest can be used for bio-composite raw material or handy craft raw material.

5. Wood color of small diameter logs have a wide range of variety from ligth yellow to the dark Brown. The wood color of small diameter logs is not different from the wood of large diameter logs.

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