UTILIZATION OF SMALL DIAMETER LOGS FROM SUSTAINABLE SOURCE FOR BIO-COMPOSITE PRODUCTS
PROJECT CODE: CFC/ITTO 62 – PD 40/00 REV 4(1)

TECHNICAL REPORT

Component 2.4
Mitigate Potential Trade Barriers

Activity 2.4.2

Coordinate with Component 2.1 to verify that appropriate tests are conducted

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Introduction

In Activity 2.1.1 on identification of suitable wood species and evaluation of the physical and mechanical properties, it was mentioned that a knowledge of the basic physical and mechanical properties of wood is of major importance in promoting the use of would be substitute for commercial or traditionally used timbers which are now in depletion. Information on these properties would facilitate their utilization as structural materials, substitute species for specific end-use, and for possible new wood application. From among the four wood species tested under this activity, three were identified and recommended for the production of wood wool cement board (WWCB). These are: *P. nodosa, A. macrophylla* and *E. urophylla*.

In Activity 2.1.2 on identification of milling issues, it was mentioned that the wood-based industry had remarkable changes in the immediate past due to the problems on raw material sustainability. The country has been importing logs to complement the needs of the plywood industries. The use of SDL was introduced more than a decade ago but its utilization has not been without problems and there were some milling issues addressed. It was recommended that the use of SDL in the processing of veneer and plywood should be promoted in order to cut down on log importation.

In Activity 2.1.3 on identification of quality control concerns for raw material and how to address them suitable, it was cited that with the dwindling supply of traditional lauans (*Shorea spp.*), the wood industry is utilizing mostly plantation species which are smaller and lower in quality although other non-commercial species are also utilized depending on supply and availability. It was concluded that for plywood, different species that differ in relative density affects drying rates and shrinkage in grain orientation of plywood: 1. Marked variation in MC between and within species is prevalent. *G. arborea*, in particular, exhibits pockets of wet spots in green and dried veneer; 2. Sapwood usually contains more moisture but less dense than the heartwood which to some extent affects veneer and plywood processing; 3. Loose cut veneer is more prone to splits and checks after drying while waviness/buckling may be pronounced in tight-cut sheets; 4. Thicker veneers require more drying than thinner ones; and 5. The desired range of final MC depends on ultimate use or type of glue for plywood. For WWCB, small diameter logs of any species can be used provided that pretreatment or water immersion to remove extractives that are inhibitory to cement setting is done. However, high density species should be avoided because of the difficulty in shredding. It was further recommended that other wood species, particularly those that are introduced species, should be studied for the production of composites.

In Activity 2.1.4 on the evaluation of the appropriate properties of products manufactured from SDL, three wood species namely: *P. nodosa, A. macrophylla* and *E. urophylla* were used as recommended under Activity 2.1.1. This involved the collection of raw materials, processing (cutting, debarking, shredding, soaking and drying) of logs to produce wood wool or excelsior, board production, property testing and evaluation of results. The objectives of this study were to determine the effect of some manufacturing variables such as wood/cement ratio (30/70, 40/60 and 50/50), board thickness (8mm, 12mm and 19mm), density (0.65, 0.75 and 0.85 g/cm^3) and the addition of chemical accelerator (no chemical, $Al_2(SO_4)_3$ and $CaCl_2$) on the basic properties of WWCB such as modulus of rupture, modulus of elasticity, nail head pull through, thickness swelling and water absorption. Results of this study showed varying outcomes depending on the wood species used. It was further surmised that in general, $CaCl_2$ and $Al_2(SO_4)_3$ are not just cement setting accelerators but also act as fortifiers or sometimes adversely affect the strength development of WWCB depending on wood species.

The methods used to develop this study (Coordinate with component 2.1 to verify that appropriate tests are conducted) are based on existing practices of the industry, previous technical papers particularly on Activities 2.1.1, 2.1.2, 2.1.3 and 2.1.4 of Component 2.1 (Address technical gaps in producing bio-composite products) as well as actual field evaluation.

Activity 2.1.1: Identify suitable wood species and evaluate the physical and mechanical properties

The Bio-Composite Products industry, particularly the plywood industry, is experiencing problems on raw material supply due to Executive Order 23 – Logging Moratorium. Some veneer and plywood mills as well as the blockboard manufacturers are still selective in using the wood species as raw materials while others simply use wood that are abundant in the vicinity. In general however, the raw materials available is limited only to plantation species although not all are suited for the production of plywood e.g. yemane (*Gmelina arborea*). As in the case of the plywood mills and blockboard plants mentioned in activity 2.3.1 (Work with mills to identify issues when incorporation of small diameter logs into the production process) of this project, one plant is strict in using *falcata* (*Paraserianthes falcataria*) for its blockboard and lumber or 95% of its total raw material requirement.

Another blockboard plant uses 70% payong-payong or umbrella tree (*Musanea cecropiades*) as raw material which is abundant and much cheaper than *falcata*. However, the recovery from *M. cecropiades* is 40% while for *falcata* is 60-70%. The problem with *M. cecropiades* is its very soft and coarse texture. It is difficult to peel especially using the spindleless lathe because of its soft core log and has high drying shrinkage. Although *A. mangium* and *G. arborea* are readily available and abundant in the area, these are not used by the company due to technical difficulties in drying and high freight cost.

One plywood mill uses 80% *falcata* as raw material while the remaining percentage is miscellaneous species/fruit trees (e.g. durian). *A. mangium*, although available in the area, is not used due to long drying time and brittle when dried.

Interestingly, one blockboard and plywood plant simply use *falcata* as raw material only for core and imports 0.35, 0.50 and 0.60 mm thick face veneer from China. This is not in harmony with other plywood mills that use 95% and 80% f*alcata* for their blockboard and plywood.

There is one plywood/blockboard producer that uses falcata (90%), acacia mangium (5%) and bagras (*Eucalyptus deglupta*) (5%) as raw materials. However, the use of

A. mangium and *E. deglupta* is limited due to problems in veneering and drying. *E. deglupta* and *A. mangium* are used for face and back.

From the foregoing discussion, blockboard and plywood producers use mostly *falcata* because of its abundance in the area . The use of other species depends on the availability. Apparently, evaluation of the physical and mechanical properties of the wood species used is not done prior to their utilization in the commercial production of blockboard and plywood. Adjustments in setting of the nose bar pressure, knife angle, etc. during peeling are made to compensate for species characteristics, log form, and defects. Actual tests (trial and error) in the production plant are done prior to using them in the commercial plant.

For the production of particleboard, testing and evaluation of the properties of wood species used are not done since these are mixtures of wood wastes gathered from mini sawmills and small wood working industries in the vicinity. In fact, the particleboard manufacturer is not particular with the wood species but rather on the supply volume.

The wood wool cement board (WWCB) producer is dependent on R&D studies on WWCB conducted by FPRDI. It is using almost 100% *G. arborea* although there were instances that it also used fully-grown *falcata* that were cut within the plant site.

Activity 2.1.2: Identify milling issues

This part of the study focuses on constraints in the manufacturing process including issues on equipment limitations for milling or drying and handling of SDL. As mentioned, various techniques of addressing the milling issues relative to SDL utilization are not new. There had been previous studies to expand the use of SDL but it would entail cost to the manufacturers. However, there are some who adopted the recommended methods or did some retooling in order to accommodate SDL in the production. Notably, the use of inappropriate equipment for processing entails low mill recovery, low productivity and high processing costs.

A number of issues and concerns have been identified when SDL are incorporated into the production process. There is one blockboard plant who simply imports veneers from China and USA instead of processing veneers for their consumption. Apparently, it is cheaper to import veneers rather than buying from local sources or than do some retooling or investing in spindleless lathe to accommodate SDL. Importation of kiln dried lumber from USA is being studied as an option by the company which is believed to be cheaper rather than processing *falcata* to make battens for blockboard. This will however result to unemployment because 70% of the machineries presently used will be idled.

One blockboard and plywood producer is equipped with 1 unit spindleless lathe and will acquire 2 more units of spindleless lathe to augment production and accommodate SDL. The company also considers acquiring a steamer to be used in softening wood species that are hard to veneer. In general, only 70% of the machineries is operational due to old age. Some machineries are 25 years old. Present lathe can only process to a minimum diameter of 14 cm. Incorporating a spindleless lathe will reduce the log core up to 5 cm.

There is one plywood plant that is designed for processing SDL. It is equipped with 2 units rotary lathe; 2 unit spindleless lathe that can veneer until 6 – 7 cm ø; 4 units rotary dryer; 2 units core builder; 3 units cold press; 3 units hot press; and 3 units glue spreader. It uses 80% *falcata* as raw material while the remaining percentage is miscellaneous species/fruit trees. Recovery from green to plywood is 60%., that is, 100 cu m of logs > 75 cu m dry veneer > 60 cu.m. plywood. *A. mangium*, although available, is not used due to long drying time and brittle when dried. The company does not buy logs with diameter of more than 50 cm due to easy dulling.

One of the largest producers of plywood in the Philippines is equipped with 3 units spindleless lathe, 4 units rotary lathe that can peel logs to 5-inch diameter and 2 units rotary lathe that can process logs to 9-inch diameter. It plans to acquire three more spindleless lathe (52" and 58") and scuff jointer to increase recovery. It uses *falcata* as raw material for core material. Although it has several units of lathe (spindleless and rotary), the company imports 0.35, 0.50 and 0.60 mm thick face veneer from China.

Interestingly, one producer uses *A. mangium* (5%) and *E. deglupta* (5%) and the bulk is *falcata* (90%) as raw materials for the production of plywood and blockboard. The use of *A. mangium* and *E. deglupta* is limited due to problems in veneering and drying. *E. deglupta* and *A. mangium* are used for back. For *falcata*, recovery is 68% from logs to lumber and 54% from logs to plywood. The company also imports logs from Papua New Guinea. The company requirement for log diameter is 30 cm and up. Recovery from imported log is 68% for lumber and 54 % for plywood.

Particleboard industry in the Philippines has also suffered from the limited supply of woodwastes as raw materials. The existing particleboard commercial plant has decided to incorporate specialized equipment to accommodate the use of coconut coir fiber for the production of resin bonded particleboard. Additional equipment and process would entail additional cost but apparently, the cost to produce particleboard using coconut coir would help in expanding the raw material base and would answer the problem on scarcity of woodwastes as raw materials.

<u>Activity 2.1.3: Identify quality control concerns for raw material and how to address them suitable</u>

It has been cited in a previous report (Activity 2.3.1 Work with mills to identify issues when incorporation of small diameter logs into the production process) that falcata is the widely used species for plywood and blockboard manufacture. Most producers are hesitant to use *A. mangium* and *E. deglupta* due some technical difficulties. *Falcata* which is one of the most widely planted introduced species in the Philippines and in view of its low density, wood processors in Mindanao prefer to utilize this species over the others. Peeler logs from old-growth plantations (16 years and up) produce face veneers, otherwise, logs are usually for corestock veneer. The following is the recommended lathe settings to produce good quality veneer from *falcata*.

Thickness	Knife Angle (deg-min)	Nosebar (%)	Remarks
1.27 mm	90-00 to 91-00	10 – 12	For thin stock
1.59 mm	90-00 to 90-15	10 – 15	For thin stock
3.18 mm	90-00 to 90-45	10 – 12	For corestock

E. deglupta is a native eucalypt species in the Philippines that can be used as substitute material for face veneer. As suggested however, *E. deglupta* must be peeled within 3 days after harvesting to prevent curling of veneer during drying. In one of the plywood mills, curling of *E. deglupta* veneer (Photo 2) was observed compared to *falcata* veneer (Photo 1). It can be speculated that peeling of logs took place more that 3 days after harvesting. This is can be manifested by the voluminous raw materials at the log yard and one of the species was *E. deglupta.* The use of *A. mangium* for plywood production has not always been without problems due to the presence of knots and stains (Photo 3).

The following is the recommended lathe settings in the production of good quality veneers from *E. deglupta*.

Veneer thickness	Knife Angle (deg-min)	Nosebar Compression(%)
1.07 mm	90 – 30	12
3.63 mm	90 – 00	12

The following is the recommended lathe setting to produce face and core veneers from *A. mangium*:

Veneer thickness	Knife Angle (deg-min)	Nosebar Compression (%)
1 mm	89 – 30	12%
2 mm	90 – 00	15%

Photo 1. *Falcata*

Photo 2. *E. deglupta*

Photo 3*. A. mangium*

In the production of resin-bonded particleboard, the wood species is not a major issue considering that the company uses mixtures of woodwastes from mini sawmills, small furniture manufacturers and wood working (builders' wood work) factory in the vicinity. The present practice in the manufacture of particleboard is different from the usual method because the binder used is methyl diisocyanate (MDI). Drying of wood chips to as low as 8 – 10% moisture content (when UF resin is used as binder) is not needed due to the tolerance of MDI to as high as 20% MC.

For wood wool cement board, the manufacturer prefers the use of 100% *G. arborea*. However, there had been deviations in the recommended material ratio (wood/cement ratio) and board density. This is due to the various construction or wall systems designed by the company. The boards may not be strong but the low property is being compensated by the construction design and plastering using concrete paste.

Activity 2.1.4: Evaluate the appropriate properties of products manufactured from SDL

Plywood Industry

Plywood industry is one of the biggest sectors of the wood-based industry that continuously submit plywood samples for testing to FPRDI to conform with the requirements of the Philippine National Standard 196:2000. Regardless however of the raw materials used, the machineries involved in production or whether plywood are imported, testing of the properties is required by the law before these are sold in the market. There are more than 20 plywood manufacturers/suppliers who submit samples for testing. The Bureau of Product Standards (BPS) of the Department of Trade and Industry (DTI) monitors and regulate the plywood industry.

Type I (Exterior) Plywood with thicknesses of 4, 5, 9 and 10 mm and Type II (Interior) Plywood with thicknesses of 2, 4, 5, 9 and 10 mm are tested at FPRDI Plywood Testing Laboratory. Tests conducted for Type I are bond strength (top, middle and bottom), moisture content (top, middle and bottom) and thickness on four sides (top, middle and bottom). The following tables are some of the test results conducted at FPRDI. Note that the name/names of the company where the plywood samples were obtained are not written in this report to protect the company's name.

Bond Test

Type I – 4mm

Panel No.	Top/End 1 Test Piece			Middle Test Piece			Bottom/End 2 Test Piece		
	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)
1	**6.9**	55, 100, 100, 95, 100, 100	**92**	**6.2**	80, 100, 100, 100, 100, 100	**97**	**8.4**	80, 100, 100, 75, 100, 100	**93**
2	**4.3**	100, 85, 95, 100, 100, 100	**97**	**3.8**	90, 100, 100, 100, 90, 90	**95**	**2.4**	40, 25, 60, 80, 90, 100	**66**
3	**5.4**	100, 100, 90, 95, 100, 100	**98**	**4.8**	100, 100, 100, 100, 100, 90	**98**	**8.1**	90, 100, 100, 100, 90, 40	**87**
4	**8.4**	70, 100, 100, 100, 100, 100	**95**	**4.7**	85, 100, 90, 100, 90, 100	**94**	**5.7**	100, 100, 100, 100, 100, 100	**100**
5	**6.2**	90, 100, 90, 90, 90, 100	**93**	**4.1**	90, 80, 85, 90, 50, 60	**76**	**6.0**	100, 100, 100, 100, 100, 100	**100**
6	**8.1**	100, 100, 100, 60, 60, 50	**78**	**5.4**	100, 100, 100, 100, 80, 90	**95**	**6.0**	100, 75, 100, 70, 85, 100	**88**
7	**9.4**	90, 100, 100, 100, 100, 100	**98**	**6.1**	100, 50, 100, 55, 85, 100	**82**	**7.8**	100, 100, 90, 90, 85, 50	**86**
8	**2.4**	60, 70, 70, 65, 85, 100	**75**	**4.6**	100, 100, 100, 100, 100, 90	**98**	**5.3**	100, 100, 100, 80, 90, 80	**92**
9	**7.0**	100, 100, 100, 100, 90, 100	**98**	**3.8**	100, 100, 100, 60, 100, 100	**93**	**4.8**	80, 70, 90, 100, 80, 100	**87**
10	**5.3**	100, 100, 100, 100, 65, 60	**88**	**4.4**	100, 80, 100, 100, 100, 50	**88**	**4.7**	90, 100, 100, 100, 100, 60	**92**

Type I – 5mm

Panel No.	Top/End 1 Test Piece			Middle Test Piece			Bottom/End 2 Test Piece		
	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)
1	**7.4**	20, 25, 35, 40, 100, 100	**53**	**6.3**	25, 40, 70, 50, 70, 70	**54**	**12.7**	100, 100, 90, 100, 100, 100	**98**
2	**12.0**	85, 80, 95, 60, 45, 95	**77**	**5.9**	100, 90, 80, 60, 70, 70	**78**	**6.9**	50, 60, 50, 30, 80, 85	**59**
3	**11.1**	90, 95, 85, 50, 90, 100	**85**	**13.6**	100, 50, 90, 85, 100, 100	**88**	**10.3**	100, 100, 100, 100, 55, 95	**92**
4	**5.9**	70, 60, 80, 65, 65, 95	**73**	**12.6**	100, 100, 100, 100, 100, 100	**100**	**5.7**	20, 25, 25, 75, 90, 75	**52**
5	**11.6**	100, 100, 90, 90, 100, 100	**97**	**11.1**	100, 100, 80, 100, 90, 100	**95**	**11.2**	85, 100, 85, 100, 90, 70	**88**
6	**5.8**	100, 100, 100, 90, 85, 95	**95**	**12.7**	100, 100, 100, 90, 85, 95	**95**	**12.5**	90, 100, 100, 100, 80, 90	**93**
7	**7.3**	70, 55, 45, 45, 90, 95	**67**	**13.7**	90, 95, 95, 100, 95, 100	**96**	**12.4**	100, 100, 100, 100, 100, 100	**100**
8	**12.3**	100, 100, 90, 100, 50, 55	**83**	**6.4**	30, 60, 85, 40, 45, 60	**53**	**6.6**	30, 90, 95, 80, 100, 100	**83**
9	**8.2**	50, 40, 40, 85, 95, 40	**58**	**6.2**	60, 70, 70, 70, 60, 60	**65**	**5.2**	40, 40, 60, 50, 65, 85	**57**
10	**9.9**	60, 100, 100, 85, 60, 100	**84**	**5.8**	60, 60, 50, 60, 50, 90	**62**	**12.5**	40, 80, 85, 80, 30, 100	**69**

Bond Test

Type I – 9mm

Panel No.	Top/End 1 Test Piece			Middle Test Piece			Bottom/End 2 Test Piece		
	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)
1	**10.3**	60, 80, 60, 60, 70, 60	**65**	**10.6**	100, 80, 100, 90, 100, 100	**95**	**10.6**	60, 60, 70, 40, 60, 60	**58**
2	**17.0**	70, 70, 75, 90, 80, 100	**81**	**11.8**	100, 100, 90, 100, 90, 100	**97**	**9.1**	80, 85, 90, 70, 60, 50	**73**
3	**8.8**	70, 80, 80, 80, 80, 80	**78**	**11.2**	100, 100, 100, 100, 100, 100	**100**	**13.4**	90, 70, 60, 40, 40, 60	**60**
4	**9.4**	100, 90, 70, 90, 80, 80	**85**	**13.2**	80, 100, 100, 100, 100, 90	**95**	**9.5**	80, 90, 80, 80, 80, 75	**81**
5	**11.9**	75, 80, 80, 90, 50, 40	**69**	**9.1**	90, 100, 80, 90, 90, 90	**90**	**9.1**	75, 85, 85, 90, 90, 80	**84**
6	**10.3**	60, 70, 60, 60, 60, 70	**63**	**10.0**	60, 70, 70, 80, 80, 80	**73**	**9.7**	75, 75,60, 65, 65, 80	**70**
7	**9.8**	80, 85, 85, 95, 85, 85	**86**	**6.1**	65, 70, 50, 70, 60, 80	**66**	**10.8**	30, 50, 80, 80, 80, 85	**68**
8	**10.6**	90, 85, 70, 80, 80, 85	**82**	**10.5**	100, 60, 100, 90, 100, 100	**92**	**14.2**	50, 60, 70, 50, 50, 50	**55**
9	**9.2**	85, 90, 95, 90, 100, 85	**91**	**9.7**	90, 90, 85, 85, 85, 80	**86**	**16.4**	60, 40, 40, 50, 90, 85	**61**
10	**11.7**	60, 75, 60, 80, 85, 30	**65**	**13.1**	75, 85, 85, 90, 90, 95	**87**	**13.9**	40, 40, 50, 50, 70, 55	**51**

Type I – 10mm

Panel No.	Top/End 1 Test Piece			Middle Test Piece			Bottom/End 2 Test Piece		
	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)	Ave. Shear Strength (kgf/cm^2)	Wood Failure (WF) of Individual Specimens (%)	Ave. WF (%)
1	**10.5**	55, 60, 80, 70, 70, 60	**66**	**7.8**	100, 100, 80, 50, 80, 70	**80**	**13.3**	70, 80, 85, 85, 85, 90	**83**
2	**18.8**	100, 100, 90, 50, 90, 100	**88**	**14.4**	90, 80, 100, 100, 100, 100	**95**	**18.6**	90, 90, 90, 100, 90, 90	**92**
3	**15.8**	100, 100, 100, 80, 80, 90	**92**	**17.2**	100, 70, 80, 60, 70, 80	**77**	**10.9**	60, 40, 60, 50, 70, 80	**60**
4	**8.9**	85, 85, 85, 85, 90, 100	**88**	**9.1**	50, 50, 60, 70, 70, 75	**63**	**12.3**	60, 70, 70, 80, 70, 80	**72**
5	**16.1**	100, 100, 90, 80, 100, 100	**95**	**16.0**	60, 60, 60, 50, 40, 40	**52**	**10.0**	70, 70, 70, 70, 80, 90	**75**
6	**17.1**	100, 100, 100, 100, 100, 90	**98**	**10.6**	60, 70, 70, 60, 60, 60	**63**	**9.6**	70, 75, 80, 85, 75, 80	**78**
7	**15.3**	90, 100, 95, 100, 90, 100	**96**	**7.1**	100, 100, 100, 100, 100, 100	**100**	**8.9**	60, 70, 50, 50, 60, 40	**55**
8	**15.6**	75, 75, 80, 70, 80, 70	**75**	**17.5**	100, 60, 60, 70, 70, 70	**72**	**12.0**	70, 70, 60, 60, 40, 45	**58**
9	**9.6**	80, 70, 75, 80, 90, 100	**83**	**9.4**	80, 80, 80, 90, 70, 70	**78**	**17.2**	80, 80, 80, 80, 80, 90	**82**
10	**11.1**	70, 70, 80, 80, 80, 70	**75**	**9.5**	60, 40, 40, 90, 90, 100	**70**	**14.5**	60, 90, 100, 60, 60, 75	**74**

Moisture Content

Remarks: The specified moisture content of the plywood as per PNS 196:2000 shall not exceed 13%.

Type I – 4mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	9.4	8.8	8.8	9.0
2	8.2	8.1	8.0	8.1
3	8.0	7.8	7.5	7.8
4	7.8	7.5	7.8	7.7
5	7.8	7.7	8.1	7.9
6	7.7	7.5	8.1	7.8
7	7.4	7.6	7.9	7.6
8	7.7	7.5	7.6	7.6
9	7.9	7.7	7.9	7.8
10	8.1	8.1	8.1	8.1

Type I – 5mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	9.7	9.5	9.9	9.7
2	8.9	9.4	9.8	9.4
3	9.7	8.8	9.6	9.4
4	9.3	9.5	9.4	9.4
5	9.8	9.2	9.6	9.5
6	9.2	9.4	9.2	9.2
7	9.8	9.1	9.2	9.4
8	9.4	9.1	8.5	9.0
9	9.5	9.0	9.4	9.3
10	9.7	10.0	11.8	10.5

Type I – 9mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	7.3	7.6	7.5	7.5
2	7.5	7.1	7.6	7.4
3	7.6	7.1	7.2	7.3
4	7.2	7.3	8.0	7.5
5	7.2	7.1	7.7	7.3
6	7.3	7.0	7.6	7.3
7	7.6	7.3	7.6	7.5
8	7.6	7.5	7.0	7.4
9	7.7	7.6	7.3	7.5
10	7.7	7.9	8.2	7.9

Type I – 10mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	9.8	8.9	10.4	9.7
2	9.3	8.9	9.8	9.3
3	9.1	8.7	9.5	9.1
4	9.2	8.3	9.3	8.9
5	9.0	8.6	9.2	8.9
6	9.3	8.6	8.7	8.9
7	8.9	8.7	8.7	8.8
8	9.4	9.2	9.0	9.2
9	9.2	8.8	9.1	9.0
10	9.5	9.1	10.0	9.6

Thickness

Type I – 4mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	3.826	3.867	3.829	3.840
2	4.006	3.891	3.900	3.932
3	4.002	3.853	3.900	3.918
4	3.810	3.855	3.880	3.848
5	3.841	3.827	3.821	3.830
6	4.171	3.838	3.895	3.968
7	3.939	3.890	3.843	3.891
8	3.823	3.842	3.989	3.885
9	3.813	3.825	3.943	3.860
10	3.905	3.899	3.993	3.932

The specified thickness tolerance for 4 mm as per PNS 196:2000 is ± 0.24 mm

Type I – 5mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	4.914	4.764	4.829	4.835
2	4.791	4.845	4.781	4.806
3	4.849	4.766	4.826	4.814
4	4.790	4.793	4.862	4.815
5	4.854	4.793	4.834	4.827
6	4.910	4.770	4.805	4.828
7	4.851	4.874	4.818	4.848
8	4.876	4.815	4.939	4.877
9	4.808	4.736	4.798	4.781
10	4.772	4.745	4.788	4.768

The specified thickness tolerance for 5 mm as per PNS 196:2000 is ± 0.24 mm

Type I – 9mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	9.103	9.072	9.285	9.153
2	9.262	8.979	9.285	9.175
3	9.054	9.031	9.112	9.066
4	9.199	9.058	9.250	9.169
5	9.109	9.019	9.252	9.127
6	9.180	9.099	9.294	9.191
7	9.234	9.055	9.305	9.198
8	9.215	8.998	9.124	9.112
9	9.222	8.952	9.045	9.073
10	8.956	9.118	9.146	9.073

The specified thickness tolerance for 9 mm as per PNS 196:2000 is ± 0.45 mm

Type I – 10mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	10.120	10.378	10.350	10.283
2	10.111	10.134	10.207	10.151
3	10.084	10.182	10.292	10.186
4	10.063	10.205	10.184	10.151
5	9.835	10.090	10.159	10.028
6	10.027	10.308	10.005	10.113
7	10.051	10.431	10.130	10.204
8	9.931	10.204	10.239	10.125
9	9.942	10.224	10.004	10.057
10	10.245	10.107	10.130	10.161

The specified thickness tolerance for 10 mm as per PNS 196:2000 is ± 0.45 mm

Delamination Test

Remarks: Per test piece (top, middle, bottom), taken from a whole panel, five test specimens were prepared. Hence, there were 150 test specimens subjected to a 3-cycle delamination test. The interpretation of test results to determine the conformance or non-conformance of the plywood lot to PNS 196:2000 is assigned to BPS.

Type II – 2mm

Panel No.	DELAMINATION TEST							
	First Cycle				**Third Cycle**			
	Number of Delaminated Specimens			**Total**	**Number of Delaminated Specimens**			**Total**
	Top/End 1	**Middle**	**Bottom/End 2**		**Top/End 1**	**Middle**	**Bottom/End 2**	
1	0	0	0	0	0	1	1	2
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	1	1
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	1
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	1	0	0	1
10	0	0	0	0	0	0	0	0
	TOTAL			**0**	TOTAL			**5**
	Percentage of **Delaminated** Specimens			**0**	Percentage of **Delaminated** Specimens			**3**
	Percentage of **Undelaminated** Specimens			**100**	Percentage of **Undelaminated** Specimens			**97**

Type II – 4mm

Panel No.	DELAMINATION TEST							
	First Cycle				**Third Cycle**			
	Number of Delaminated Specimens			**Total**	**Number of Delaminated Specimens**			**Total**
	Top/End 1	**Middle**	**Bottom/End 2**		**Top/End 1**	**Middle**	**Bottom/End 2**	
1	0	0	0	0	0	4	1	5
2	0	0	0	0	0	4	0	4
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	0	1
5	0	0	0	0	2	1	0	3
6	0	0	0	0	1	0	0	1
7	0	0	0	0	2	0	0	2
8	0	0	0	0	1	0	0	1
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
	TOTAL			**0**	TOTAL			**17**
	Percentage of **Delaminated** Specimens			**0**	Percentage of **Delaminated** Specimens			**11**
	Percentage of **Undelaminated** Specimens			**100**	Percentage of **Undelaminated** Specimens			**89**

Type II – 5mm

Panel No.	DELAMINATION TEST							
	First Cycle				**Third Cycle**			
	Number of Delaminated Specimens			**Total**	**Number of Delaminated Specimens**			**Total**
	Top/End 1	**Middle**	**Bottom/End 2**		**Top/End 1**	**Middle**	**Bottom/End 2**	
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	1	1
7	0	0	0	0	0	1	0	1
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	1	0	0	1
	TOTAL			**0**	TOTAL			**3**
	Percentage of **Delaminated** Specimens			**0**	Percentage of **Delaminated** Specimens			**2**

Percentage of **Undelaminated** Specimens	**100**	Percentage of **Undelaminated** Specimens	**98**

Delamination Test

Type II – 9mm

Panel No.	DELAMINATION TEST							
	First Cycle				Third Cycle			
	Number of Delaminated Specimens			Total	Number of Delaminated Specimens			Total
	Top/End 1	Middle	Bottom/End 2		Top/End 1	Middle	Bottom/End 2	
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
	TOTAL			**0**	TOTAL			**0**
	Percentage of **Delaminated** Specimens			**0**	Percentage of **Delaminated** Specimens			**0**
	Percentage of **Undelaminated** Specimens			**100**	Percentage of **Undelaminated** Specimens			**100**

Type II – 10mm

Panel No.	DELAMINATION TEST							
	First Cycle				Third Cycle			
	Number of Delaminated Specimens			Total	Number of Delaminated Specimens			Total
	Top/End 1	Middle	Bottom/End 2		Top/End 1	Middle	Bottom/End 2	
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	1
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
	TOTAL			**0**	TOTAL			**1**
	Percentage of **Delaminated** Specimens			**0**	Percentage of **Delaminated** Specimens			**1**
	Percentage of **Undelaminated** Specimens			**100**	Percentage of **Undelaminated** Specimens			**99**

Moisture Content

Remarks: The specified moisture content of the plywood as per PNS 196:2000 shall not exceed 13
The interpretation of Test Results to determine the conformance or non-conformance of the plywood lot to PNS 196:2000 is assigned to BPS.

Type II – 2mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	11.7	11.5	11.4	11.5
2	11.3	11.5	11.3	11.4
3	11.5	11.4	11.2	11.3
4	11.3	11.2	10.5	11.0
5	10.9	10.8	10.6	10.8
6	10.7	11.2	10.7	10.9
7	10.9	11.2	10.9	11.0
8	11.3	12.2	11.5	11.7
9	11.8	11.6	11.4	11.6
10	11.4	11.5	11.3	11.4

Type II – 4mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	8.8	9.8	9.1	9.3
2	9.1	9.5	9.4	9.3
3	9.5	10.2	9.1	9.6
4	9.1	9.5	8.6	9.1
5	8.9	9.8	8.4	9.0
6	9.4	9.1	8.5	9.0
7	8.9	9.7	8.9	9.2
8	9.1	9.5	10.1	9.6
9	9.5	9.6	9.3	9.5
10	9.8	9.9	10.4	10.0

Type II – 5mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	12.0	11.1	10.7	11.3
2	11.8	11.0	11.1	11.3
3	11.1	11.7	11.1	11.3
4	11.3	11.0	11.8	11.4
5	11.1	11.1	11.4	11.2
6	11.2	12.5	10.7	11.5
7	11.5	11.8	10.8	11.4
8	11.1	12.3	11.9	11.8
9	11.9	11.7	11.5	11.7
10	11.8	12.0	12.5	12.1

Type II – 9mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	12.2	12.2	10.1	11.5
2	12.1	11.8	10.5	11.5
3	11.6	10.1	9.5	10.4
4	9.9	10.2	9.6	9.9
5	10.0	10.5	9.3	9.9
6	9.7	9.5	11.7	10.3
7	9.7	9.4	10.3	9.8
8	9.7	10.1	9.3	9.7
9	9.9	9.5	9.5	9.6
10	10.0	9.8	9.7	9.8

Type II – 10mm

Panel No.	Moisture Content (MC), %			Average Panel MC (%)
	Top/End 1	Middle	Bottom/End 2	
1	10.3	9.7	10.0	10.0
2	10.4	10.1	10.2	10.3
3	9.6	9.8	9.4	9.6
4	9.3	9.1	9.1	9.2
5	9.2	8.9	8.9	9.0
6	9.2	9.0	9.1	9.1
7	9.1	9.4	9.0	9.2
8	8.8	9.4	9.1	9.1
9	10.0	9.1	9.4	9.5
10	9.1	9.5	9.9	9.5

Thickness

Type II – 2mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	2.194	2.254	2.305	2.251
2	2.255	2.283	2.251	2.263
3	2.240	2.239	2.329	2.269
4	2.249	2.302	2.304	2.285
5	2.304	2.255	2.351	2.303
6	2.272	2.252	2.289	2.271
7	2.280	2.306	2.195	2.260
8	2.233	2.243	2.366	2.281
9	2.221	2.209	2.214	2.215
10	2.197	2.215	2.305	2.239

There is no specified thickness tolerance for 2 mm as per PNS 196:2000.

Type II – 4mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	4.058	3.991	3.965	4.004
2	4.035	4.048	4.162	4.082
3	3.984	3.962	4.013	3.986
4	4.126	3.785	4.044	3.985
5	4.007	3.925	4.090	4.007
6	3.963	3.943	3.906	3.938
7	4.144	3.924	3.962	4.010
8	3.967	3.943	3.926	3.945
9	3.987	3.882	4.121	3.996
10	4.004	4.029	4.047	4.026

The specified thickness tolerance for 4 mm as per PNS 196:2000 is ± 0.24 mm

Type II – 5mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	4.895	4.774	4.899	4.856
2	4.873	4.789	4.982	4.881
3	4.931	4.870	4.842	4.881
4	4.968	4.884	5.107	4.986
5	5.025	4.841	4.865	4.910
6	4.924	4.911	4.934	4.923
7	4.817	4.874	4.837	4.843
8	4.898	4.839	4.799	4.845
9	4.983	4.844	4.829	4.885
10	4.938	4.856	4.929	4.908

The specified thickness tolerance for 5 mm as per PNS 196:2000 is ± 0.24 mm

Type II – 9mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	9.164	9.027	9.253	9.148
2	9.157	8.981	8.951	9.029
3	9.145	9.013	9.215	9.124
4	9.047	8.964	8.940	8.984
5	9.062	8.882	8.993	8.979
6	8.963	8.980	8.901	8.948
7	9.106	8.928	9.040	9.025

8	9.075	9.152	9.039	9.089
9	9.112	9.081	8.955	9.049
10	8.836	9.062	9.052	8.983

The specified thickness tolerance for 9 mm as per PNS 196:2000 is ± 0.45 mm

Type II - 10mm

Panel No.	Average Thickness of Four Sides (mm)			Average Panel Thickness (mm)
	Top/End 1	Middle	Bottom/End 2	
1	9.959	10.006	10.138	10.034
2	10.035	9.996	10.127	10.053
3	9.998	10.089	10.008	10.032
4	10.060	9.936	9.995	9.997
5	9.956	10.022	10.062	10.013
6	10.082	9.999	10.036	10.039
7	10.028	10.047	10.055	10.044
8	10.085	9.976	9.945	10.002
9	10.068	10.061	10.038	10.056
10	10.124	10.033	10.070	10.076

The specified thickness tolerance for 10 mm as per PNS 196:2000 is ± 0.45 mm
The interpretation of test results to determine the conformance or non-conformance of the plywood lot to PNS 196:2000 is assigned to BPS.

Particleboard Industry

Resin-bonded particleboard test samples (veneer overlayed and no overlay) from the commercial plant were subjected for testing of their basic properties. The test results are shown in Tables 1 and 2 for veneer ovelayed particleboard and raw particleboard (no overlay), respectively. The Philippine National Standard for Particleboard is presented in Table 3 while the Joint Japan, New Zealand and Australian Standard for Wood-Based Panels is presented in Table 4. No standards had been set for resin-impregnated and paper-coated particleboards under PNS and JANS Standards.

Table. 1. Test results of veneer overlayed particleboard

Sample No.	Density g/cm^3	MOR⊥ kgf/cm^2	MOR // kgf/cm^2	MOE⊥ kgf/cm^2	MOE // kgf/cm^2	IB kgf/cm^2	NHPT kgf	TS %	WA %
1	0.65	52.88	61.44	6,422.32	9,705.40	3.68	69.5	4.09	46.29
2	0.66	67.41	63.51	8,076.31	9,901.04	5.08	39.5	4.91	44.70
3	0.68	76.22	65.59	8,841.68	9,921.33	4.72	54.5	3.80	42.54
4	0.70	80.37	57.03	9,190.56	10,190.46	5.12	46.5	5.69	44.92
5	0.68	69.24	67.66	8,517.24	9,346.96	2.92	43.0	3.35	48.52
Av.		69.22	63.04	8,209.62	9,813.04	4.30	50.6	4.36	45.39

Legend: MOR ⊥ - Modulus of rupture. Loading applied perpendicular to the grain of the veneer overlay.
MOR // - Modulus of rupture. Loading applied parallel to the grain of the veneer overlay.
MOE ⊥ - Modulus of elasticity. Loading applied perpendicular to the grain of the veneer overlay.
MOE // - Modulus of elasticity. Loading applied parallel to the grain of the veneer overlay.

Table 2. Test results of veneer particleboard (no veneer overlay)

Sample No.	Density g/cm^3	MOR kgf/cm^2	MOE kgf/cm^2	IB kgf/cm^2	FSH kgf	TS %	WA %
1	0.789	57.852	7,564	5.84	54.5	19.79	34.18
2	0.866	59.535	8,669	9.16	46.5	14.28	35.23
3	0.860	93.540	13,626	4.36	64.5	13.40	55.0
4	0.774	69.841	7,609	5.48	61	16.14	55.0
5	0.813	68.549	7,726	5.64	73.5	20.4	44.86
Average		69.86	9,039	6.09	60	16.8	44.85

Table 3 Philippine National Standard (PNS 230:1989 Specification for Particle Boards)

Properties	MOR kgf/cm^2	MOE kgf/cm^2	IB kgf/cm^2	FSH kgf	ESH kgf	TS %	WA %
Classification							
1. Pressed and Impregnated							
Paper-coated Particleboards							
1.1 Type 200	180	2.5 x 10^4	5	50	25		
1.2 Type150	140	2.0 x 10^4	3	40	20	20% max	40% max
1.3 Type 100	80	1.4 x 10^4	2	30	15		
2. Veneered							
2.1 Longitidunal	250	3 x 10^4	5		40		
2.2 Lateral	90				15		

Table 4. JANS Requirements for Standard General Purpose Particleboards for use in Dry Conditions

Property	Test Method	Unit	Requirement				
			Thickness Ranges (mm, nominal)				
			> 5 - 8	> 8 - 12	> 12 - 22	> 22 - 33	> 33
Bending Strength	JANS 6	N/mm^2	15	13	12	10	9
Internal Bond	JANS 4	N/mm^2	0.45	0.35	0.3	0.25	0.20
Thickness Swell	JANS 7	%	30	25	20	18	18

Wood Wool Cement Board Industry

The wood wool cement boards (WWCB) produced in the commercial plant had been tested several times and the company has established the properties as presented in Table 5. Note that figures in table are based from the Company Brochure.

Table 5. Properties of WWCB Produced at the Commercial Plant

	Thickness, mm				
	10	15	20	25	50
MOR, MPa	6.0	5.5	5.5	5	4.6
MOE, GPa	2.5	2.5	2.5	2.5	2.5
NHPT, kgf	60	70	85	105	-
WA, %	30	30	30	30	-
TS, %	1.5	1.0	0.8	0.5	-

Table 6. Wood Wool Cement Board – Performance Requirements

Board thickness (mm)	Mean bending strength (MPa)					
	Board Type A		Board Type B		Board Type C	
	Dry	Wet	Dry	Wet	Dry	Wet
8	6.0	4.0	4.0	3.0		
12	6.0	4.0	4.0	3.0		
19	5.0	3.0	3.5	2.5		
25	4.0	2.5	3.5	2.5	1.5	1.5
50					1.5	1.5

Board thickness (mm)	Mean modulus of elasticity (GPa)			
	Board Type A		Board Type B	
	Dry	Wet	Dry	Wet
8	2.5	2.0	1.7	1.0
12	2.5	2.0	1.7	1.0
19	2.5	2.0	1.7	1.0
25	2.5	2.0	1.7	1.0

Board thickness (mm)	Mean nail head pull through (kgf)			
	Board Type A		Board Type B	
	Dry	Wet	Dry	Wet
8	40.80	30.60	20.40	15.30
12	61.20	40.80	40.80	20.40

19	81.60	56.10	61.20	45.90
25	102.00	71.40	71.40	61.20

Board thickness (mm)	Mean thickness swelling (%)	
	Board Type	Board Type B
8	1.50	1.50
12	1.00	1.00
19	0.80	0.80
25	0.50	0.50

Board thickness (mm)	Mean water absorption (%)	
	Board Type	Board Type B
8	30	30
12	30	30
19	30	30
25	30	30

Conclusions and recommendations

1. Wood-based industry particularly the plywood industry depends mostly on the use of *falcata*. Some SDL like *G. arborea*, *E. deglupta*, *A. mangium* and others are not extensively used due to technical problems like difficulty in veneering, drying and curling (after drying). Apparently, evaluation of the physical and mechanical properties of the wood species to determine their suitability for plywood manufacture is not conducted prior to commercial use. Trials were done directly at the production line. Similarly, for particleboard plant evaluation of the physical and mechanical properties of the materials are not done prior to their use in the commercial production. The raw materials are mixtures of wood wastes thus there is no other method for the company but to try them in the production line. It is recommended however that laboratory experiments are

conducted to establish the manufacturing conditions when using mixtures of wood wastes. This is to assure that the quality of the finished product would comply with the minimum requirements of the standards. Parameters like particle geometry, resin content, pressing schedule (pressing time, specific pressure, platen temperature), moisture content of the raw materials and glued materials, board density among other things should be considered to establish the optimum manufacturing conditions.

2. Most plywood mills are equipped with rotary lathe which are designed for big diameter logs (mostly imported). Incorporating spindleless lathe in the production line when using SDL will improve productivity but the cost to acquire the machine may be prohibitive to some mills. Further, log cores from the rotary lathe can still be processed in the spindleless lathe. Considering that the available materials locally are mostly SDL, their utilization is recommended in the processing of veneer and plywood in order to cut down on log importation.

3. Different wood species differ in drying rates and in drying shrinkage as a result of their difference in densities. In fact, a single log or wood species affects veneer and plywood processing to some extent due to more moist and less dense sapwood than heartwood. Many other factors like splits and checks as well as waviness/buckling, thickness of veneers, MC, type of glue and others should be strictly considered in the quality control in order to meet the minimum strength requirements of plywood.

4. FPRDI, being the government agency mandated to test the properties of plywood, is continuously serving the industry. Plywood manufacturers and traders submit samples for testing. Regardless of the wood species used, tests are conducted to determine if they pass the standards. This is not in harmony with Activity 2.1.4 because the raw materials are not identified whether they are from SDL sourced locally or from imported big diameter logs (not considered as SDL). The interpretation of test results to determine the conformance or non-conformance of the plywood lot to Philippine National Standard 196:2000 is

assigned to the Bureau of Product Standard of the Department of Trade and Industry.

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