FPRDI-DOST

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

ADDRESS TECHNICAL GAPS IN PRODUCING BIO-COMPOSITE PRODUCTS

ACTIVITY 2.1.3. QUALITY CONTROL

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I. INTRODUCTION

Plywood and fiberboard are the two most important bio-composite products in the Philippines. With a dwindling supply of traditional lauans (*Shorea spp.*), the industry is utilizing mostly plantation species which are smaller and lower in quality. Other non-commercial species are also utilized depending on supply and availability.

Plywood manufacturing in the Philippines started when Cadwalder Gibson Company put up a manufacturing plant in Limay, Bataan, Luzon Island in 1919. After World War II, several pioneering companies, namely Sta. Clara Lumber Co. (1947), Interwood, Philippine Plywood and Woodworks (1949) and Plywood Industries and Marli Plywood (1954) were the early plywood producers.

In the 70's, the bulk of the world plywood production came from Southeast Asia, specifically from Indonesia, Malaysia and the Philippines. Plywood production in the Philippines peaked between 1970 and 1980, when 33 companies achieved a combined yearly output of about 565,000 cu m. The much needed retooling is slow due to high acquisition costs of new machinery/equipment, especially for small diameter trees from plantations. As in other wood-based industries, the veneer and plywood sector suffers from the perennial problem of scarce raw materials (peeler/veneer grade logs from *Shorea* species).

Fiberboard manufacture, on the other hand, was started by the Philippine Wallboard Corporation, a subsidiary of Nasipit Lumber Company in 1957. As a pioneer, the company had a virtual monopoly of the product until its closure in 1995.   However, in 2000, New South Star Manufacturing Company in Butuan City, located in the northeastern island of Mindanao, opened a hardboard plant. This was followed of the same year by the establishment and operation of Mindanao Fibertech Board Corporation (now ROLEX Industrial Corporation) in Brgy. Capricorn, Lasang, Davao City, also in Mindanao.

Wood wool cement board (WWCB) started in early 90s with the first commercial plant established in Pamucutan, Zamboanga, in Mindanao under the name ZAMBOARD. With the technical assistance of FPRDI, several plants were put-up in various parts of the country. Some of these were in Koronadal City, Davao City and Zamboanga City in Mindanao; Kabangkalan, Negros Occidental and Cebu in the Visayas; and two in Luzon. All these used wood as raw material. There were also cement bonded board plants but instead of using wood, agricultural residues like rattan shaving and abaca fiber wastes are used as raw material. There were also other FPRDI clients who were interested to put-up WWCB commercial plants but due to financial constraints, their project did not materialize. It is unfortunate however that most of the commercial plants established several year ago are not operational anymore.

II. Small Diameter Logs As Raw Material for Bio-Composite Products

Plywood Manufacture

The physical, mechanical, chemical and anatomical properties of wood affect the technological properties associated with plywood manufacture. The Forest Products Research and Development Institute (FPRDI) has categorized species according to property requirements for veneer and plywood manufacture as: necessary (++), desired (+), most suitable (A), acceptable (B) and least acceptable (C).

1. Peeling and gluing : ++
   A – easy to peel and glue
   B – modification required in either peeling or gluing
   C – modification required in both peeling and gluing

2. Relative density based on green volume and oven dry weight : ++
   A – 0.30 to 0.60
   B – 0.60 to 0.70
   C – 0.70 and above

3. Drying and Volumetric Shrinkage (VS) : ++
   A – Easy to dry; VS = 7.8 – 10.5%
   B – Easy to dry; VS = 10.5 – 13.2% or

Difficult to dry; VS = 7.8 – 10.5%
C – Easy to dry; VS = 13.2 – 16.1%

4. Grain and texture : +
   A – fine texture and straight grain
   B – moderately coarse texture and straight grain
   C – Moderately coarse texture and interlocked grain

5. Finishing (finishing, filling, painting and printing) : +
   A – finishes well with minimum finishing material
   B – finishes with moderately more finishing material than A
   C – finishes with considerable amount of finishing material

Veneer Cutting

In the case of veneer and plywood manufacture, the following properties are the main consideration: veneer cutting, drying, adhesive and finishing characteristics ( ). High quality veneer has uniform thickness, moderately compressed, reasonably tight and smooth. Rotary-cutting process is used for higher veneer recovery and production rate while veneer slicing is used for fancy and decorative purposes. More than 90% of all veneers produced in the Philippines are rotary-cut. Some mills have installed spindleless lathes to accommodate small diameter logs as well as process log cores from old-model rotary lathes. Veneer recovery is increased by 10% due to smaller core diameter (50mm) after peeling.

To minimize splitting of veneers during cutting, preconditioning of peeler blocks like heating is recommended.

Veneer Drying

Moisture content (MC) of green veneer must be reduced to a maximum of 12% to make it suitable for the production of quality plywood. Certain types of adhesive require a certain level of MC for optimum glue bond, e.g., for urea formaldehyde (UF) 12% and phenol formaldehyde (PF) 7% maximum. Veneer dryers are usually steam heated conventional type (airflow is parallel to the veneer surface) or jet type (heated air passes through orifices or nozzles in blow boxes and impinges at right angles on the veneer sheet with great velocity) fed by roller conveyor or wire-mesh continuous type. The following material variables are important in drying veneer from small diameter logs:

1. Species – Different species differ in relative density which affects drying rates and shrinkage in grain orientation.
2. Green MC – Marked variation in MC between and within species is prevalent. *Gmelina arborea* exhibits pockets of wet spots in green and dried veneer.
3. Heartwood/sapwood condition - Sapwood usually contains more moisture but less dense than the heartwood.
4. Tightness of green veneer - Loose cut veneer is more prone to splits and checks after drying while waviness/buckling may be pronounced in tight-cut sheets.
5. Veneer thickness – Thicker veneers require more drying than thinner ones.
6. Target dry MC – The desired range of final MC depends on ultimate use or type of glue.

The dryer variables that must be controlled are the following:

1. Temperature of circulating air – Steam pressure and condition of dryer accessories and pressure-regulating valves and drainators
2. Air velocity – This is dictated by capacity of fans, air baffle design and steadiness of electric current.
3. Absolute humidity – Controlled by opening and closing of stack damper. Stack is kept closed if high humidity is desired.
4. Drying time – This depends on the interplay of the various factors enumerated.

Veneer Quality Control

The following factors determine quality of veneer:

1. Log Grade – High grade logs produce high quality veneers. Logs which are straight-grained, cylindrical, well-centered pith, no visible defects like splits, knots, heart checks, heart shakes, brash center (brittle heart), pinholes/grubholes, etc. yield good quality and high veneer recovery.

2. Condition of Equipment – The knives and nosebars of lathes and slicers should be properly ground to sharp, straight and even edges.

3. Skill of Operator – The skill and experience of the lathe or slicer operator significantly contributes to veneer quality.

4. Knife and Nosebar Alignment – In rotary cutting, the knife edge should be mounted with its tip horizontal to the spindle center. If misaligned, uneven thickness, rough surfaces and loose veneers are produced. Likewise, if the knife and nosebar are not parallel to each other, veneer thickness will be uneven.

5. Lathe Settings – The knife angle (KA), horizontal nosebar opening (HNB) and the vertical nosebar opening (VNB) must be properly adjusted depending on species, condition of the logs, etc. Too high knife angle results to corrugated veneers while too low results to thick and thin veneers.

6. Cutting Speed – High cutting speed increases production but requires more energy and induces roughness and compression set.

7. Preheating – Preheating of bolts especially from dense species improves veneer quality like smoothness, tightness and uniformity of thickness.

FPRDI has developed the following standard for testing veneer quality:

1. Veneer thickness uniformity tolerance. The specimens for the evaluation of thickness uniformity will be stored in green planer chips for 2 to 24 hours to

recover from possible temporary compression effects. Twelve (12) thickness measurements will be taken on each specimen. These will be measured to the nearest 0.01 mm using an electronic micrometer caliper. Measurements will be made at approximately 11 cm interval at 6 points along the two lines drawn across the grain. A total of 72 thickness measurements will be made on each of the veneer.

Thickness (mm)	Tolerance (mm)
0.8	0.002 – 0.004
1.5	0.003 – 0.050
3.2	0.060 – 0.100

2. <u>Tightness.</u> Tightness will be measured by the depth of lathe checks. The tightness samples are given a brush application of a black water-soluble dye (china ink) on the open face (loose side) while still in the green condition. The specimen will then be screw mounted on a specially prepared wedge block and machined on a sander to expose a plain-scarfed surface with a slope of approximately 1:12. The penetration of the dye clearly defines the individual lathe checks. From each open face of the specimen, the depth of the three deepest lathe checks will be measured on the scarf surface. Each check depth value will be expressed as a percentage of veneer thickness. Each run of veneer will be represented by a replicate with reading measurement per replicate.

Tightness tolerance:

Thin veneers	< 30%
Thick veneers	< 50%

3. <u>Smoothness.</u> Specimens will be thoroughly air dried before evaluated by means of the shadow-sectioning instrument. The readings of depth of surface roughness will be measured to the nearest 0.01 mm on each specimen at predetermined positions in the roughest portions of the samples on the tight side of the veneer. Consequently, three smoothness

measurements per specimen should represent a replicate. Two replicates are to be made on each run of veneer.

Smoothness tolerance:

- 0.008 mm for rough veneers

< 0.008 mm for smooth veneers

Assembly and Lay-Up

Sorting of faces and backs by pairs such that the tight side of veneers will appear on both surfaces of the panel is done and piled in front of the glue spreader wherein the core or crossbands come out with glue on both sides. Core voids or core laps are checked during the assembly and lay-up.

Gluing

Adhesive mixtures are composed of synthetic resin, its catalyst or hardener, extender, filler, fortifier if needed, and water. These components are mixed to have the desired resin solids content of 29-31% for UF and 23-31% for PF. The former is used for water resistant while the latter is water boil-proof bond. Both UF and PF are of the thermosetting type, i.e., they require heat to cure or harden.

The glue spreader is used in applying the glue mix over the surfaces of the core veneer or crossband. It has a micrometer which regulates the amount of spread per unit area depending on the type of glue, species, quality of veneer, etc. Some important considerations are:

1. Uniformity of glue spread – Spread expressed in grams per square meter of single glue line (GSMSGL) on a wet basis should be uniform for optimum glue strength. This should be checked two or three times daily by spreading sample pieces (1m x 1m) of veneer of the same MC, species, thickness, etc. to determine the accuracy of the target spread versus the actual spread.

2. Adequacy of the glue spread – Glue amount should not exceed the maximum requirement of a certain bond quality or not too scanty to develop poor bond quality.

3. Moisture content of veneers – The optimum MC of veneers is 5% and 9%, respectively, for PF and UF adhesives.

4. Assembly time – This is the time interval between the spreading of the adhesive to the adherend and the application of pressure or heat, or both, to the assembly. This is equivalent to the amount of time needed for the glue to saponify the surface of the veneers.

5. Surface ageing – The length of time the veneers are stored affects the glueability of the wood.

6. Age of glue mix – For PF resins, the age of glue mix or working or pot life should not be more than 4 hours. For UF, it is 3 hours maximum.

Pressing Time, Specific Pressure and Platen Temperature

Assemblies are pressed to ensure proper alignment of veneer components and close contact between the wood and the glue. Pre-pressing by a cold press is usually done before hot pressing. The pressure required is equivalent to 75-80% of hot press specific pressure.

Pressing time is related to the rate of cure or condensation/polymerization of the type of glue used and the distance to the deepest glue line of the panel while pressure is applied on the assembly during hot pressing. The glue manufacturer usually gives the recommended pressing time and specific pressure especially for multiple panels.

To maintain the nominal thickness of the panel after hot pressing, the specific pressure must be based on the species with the lowest relative density, if there are two or more species used in the assembly.

The recommended platen temperature in hot pressing should be from 105 to 125 C for UF and 140 to 145 C for PF resins.

Finishing Operations

1. Reconditioning – The assembly is reconditioned to bring back the MC to its original level after hot pressing. For UF plywood, this is done by stacking the hot panels to atmospheric conditions as they cool. Re-drying the panels is sometimes done for PF plywood due to increase in MC.

2. Panel sizing – Lengthwise and crosswise sizers cut panels into standard sizes, usually 4' x 8', by trimmers equipped with two parallel short-direction saws at right angles to the two parallel saws.

3. Repairing – Application of putty on surfaces with pin holes, splits and other defects is done to improve grade of plywood.

4. Sanding/Scraping – Panels are then sanded to remove surface imperfections and give a smooth finish to the surface. Philippine market requires only the face of the plywood sanded and the reverse side (or back) clean and free from tapes.

Plywood Grading

In the Philippines, all plywood sold in the domestic market must be properly marked to conform with PNS 196:1992 wherein the general specifications of the panels and the bond quality should be met (Annex A). The definition of plywood was also broadened to include blockboard and stripboard. **Type I** (Exterior) plywood shall withstand all weather and water exposure and shall not be affected by microorganisms and shall pass the cyclic boil test as described in Annex A. **Type II** (Interior) shall retain its bond strength when occasionally subjected to thorough wetting and drying conditions and shall pass the test prescribed in Annex A.

Quality Control Measures in Utilization of Small Diameter Plantation Species

1. Bagras (*Eucalyptus deglupta*)

   Eucalyptus deglupta is a native eucalypt species in the Philippines. Picop Resources, Inc. is one of the early companies that established plantations in Mindanao. This species is substitute material for face veneer, often mistaken as lauan (*Shorea spp.*).

   Most plywood manufacturers that were interviewed said that the species must be peeled within 3 days after harvesting to prevent curling of veneer during drying.

   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

2. Moluccan sau (*Paraserianthes falcataria*)

   Moluccan sau is one of the most widely planted introduced species in the Philippines. Owing to its low density, tree farmers, log traders and 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. EMCO Plywood Corp. is producing 100% plywood made of Moluccan sau for export to Hongkong. The company adds 1 minute pressing time to the usual 4 min using more filler and higher resin solids (40-42%) in their UF and PF glue formulations.

   Lathe Settings in the Production of Good Quality Veneer from Moluccan Sau

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	90-00 to 90-45	10 – 12	For corestock

3. Yemane (*Gmelina arborea*)

Yemane or gmelina 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.

4. Mangium (*Acacia mangium*)

Proper grading of veneer logs is essential to produce good quality veneers due to prevalence of knots. Face and core veneers can be produced using the following setting:

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

5. Gubas (*Endospermum peltatum*)

Gubas is also a potential source of veneer for plywood although in the Philippines, it is used mainly for match splint production. The following lathe settings are recommended by FPRDI:

Thickness	Knife Angle (deg-min)	Nosebar Compression (%)
1 mm	90 – 00	12
2 mm	90 – 00	15

6. Big-leafed mahogany (*Swietenia macrophylla*)

This species slices 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.

7. Kaatoan bangkal (*Anthocephalus chinensis*)

FPRDI recommends lathe settings of 90 – 00 knife angle and 15% nosebar compression for smooth, uniform in thickness and moderately tight 1 mm thick veneers.

8. Malapapaya (*Polyscias nodosa*)

   Same settings as for *Anthocephalus chinensis*.

Hardboard Manufacture

Wood wastes in the form of slabs, edgings and trimmings from neighboring sawmills are purchased by the two plants surveyed for hardboard manufacture. Both plants buy *G. arborea* and *A. mangium* wastes although *Paraserianthes falcataria* is accepted as long it will not exceed 30% of the total volume purchased.

The wastes are chipped then washed to remove dirt and debris. The chips are then steam pressure cooked in digesters to soften the chips and release the wood sugars. After cooking, the soft chips are refined into fiber form then fed into washers which use water and pressure to wash out the wood sugars.

Wet Process Hardboard Manufacture

Both plants employ the wet process of manufacturing hardboard. After refining, the wood fiber is mixed with water, alum, PF resin, and wax. Alum is added to the fiber slurry to control pH and help precipitate the wax and the resin onto the fibers. The mixture of fiber slurry, additives and water is fed into a wet forming machine with a moving wire screen where they form a continuous fiber mat. Water drains through the wire screen then the fiber mat is compressed in press rolls to squeeze out further the water. The edges of the fiber mat are trimmed with water jets prior to hot pressing.

The fiber mats in carrying wire are taken to a pre-loader to await hot pressing. The mats are loaded in a 6-opening, steam-heated press. The hardboard mats takes about 8 minutes pressing time at 200 ^{0}C. The pressed hardboards are cooled and stacked. Both plants manufacture only 1/8" x 4' x 8' panels. Final hardboard densities range from 700 to 800 kg/cu m.

Quality Control in Hardboard Manufacture

Some of the desirable properties of hardboard are:

1. Smooth, flat, of uniform color and free from blemish;
2. Variation in thickness and dimension within the least possible tolerance;
3. Ease in sawing and machining operation;
4. Adequate in strength; and
5. Dimensionally stable to changes in atmospheric conditions.

To achieve this, Phil. Wallboard Corp. had the following quality control measures:

1. Testing of freeness of the pulp at defibrators and raffinators every two hours;
2. Checking pH of the pulp at the headbox every two hours;
3. Checking of amount of paraffin in the solution every hour; and
4. Addition of chemical additives to improve strength properties and dimensional stability of hardboard.

The pioneer company also established the suitability of the following species for hardboard manufacture:

1. *Agathis philippinensis*
2. *Syzigium sp.*
3. *Ceiba pentandra*
4. *Parkia timoriana*
5. *Paraserianthes falcataria**
6. *Senna spectabilis*
7. *Eucalyptus deglupta**
8. *E. robusta**
9. *Pinus kesiya*

10. *Podocarpus sp.*
11. *Lithocarpus sp.*
12. *Spathodea campanulata*
13. *Samanea saman*
14. *Mallotus mollissimus*
15. *Cocus nucifera*
16. *Trema orientalis*
17. *Endospermum peltatum**
18. *Dipterocarpus spp.*
19. *Shorea spp.*
20. *Anthocephalus chinensis**
21. *Polyscias nodosa**
22. *Alphitonia philippinensis*
23. Coco coir is also acceptable as long as fines will not exceed 15%

*Plantation species in the Philippines

Wood Wool Cement Board Manufacture

Wood wool cement board (WWCB) is a panel product made-up of wood excelsior bonded with a General Purpose Portland Cement. The common primary requirement for WWCB as a substitute material for housing is that, it has to possess properties equal or superior to the existing panels in the market. Wood is light in weight, elastic and can easily be machined while cement is incombustible, resistant against water/humidity.

The properties of WWCBs are affected by the type and amount of raw materials present in the boards, wood species, type of cement, wood to cement ratio, amount of water for hydration, type of cement setting accelerator, density. In addition, processing techniques such as shredding, mixing, mat forming and handling of the finished product also affect board properties.

Proper production principles of WWCB are very important to make sure that good quality products are manufactured. The process and quality control procedures applied in board production ensure a more efficient use of raw materials at minimal production cost.

The first essential step in quality control is to ensure that the raw materials are thoroughly inspected when they are received at the manufacturing plant. Acceptable form and condition of logs are required for proper shredding and high yield of wood wool. Wood billets with at least 120 mm diameter should be used. Raw materials should be carefully checked to avoid or minimize adverse effect on manufacturing and board quality. Decay and foreign objects (nails, metals etc) should be removed so as not to damage the cutters and knives of the shredder. Mixture of wood species is possible in the production of WWCB provided that it will not adversely affect board quality. Cement as binder should be freshly manufactured to ensure good quality boards.

The compatibility of wood species with cement is an important factor to be considered. Although not all species are compatible with cement, this incompatibility is resolved by soaking the shredded wood in water for at least 24 hours to leach out water soluble extractives that are inhibitory to cement setting and its subsequent hardening. Aside from the wood species compatibility with cement, some wood species are difficult to shred and this affects board quality. Some wood species produce discontinuous and fuzzy wood wool and large amount of dusts that adversely affect the finished product. Dusts should be minimized if not discarded because it has more surface area requiring more cement to bind the wood wool interface.

Quality Control

Quality control verifies if the recommended manufacturing process is observed and if the products meet the required specifications. If the quality control carried out on the raw materials and process is adequate, quality control on the final product may not be necessary. However, raw materials and processes involved should be checked and re-checked when the properties of the final product do not meet the standards.

In WWCB production, the following should be strictly done:

1. Monitor soaking of wood wool in water ensuring that the materials are totally immersed in water.
2. Wood with remarkable decay should be discarded.
3. Knives and cutters of the shredder should be checked to make sure that the wood wool or wood excelsior dimensions are within the limit.
4. Raw materials ratio (wood/cement), amount of water should be within the parameters. Make sure that enough amount of cement and water are used that will result to good bonding between interfaces of fibers.
5. Mixing of wood wool, cement and water should be done continuously until all the surfaces of the wood wool are covered with cement paste.
6. During mat forming, uniform distribution of the mixture is a must to arrive at a uniform density distribution and board thickness.
7. Ensure that there is no excess water that may cause the settling of the cement at the bottom of the board. This will result to poor bonding thus poor quality boards.
8. Distance bars or thickness bars should be properly placed between caul plates to ensure thickness uniformity. Avoid wood wool that are inserted between thickness bars and caul plates.
9. Perforations should be avoided particularly on thin boards with low density.
10. Proper handling is necessary when the boards are unloaded form the press and even during transport particularly during the curing and conditioning period which is 28 days from date of manufacture.

CONCLUSION AND RECOMMENDATION

1. Different species that differ in relative density affects drying rates and shrinkage in grain orientation of plywood.
2. Marked variation in MC between and within species is prevalent. *Gmelina arborea*, in particular, exhibits pockets of wet spots in green and dried veneer.
3. Sapwood usually contains more moisture but less dense than the heartwood which to some extent affects veneer and plywood processing.
4. Loose cut veneer is more prone to splits and checks after drying while waviness/buckling may be pronounced in tight-cut sheets.
5. Thicker veneers require more drying than thinner ones.
6. The desired range of final MC depends on ultimate use or type of glue for plywood.
7. Small diameter logs of any species can be used for wood wool cement board 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.
8. Wood species, particularly those that are introduced species, should be studied for the production of composites.

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