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A guide to the rotary veneer processing of coconut palms

Robert McGavin, William Leggate, Henri Bailleres, Gary Hopewell and Chris Fitzgerald

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Cover image: Coconut palm logs ready for veneer processing. **Photo:** Robert McGavin.

Foreword

ACIAR has supported collaborative forestry research in the Indo-Pacific region for 35 years, focusing on smallholder timber growing and the production of value-added products, to enhance the returns from tree growing.

Few trees are as easily recognised as the iconic coconut palm—ubiquitous in tourist brochures throughout the tropical world and a crucial source of food and fibre in many developing countries.

Most people however, are probably unaware that worldwide, and in the Pacific in particular, that the coconut estate is in a parlous condition. Many coconut plantations are very old, have many dying palms and are declining in production. The plantations and the remaining stems are too tall to enable easy harvesting of nuts. Surviving plants are threatened by the coconut rhinoceros beetle, which breeds and thrives in dead palms and fronds on the forest floor.

Technically, coconut palms are not trees. The palm stems have quite different anatomical properties to trees and they don't behave like timber when sawn. This limits the ways of converting coconut stems to high-value products, which in turn means that there is little incentive for farmers to cut down their old or diseased palms to renew the coconut estate. In recognition of this dilemma, ACIAR supported research to develop value-added products from senile coconut palm stems, which occur in large numbers in many countries in the Indo-Pacific region.

One of the most exciting prospects for smallholder timber arising from the research is the new innovative 'spindleless' lathe technologies to peel coconut stems to produce thin veneer sheets. The veneer sheets can then be used to produce high-value engineered wood products, either solely from coconut veneer or in combination with veneers from other locally-abundant tree species.

Spindleless lathes can be purchased for a fraction of the cost of traditional veneer lathes, so the new technology has great potential for widespread adoption in many developing countries. However, in order to get the best results from coconut palms with these technologies, it is essential that the knowledge from ACIAR's research investments is widely disseminated. Skilled practitioners informed by the latest research are needed to accelerate production of high-quality veneer products.

This guide on rotary veneer processing of coconut palms and the associated manufacturing of high-quality veneers draws on several ACIAR projects, led by the Queensland Department of Agriculture and Fisheries. It provides valuable information about the characteristics of coconut woody tissue and different processing equipment that can be used to produce rotary veneer. It also provides guidance on how to process coconut stems into veneer, along with the techniques to dry and grade the veneer sheets. Finally, it describes the production and testing of high-value engineered 'cocowood' products suitable for a range of appearance and structural applications.

Veneer production provides a unique opportunity to add significant value to otherwise worthless senile coconut stems. It creates an incentive for large-scale rejuvenation of the coconut estate, because revenue from processing the old senile stems can be used to replant plantations with better genetics and clean up the dead and dying material that provides habitat for the rhinoceros beetle. The new technology has enormous potential to improve livelihoods for smallholder farmers, generate new products and export opportunities for Pacific countries, and help reduce the devastating impact of coconut rhinoceros beetles in the Pacific and elsewhere.

If we are to conserve the iconic swaying coconut palms as both a classic tourist image and an incredibly versatile 'tree of life', then we need to work out how to rejuvenate a vast, dispersed, old and precarious coconut estate. This guide, though very technical in nature, represents a crucial piece of the puzzle if we are to develop economic ways of rejuvenating the coconut estate.

Andrew Campbell
Chief Executive Officer, ACIAR

Guest foreword

Although it is no longer the main economic crop for most countries, coconut palm continues to be an important source of food and livelihoods for many Pacific island families and communities. However, a main challenge in maintaining and enhancing the importance of coconut in the Pacific is the senility of a large percentage of the existing coconut resources, which have lost their vitality and productivity, and also pose a risk of becoming breeding grounds for rhinoceros beetles. But this also presents a source of raw materials which, potentially, could be turned into high-value products, incentivising farmers and families to regenerate their coconut plantations by removing their senile palms to make way for younger and more productive palms.

Research on the utilisation of senile palms for the production of wood and wood products has been happening for some time now. I can recall the early part of my forestry career in the Fiji Forestry Department in the late 1970s and early 1980s, when I was involved in studies to look at the properties and potential end uses of coconut wood.

In 2005 with funding from ACIAR, we (SPC Land Resources Division's Forests and Trees Team), with the support of the Queensland Department of Agriculture and Fisheries (Queensland DAF) and a number of Pacific island stakeholders, implemented a collaborative research project which looked again at the properties of coconut wood and identified the technology and processes for the manufacture of high-value flooring, targeting the tropical hardwood flooring markets in Europe. But, while the results indicated that producing high-quality flooring from coconut was possible, a major challenge was that, given the wood structure of coconut, the sawing technology was probably unsuitable as it was resulting in low recovery of the high-density material required for the end product.

Our attention then turned to spindleless lathe technology for the production of rotary veneers as a possible solution to the problem. Again with the support of ACIAR and partners, including the Queensland DAF, the University of Tasmania, and national forestry agencies of Fiji, Samoa and Solomon Islands, we implemented a project from 2012 to 2016 looking at developing technologies and processes to produce high-quality veneers and veneer-based products from senile coconut palms.

This publication is testament to the success of the project, and the exciting potential that the spindleless lathe technology has brought in terms of recovery and quality of veneers, and the range of possible products and markets.

I wish to take this opportunity to sincerely thank the team from the Queensland DAF led by Dr Robert McGavin and Dr Henri Bailleres for their contributions to enhancing our knowledge about coconut 'wood', including the production of this manual. The manual is going to be an excellent resource for people in the Pacific islands who may wish to consider using the spindleless lathe technology in the processing of senile coconut palms for the manufacture of many engineered wood products.

Sairusi Bulai
Acting Deputy Director (Sustainable Resources Management), Land Resources Division, Pacific Community (SPC)

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Robert McGavin led the DAF research team which included Henri Bailleres, Eric Littee, Rod Vella, Fred Lane, Joh Fehrmann, Chris Fitzgerald, Dan Field, Rica Minett and William Leggate.

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The authors acknowledge the material they have drawn on from several publications and web-based resources. These are listed in the 'Further reading' section at the end of each chapter.

The authors also gratefully acknowledge the work undertaken by John Huth (Queensland DAF), Simon Dorries (Chief Executive Officer, Australian Forestry Standard) and Susan House in reviewing and commenting on the draft versions of this book.

Preface

The process of rotary veneer production is to remove a continuous thin ribbon of wood from a peeler billet periphery using a knife that is positioned parallel to the grain. The billet is rotated against the knife using a drive mechanism that varies in design and approach, depending on the technology being used.

The advantages of rotary veneer processing and the resulting products compared to other options such as sawing are multifaceted and are discussed in detail in the second chapter of this book. Improved recovery is foremost, with typical recovery from rotary peeling usually much greater than that achievable by sawmilling logs of similar quality and size. This improved recovery is largely because the peeling process does not produce sawdust or wood chips, unlike log conversion by sawing. This improved yield has a significant effect on the potential return on investment to the processor. Veneer can also be rapidly dried (i.e. pre-shrunk for downstream processes such as gluing and to prevent performance issues in-service) compared to the time required to dry sawn wood products, resulting in reduced energy costs, and fewer inventory and storage issues.

Developments in the engineering of veneer-based products during the last century have also resulted in materials that are stable and straight, and can be manufactured in a wide range of sizes to a consistent quality. In sawn timber, the grade quality and therefore piece value is limited by the major defect, whereas the manufacture of veneer-based products allows for randomisation of defects to attain the best grade possible and enable supply of a consistent and homogeneous product. This means that rotary veneer processing provides an opportunity to use low-quality logs that are not suitable for sawing or other process options.

This book describes best practice for the production of rotary veneer. The book is focused on the production of coconut palm rotary veneer (or cocoveneer), with emphasis on the Pacific region's coconut resource, but it also presents more general information on producing rotary veneer from traditional forest resources which will be useful in other countries, including Australia.

These technical guidelines are based on the R&D portfolio of the Queensland Department of Agriculture and Fisheries (DAF), which included activities predominately undertaken within the ACIAR project 'Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities' (FST/2009/062).

The book has 10 chapters:

- Chapter 1 provides an overview of the processing of coconut palm logs into rotary veneers.
- Chapter 2 provides a summary of rotary veneer product types and uses, and highlights the advantages of veneer processing compared to solid wood processing.
- Chapter 3 summarises the key wood properties and processing characteristics of coconut palms that influence veneer production. These properties were primarily collated during ACIAR project 'Improving the value and marketability of coconut wood' (FST/2004/054).
- Chapters 4, 5 and 6 describe recommended best practice for rotary-peeled veneer manufacture from the log grading stage to veneer drying.
- Chapters 7, 8 and 9 summarise veneer grading, quality control and veneer recovery.
- Chapter 10 details the research outcomes resulting from processing and product manufacture activities undertaken during the ACIAR project 'Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities' (FST/2009/062).

While this book describes best practice recommendations for rotary-peeled veneer production from coconut palm logs covering a wide range of scenarios, it is impossible to cover all situations. Specific recommendations will ultimately vary depending on equipment type, plant layout, level of investment, scale of operation, and resource, labour, product, market and economic considerations. For example, optimal lathe settings will be strongly influenced by lathe type and target product.

It is also important to highlight that although the book provides general recommendations, veneer product manufacturers and veneer users should also seek specific expert assistance.

Workplace health and safety (WHS) aspects are outside the scope of this book. However, strict attention to best-practice WHS measures is of paramount importance and readers should seek specialist advice on this matter.

This book forms part of a series. Details relevant to veneer processing for manufacturing veneer-based products from small logs, such as those harvested from short-rotation hardwood plantations, are provided in the partner publication 'A guide to manufacturing rotary veneer and products from small logs' (Leggate et al., ACIAR Monograph 182).

Glossary

These definitions are drawn from several sources listed in 'Further reading' below.

Term	Definition
ADHESIVE	A substance that is used to bond materials to each other through surface attachment
AS/NZS	Australian and New Zealand standards
BACK	The veneer ply on the back side of the panel
BILLET	An alternative name for a log which has been prepared for rotary peeling
BOND	To glue together, as when veneers are bonded to form a sheet of plywood
CLIPPER	A machine used to cut the veneer ribbons or sheets into specified widths
COCOVENEER	Rotary veneer recovered from the stem of a coconut palm
COCOWOOD	Sawn timber recovered from the stem of a coconut palm
CORE	The inner part of a veneered panel or plywood between the face and back veneers
CROSS BAND	A veneer within a panel or plywood in which the veneer grain directions are parallel to the shorter panel dimension; also defined as the inner layer with a grain direction that is at right angles to the outermost plies
DEFECT, OPEN	Open checks, splits, joints, knot holes, cracks, loose knots, gaps, voids or other openings interrupting the smooth continuity of the wood surface
DENSITY	The weight per unit volume, in kilograms per cubic metre (kg/m^3)
DISCOLORATION	Stains in wood substances; areas of colour differing from the average colour of the surrounding piece or from the colour normally associated with the piece and occurring in either streaks or patches. Common veneer stains include sap stains, fungal stains, stains produced by chemical action caused by the iron in the cutting knife coming into contact with the tannic acid of the wood, or chemical reactions between extractives in wood and glue or finish discolorations. Discoloration may be naturally occurring or as a result of processing operations and adhesive bleed through
ENGINEERED WOOD PRODUCT (EWP)	A wood product manufactured by bonding together wood strands, veneers, lumber or other forms of wood fibre to produce a larger and integral composite unit with superior performance characteristics; these high-performance building components achieve predictable and reliable performance with the efficient use of natural resources

Term	Definition
EXTERNAL GRADE DEFECT	Refers to an abnormality on the bark surface of the tree or log that is clearly visible; they often indicate interior wood grade, and include bumps, bulges, knots, lesions, sweep and holes
FACE VENEER	A term used to describe better quality veneers that are used on the visible surfaces of a panel
FISHTAILS	Wane ends or otherwise defective areas that preclude the veneer piece from being used full length; the affected veneer can be cut back and full thickness areas recovered to be used as cross banding
FUNGAL DECAY	Decomposition of wood by fungi
GLUE LINE	The adhesive joint formed between two materials such as veneers in a plywood panel or between face veneers and core in a composite panel
GRADE	Refers to the letter-graded quality of veneers used in plywood manufacture (e.g. A, B, C and D), or to particular panels, e.g. A–A which indicates the veneer grade on the face and back of the manufactured panel
GRADE DEFECT	Refers to those defects that take away from the appearance, mechanical performance or otherwise limit the usefulness of the veneer
GRADING	Classifying veneers according to quality standards
GRAIN	The direction, size, arrangement and appearance of the fibres in timber and veneer: the natural growth pattern in wood. The grain runs lengthwise in the tree and is strongest in that direction. Similarly, grain usually runs the long dimension in the long-bands (including the face veneers) in a panel of plywood, making it stronger in that direction
GRAIN SLOPE	Expression of the angle of the grain to the long edges or the length of the veneer
GRAIN TEAR-OUT	Gouges in veneer surface
GREEN VENEER	Veneer that has not been dried and has a high moisture content
HOLE	An opening that extends partially or entirely through the piece, attributable to any cause
INNER PLIES	All plies of a plywood panel except face and back; also referred to as the core
INSECT ATTACK	Deterioration caused by insects such as borers or termites
INTERNAL GRADE DEFECT	Refers to those defects that are not apparent on the exterior bark surface of a tree but become visible on the end when the tree is felled; common interior grade defects include splits, stain, double pith, brittle heart, insect galleries, fungal defects and eccentricity

Term	Definition
JOINT	Seam produced by joining the edges of veneer sheets together
KNIFE PITCH ANGLE	The angle between the knife face and a horizontal plane (when the billet is peeled at various diameters); also called slope angle
KNIFE, LATHE	A sharp-edged tool used to cut the veneer from the peeler billet as part of the peeling process
KNIFE MARK	A mark on the surface of a veneer usually caused by a chipped blade resulting in a raised strip along the veneer surface
LAMINATED VENEER LUMBER (LVL)	A composite of wood veneer sheet elements with wood fibres primarily oriented along the length of the member, where the veneer element thicknesses are 6.4 mm or less; LVL is one of several types of EWP
LAYER	In plywood, a layer consists of one or more adjacent plies having the wood grain in the same direction
LAY-UP	Usually defined as the step in wood panel manufacture where veneers or reconstituted wood layers are 'stacked' in complete panel 'press loads' after gluing and before pressing; also the term given to constructing a panel
LONG-BAND	A veneered sheet or panel in which the veneer grain directions are parallel to the long panel dimension
LOOSE SIDE (OF VENEER)	The side of the sheet that was in contact with the knife while the sheet was being cut; it contains cutting checks (lathe checks) because of the bending of the wood at the knife edge
MODULUS OF ELASTICITY (MoE)	A measure of stiffness of an elastic material
MODULUS OF RUPTURE (MoR)	The maximum fibre stress at failure in bending
MOISTURE CONTENT	The proportion of moisture in wood, expressed as a percentage of its oven-dry weight
MULTILAMINAR WOOD	Large blocks composed of multiple veneers glued together
NOSE BAR	A bevelled or roller bar mounted parallel with the tip of the lathe knife and designed to compress the veneer billet into the cutting edge of the lathe knife; also known as a pressure bar
PARENCHYMATOUS	Simple and unspecialised plant tissue with no structural function but having storage capacity
PATCHING	Replacing voids in veneer with a wooden or plastic composite patch or plug

Term	Definition
PLYWOOD	A panel product made from peeled veneer layers that are arranged perpendicular to each other and bonded by adhesive
PLY	Layer of veneer or single veneer in a panel
POLYPHENOLS	Compounds featuring more than one phenolic unit, such as tannin
PRE-CONDITIONING	Preparing a peeler billet (using heat and wetting agents) for peeling
PRESERVATIVE	Product that prevents or limits wood deterioration
PRODUCT STANDARD	An industry manufacturing or performance specification
QUALITY CONTROL	A system of process and product monitoring that aims to ensure procedures and protocols are being followed to produce a consistent product of the required quality
RAPHIDE	A needle-shaped crystal of calcium oxalate occurring in clusters in plant tissue
RECOVERY	**GREEN VENEER RECOVERY** provides a useful measure of the maximum recovery, taking into account log geometry (sweep, taper, circularity) and lathe limitations (e.g. peeler core size). Green veneer recovery disregards internal log quality. Green veneer recovery is expressed as a percentage of billet volume
	GROSS VENEER RECOVERY provides a useful measure of the maximum recovery of dried veneer that meets the relevant quality specifications. This recovery includes the losses accounted for in green veneer recovery but also includes additional losses from visual grading (i.e. veneer that failed to meet grade) and the drying process (e.g. veneer shrinkage, splits). Gross veneer recovery is expressed as a percentage of billet volume
	NET VENEER RECOVERY provides a useful measure of process efficiency, as it identifies the saleable product, taking into account the product manufacturing limitations. Net veneer recovery includes the losses accounted for in gross veneer recovery but also includes the additional losses due to the trimming of veneer before, during and after product manufacture. Net veneer recovery is expressed as a percentage of billet volume
	GRADED VENEER RECOVERY for an individual grade can be calculated using the same method as for net veneer recovery but using the veneer volumes that meet the specific grade (e.g. A, B, C or D grades in accordance with AS/NZS 2269.0:2012 ‘Plywood—Structural—Specifications’). Graded veneer recovery is expressed as a percentage of billet volume

Term	Definition
REPAIR	Any patch, plug or shim in a veneer. A patch is an insert of sound wood or synthetic material to replace a defect in veneer. 'Boat' patches are oval shaped with sides tapering to points or small rounded ends. 'Router' patches have parallel sides and rounded ends. 'Sled' patches are rectangular with feathered ends. A plug may be a circular or dog-bone shaped wood patch or a synthetic filler of fibre and resin to fill openings and provide a smooth, level, durable surface. A shim is a long narrow wood or synthetic repair not more than 4.8 mm wide. Various other shapes of plug or patch may be encountered
RESIN	A general term for synthetic adhesives. It is also a pale brown exudate produced by many softwoods in response to injury in the cambium
ROTARY VENEER	A veneer produced when a billet mounted in a lathe is rotated against a lathe knife; this method of peeling is used to produce veneers for manufacturing products such as plywood, LVL, multilaminar wood and other EWPs
ROUGHNESS	Unevenness of the surface of the veneer or plywood
SCLERENCHYMA	Strengthening tissue in a plant formed from cells with thickened walls
SCRATCH	A surface split or gouge that does not penetrate through a veneer sheet
SEASONING (DRYING)	Drying timber to a moisture content range appropriate to the conditions and purposes for which it is to be used
SHRINKAGE	A change in dimensions occurring as the wood dries from a green (wet) to a seasoned (dry) condition; shrinkage can occur in three directions: radial, tangential and longitudinal
SLICED VENEER	Veneer produced by moving a log or sawn flitch within a slicing machine that shears off the veneer in sheets
SMOOTH, TIGHT CUT	Veneer carefully cut to minimise peeler or slicer checks
SPINDLED LATHE	A traditional lathe used in rotary veneer production, which uses spindles or 'chucks' to hold the billet in position and to rotate the billet against the knife; this method has proved reliable and an effective way to produce high-quality veneer, even at high production speeds
SPINDLELESS LATHE	A lathe with no spindles; rotary drive is provided through powered backup rollers and often with support from a driven roller nose bar. While spindleless lathes still produce peeler cores, their diameters are often smaller (in the order of 20–60 mm) than those from a spindled lathe. This lathe type is well suited to small-diameter billets

Term	Definition
SPLIT	A separation of the fibres in the direction of the grain and extending through the thickness of the veneer
SWEEP (BEND)	A lengthwise curvature of a log (a trend away from the true cylindrical form), the extent of which may cause a peeler log to be discarded
TIGHT SIDE (OF VENEER)	The side of a veneer sheet that was not in contact with the knife while the sheet was being peeled and contains no lathe checks
UNIT SHRINKAGE	The percentage of change in dimensions with each 1% change in moisture content (below about 25% moisture content)
VENEER-BASED PRODUCTS	Products made from peeled or sliced veneers. Examples of veneer-based products produced from peeled veneers include plywood and LVL
VENEER	A thin sheet of wood of uniform thickness (usually1–4 mm for rotary peeled and <1 mm for sliced), created by peeling (peeled veneer) or slicing (sliced veneer) from logs for use in plywood, face decorative veneers, LVL, veneer multilaminar blocks, etc. Also can be defined as a thin sheet of wood laminated with others under heat and pressure to form plywood, or used for faces of composite panels. Also called ply
VENEER COMPOSING	Veneer composing means to dock and butt-join random-width veneers and sections freed from defects and combine them in a full-size sheet for plywood panel production
WANE	The natural absence of wood in a veneer section
WAVINESS	Undulations in the veneer surface preventing the veneer from being flat; waves can split and overlap during pressing into veneer-based products

FURTHER READING

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Rotary veneer processing of coconut palms: an overview

1

INTRODUCTION

Definition of rotary veneer

Traditionally, a veneer is a thin layer of wood usually 1–4 mm in thickness, removed from a log using a rotary peeling process. For the purposes of this publication, veneer is also a thin layer of coconut removed from a coconut stem using a rotary peeling process; this is called *cocoveneer*. Cocoveneer is usually 2.5–6 mm in thickness. Other forms of veneer such as sliced or sawn veneers are not discussed in this publication.

The process of rotary veneer production is to remove a continuous thin ribbon of veneer or cocoveneer from a peeler billet periphery using a knife that is positioned parallel to the grain. The billet is rotated against the knife using a drive mechanism that varies in design and approach, depending on the technology being used.

Uses of rotary veneer

Rotary-peeled veneers can be used to manufacture products suitable for structural and appearance applications. Common structural applications for products manufactured from rotary-peeled veneers include structural plywood, formwork plywood for concrete construction, packaging, marine ply and laminated veneer lumber. Decorative uses for rotary-peeled veneer include architectural uses, furniture and joinery. Cocoveneer could be suitable for the manufacture of many of these products.

Advantages of veneer-based wood products

Significant advantages of veneer-based products compared to solid wood products include the following.

- Increased yield and value from forest resources. Rotary-peeled veneers provide an opportunity to use lower quality and different log resources that are not suitable for traditional, sawn products. Additionally, recovery rates are usually higher from a rotary peeling process compared to sawing, especially with small-diameter log resources.
- More predictable performance, faster production and a greater range of possible product dimensions. Rotary veneer-based products can be produced in greater lengths, widths and thicknesses compared to products produced by traditional sawing.
- Unlike sawn timber products, veneer-based products allow randomisation of defects. The advantage of this is that defects are not concentrated at one location in the product. The ability to use defective material permits log resources with numerous defects to be converted into veneer-based products that are suitable for structural and appearance applications.
- Versatility and suitability for diverse applications and all building types ranging from detached domestic housing to multi-residential and commercial buildings.
- Greater stability, shear strength and impact resistance. Plywood's cross-laminated construction means that movement within the plane of the panel is minimal. The axial alignment of the grain in one sheet of veneer restrains the tangential movement in adjacent veneers. Unlike solid wood products, shrinkage and strength properties are similar in both planes.
- Greater control over the wood property variability and gradients within the final product compared with sawn products. Veneer-based products can be engineered to suit different structural and appearance applications.
- An ability to span wide supports and good creep resistance. Their ability to withstand large racking forces can make them the preferred building material choice in areas that experience extreme events (e.g. earthquake- or cyclone-prone regions).

Suitability of coconut palm stems for veneer-based products

Until recently, attempts to process coconut palm stems into rotary veneer have been largely unsuccessful. This has been mainly due to the spindles or chucks of traditional lathes being unable to transfer the forces between the turning spindles and the low density, soft inner part of the coconut billet. This prevents the billet from correctly rotating, limiting the quantity and quality of veneers that can be produced. However, technological advances in peeling equipment have provided spindleless veneering approaches that have enabled this problem to be largely overcome. The development of this technology has been primarily focused on the processing of very small and young plantation hardwood logs; however, it can be successfully adapted for the processing of coconut stems.

GENERAL OVERVIEW OF COCONUT PALM VENEER PROCESSING

Veneer-based product manufacturing typically involves three main stages:

- veneer manufacture (billet storage, handling and peeling)
- veneer clipping, drying and up-grading
- product manufacture (lay-up, pressing and finishing) (Figure 1.1).

Recommended practices for the first two stages are outlined below. Details of the final stage are not included in this book, but are detailed in the partner publication 'A guide to manufacturing rotary veneer and products from small logs' (Leggate et al. 2017).

Stage 1: Veneer manufacture

Grading, sorting and handling logs

- Select logs that meet required specifications—appropriate quality and size.
- Sort logs into batches based on quality and size.
- Minimise time between harvesting and processing to avoid degradation.
- Store logs off the ground and protect where necessary from drying, biological attack from insects and decay.
- Cut logs to billets of appropriate length before peeling.

Debarking, pre-conditioning and round-up

- Debarking (or removal of the cortex layer) and rounding up may be undertaken before or after pre-conditioning. Rounding up produces cylindrical billets in preparation for veneer peeling.
- Pre-conditioning (heating) billets is necessary prior to peeling, particularly when peeling senile coconut stems which have medium- to high-density zones on the billet periphery. Failure to pre-condition correctly will lead to high lathe loadings, poor-quality veneer and unsuccessful peeling. A temperature of 80–90 °C is suitable, particularly for medium- to high-density coconut.
- Ensure billets are kept free of stones, dirt and other debris in order to avoid damage to peeler knives and other equipment.

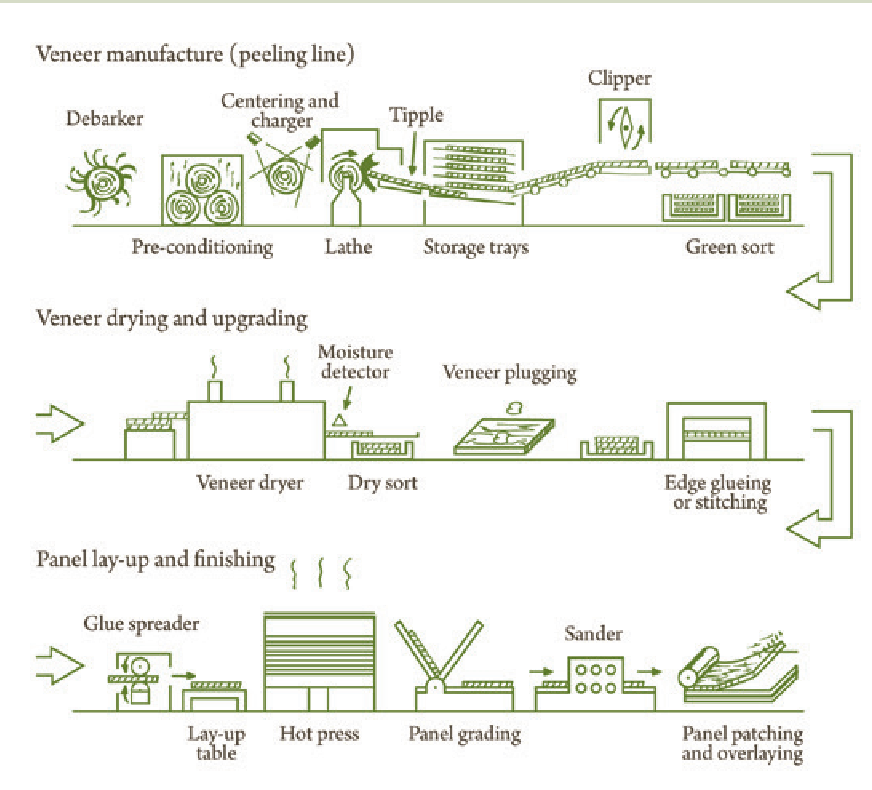

Figure 1.1. The three stages of panel manufacture. Source: Walker (2006), p. 399.

Peeling

- Choose lathes compatible with log resource characteristics, target products, available supporting infrastructure and labour and other economic factors. Spindleless lathes are necessary for rotary peeling of coconut stems due to the incompatibility of spindles with the low-density, soft core of the coconut palm stem.
- Adopt a lathe set-up appropriate for the resource and target products. Optimal settings are determined by a range of conditions and parameters including the lathe capacity, supporting infrastructure (e.g. billet pre-conditioning), log size, log quality, range of log densities, speed of production and actual veneer quality requirements (including target thickness and thickness tolerance).

Stage 2: Veneer clipping, drying and upgrading

Clipping and sorting

- Choose a clipping strategy that recovers the highest amount of accurately sized veneer with acceptable quality.
- Sort the veneers, where appropriate, according to quality, sizes, cross bands, long bands, fishtails and target end-product.

Drying

- Separate veneers into types that will dry at different rates, for example, it might be necessary to separate cocoveneers into several density batches.
- Determine target moisture content according to adhesive, product and market requirements.
- Dry the veneers as soon as possible after peeling to avoid degradation (e.g. by moulds, veneer distortion or buckling).
- Re-dry veneers that do not meet moisture content requirements.

Grading and sorting

- Grade the veneers according to the requirements of relevant standards and/or requirements of customers.
- Consider upgrading veneers through composing and patching. However in some cases, the preference is to patch panels instead.
- Sort the veneers according to end-product requirements, for example, quality, size, colour and density.

Storage

- Ideally the storage area should be dry and enclosed thus providing protection from the weather and extreme UV radiation. There should be adequate air circulation.
- Veneers should be stored flat and the stacks need to be evenly supported, kept clear of the ground, and protected, to avoid machinery damage.
- The surface of stacks should be kept free of contaminants, for example, dust, oil and adhesives. This can be achieved by wrapping in plastic that can also protect the veneers from significant changes in moisture content.

Quality control

- Adopt a quality control system that includes procedures, protocols and assessments to ensure that veneers adhere to the requirements of relevant standards and/or customer expectations.

REFERENCE AND FURTHER READING

Leggate W., McGavin R. and Bailleres H. 2017. A guide to manufacturing rotary veneer and products from small logs. ACIAR Monograph 182. ACIAR, Canberra.

Walker J.F. 2006. Primary wood processing: principles and practice, 2nd edition. Springer, Netherlands.

Rotary-peeled products: advantages and uses

2

ADVANTAGES OF VENEER-BASED WOOD PRODUCTS

The concept of rotary peeling a log to produce veneer, as an alternative to sawing to produce boards, arose due to the significant advantages the process provides. Improved recovery is foremost. This is especially true for coconut palms where typical recovery from rotary peeling can be twice that achievable by sawmilling similar quality and sized logs. The higher recovery is possible because the peeling process produces less waste such as sawdust or wood chips. This also increases the potential return on investment to the processor.

Veneer can be rapidly dried—pre-shrunk for downstream processes such as gluing and to prevent performance issues in-service—when compared to the time required to dry solid wood products. This results in faster production, energy cost savings, and fewer inventory and storage issues.

Developments in the engineering of veneer-based products during the past century have resulted in materials that are stable and straight, and can be manufactured in a wide range of sizes to a consistent quality (Figure 2.1). In sawn timber, the grade quality and therefore piece value is limited by the major defect, whereas the manufacture of veneer-based products allows for randomisation of defects to attain the best product grade possible. This enables a veneer product manufacturer to supply a consistent, homogeneous product with good qualities. The ability to use variable quality veneers in product manufacture permits a wider range of log resources and log qualities to be converted into veneer-based products that are suitable for both structural and appearance applications.

Figure 2.1. Veneer-based construction products—stable, consistent and strong.

Another important and valuable advantage of veneer-based wood products is their stability under cyclical environmental conditions. Plywood is the best known product made from rotary-peeled veneer. It is comprised of layers of veneer known as plies glued together in a cross-laminated construction (i.e. the grain of adjacent plies alternating by 90°). The cross-lamination of plywood means that movement within the plane of the panel is minimal. The axial alignment of the grain in one sheet of veneer restrains the tangential movement in adjacent veneers. In addition to improving stability, cross-lamination greatly improves shear strength and impact resistance, and allows fastenings very close to the sheet edge. Unlike solid wood products, shrinkage and strength properties are similar in both planes. The ability to withstand large racking forces can make veneer-based products the preferred building material in areas that experience extreme events (e.g. earthquake- or cyclone-prone regions).

More specific to coconut palms, one of the key advantages of rotary peeling over sawing processes is the ability to recover much higher volumes of the higher density zone on the outer part of the stems. The higher density coconut stem is favoured for its darker colour, more attractive appearance, and better hardness and mechanical properties.

USES OF ROTARY-PEELED VENEER

Rotary-peeled veneers are most commonly used in structural applications, but they are also used in the manufacture of architectural and decorative products (Figure 2.2). Rotary-peeled veneers are usually 1–4 mm thick from traditional wood resources and 2.5–6 mm thick from coconut palm stems.

Although some products, such as ice-cream sticks and coffee stirrers, are made from single sheets of rotary-peeled veneer, most veneer is glued to form panels or beams (Figures 2.3 and 2.4). The opportunities for products manufactured from cocoveneer are yet to be fully explored.

Figure 2.2. Veneer-based decorative products. Photo: Austral Plywoods.

Figure 2.3. Structural beam products manufactured from rotary veneer.

Figure 2.4. A plywood noise barrier.

Plywood panels

Plywood is a major traditional use of rotary-peeled veneer and is comprised of layers of veneer known as plies, glued together with the grain of adjacent plies alternating by 90°. The high-volume uses for plywood panels are:

- structural, for sheathing and bracing
- form ply for concrete construction
- flooring, usually covered with carpet, tiles or solid timber overlay
- noise barriers along roads and railways
- boat building, truck, trailer and horse float trays and beds
- shipping container flooring
- stair treads and risers
- train, bus and tram floors
- bridge decks
- soffits and fascias
- box beams
- webs in I-beams and trusses
- exterior residential cladding
- temporary hoarding
- sign boards
- wall and ceiling lining

- kitchen and laundry benches
- walkways
- aircraft components.

Decorative uses for plywood (Figures 2.5 and 2.6) include:

- architectural fit-outs, e.g. feature walls and ceilings
- furniture
- decorative flooring.

Figure 2.5. Decorative plywood ceiling. Photo: Austral Plywoods.

Figure 2.6. Decorative plywood panel made from coconut palm face veneers.

Novel hybrids

A range of facings can be used over plywood for special applications in architecture and art projects. For example, aluminium, galvanised iron, copper, stainless steel, fibreglass and carbon fibre have all been used as facing over plywood. Blending forest resources, for example cocoveneer faces combined with softwood or hardwood core veneers, allows optimisation of the best properties of the different materials and helps gain maximum recovery and value from each resource. Other reconstituted wood-based products can also be combined with rotary-peeled veneer to form a composite panel or beam combining the best properties of both materials, for example veneer-faced medium-density fibreboard (MDF) (Figure 2.7). Likewise, sawn wood or cocowood can be blended with veneers to produce a range of products including engineered flooring (Figure 2.8).

Figure 2.7. VJ style wall panelling made from cocoveneer and medium density fibreboard.

Figure 2.8. Engineered flooring combining sawn coconut and plywood.

Laminated veneer lumber

Laminated veneer lumber (LVL) is a solid wood substitute manufactured from rotary-peeled veneers adhered in parallel layers to form a beam (Figure 2.9). This product has made inroads to many markets as a substitute for sawn timber or steel in load-carrying beam applications such as:

- lintels and headers over windows, doors, verandas and other openings in construction
- sub-floor framing as joists and bearers
- internal framing
- furniture
- bridge components.

Figure 2.9. Cocoveneer laminated veneer lumber.

Multilaminar wood

Multilaminar wood is made of superimposed layers of veneer, which are spread with adhesive and then pressed to form a block from which sliced veneers or sawn pieces are obtained, mainly for decorative purposes. The construction strategy is similar to that of LVL; however, usually much thicker sections are produced. Various effects, colours, forms and patterns can be achieved by mixing qualities, bleaching or dyeing veneers, using different glue types with varying colours, block moulding and also slicing or sawing the blocks at different angles (Figures 2.10–to 2.13).

Figure 2.10. Detail of a cocoveneer multilaminar block.

Figure 2.11. Sawn section from a cocoveneer multilaminar block.

Figure 2.12. Examples of multilaminar wood applications.

Figure 2.13. Detail of a multilaminar wood product.

Veneer-based mass panels

Mass wood panels are emerging as a popular engineered wood product choice for the construction of medium to tall timber buildings. The most common type of mass wood panel is cross-laminated timber and it is used mainly as wall, floor and ceiling panels. Cross-laminated timber is traditionally made using sawn timber feedstock. Veneer-based mass panels provide an alternative to cross-laminated timber and can be manufactured with panel sizes over 10 m in length, up to 3.6 m in width and typical thickness exceeding 170 mm. They offer many advantages over cross-laminated timber including superior mechanical properties and more efficient use of the forest resources. Veneer-based mass panels have existed in Australia since the 1980s with development mainly focused on bridge decks.

Fit for purpose

While a wide range of products can be manufactured from rotary-peeled veneer, not all logs delivered to the mill are suitable for all products. The grade quality of the logs and of the dried veneer will determine the suitability for possible applications and products.

From the research undertaken in the ACIAR project 'Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities' (FST/2009/062), cocoveneer achieved relatively low mechanical properties (stiffness) compared with many existing commercial wood species. This may limit its suitability for some structural products in current markets unless careful grading techniques are used, the cocoveneer is blended with other forest resources, or specific markets can be identified that have lower mechanical quality requirements (or at least low modulus of elasticity). However, it is suitable for applications where appearance qualities are prioritised.

FURTHER READING

Bootle K.R. 2010. Wood in Australia: Types, properties and uses, 2nd edition. McGraw Hill, Roseville, Australia.

Corkhill T. 1979. The complete dictionary of wood. Dorset Press, New York.

3 Characteristics of coconut woody tissue

The coconut palm (*Cocos nucifera* L.) belongs to the monocotyledon plant group (monocots), and is thus closely related to grasses and bamboos. The mature coconut palm reaches an average height of 20 m and an average butt diameter of 300 mm (Figure 3.1). These average values can differ depending on age, site and variety (Killmann and Fink 1996).

Figure 3.1. A typical senile coconut plantation in Fiji.

ANATOMY OF THE COCONUT PALM

The stem of a coconut palm is covered with a cortex, typically 1–1.5 cm thick, which is a fibrous tissue that provides a similar function to the protective bark layer on trees but with the additional function of anchoring the palm frond bases (Figures 3.2 to 3.4) (Tomlinson 1990). The central cylinder is described by Butterfield et al. (1997) as a '...central core of primary vascular bundles embedded in a parenchymatous ground tissue' (Figure 3.2). The concentration of vascular bundles increases radially from the centre to the stem periphery, corresponding with increasing density.

The vascular bundles have honeycomb-like prismatic cells and dense fibres aligned along the length of the stem, while the ground tissue is made up of thin-walled, polyhedral parenchyma (Gibson 2012). Combined, the ligno-cellulosic fibres differ anatomically from woody plants, which are classified in the dicotyledon plant group (dicots). The main characteristic of monocot tissues is the presence of scattered vascular bundles (Figure 3.5), and because of these, the woody tissue of coconut palm is not wood in a strict botanical sense.

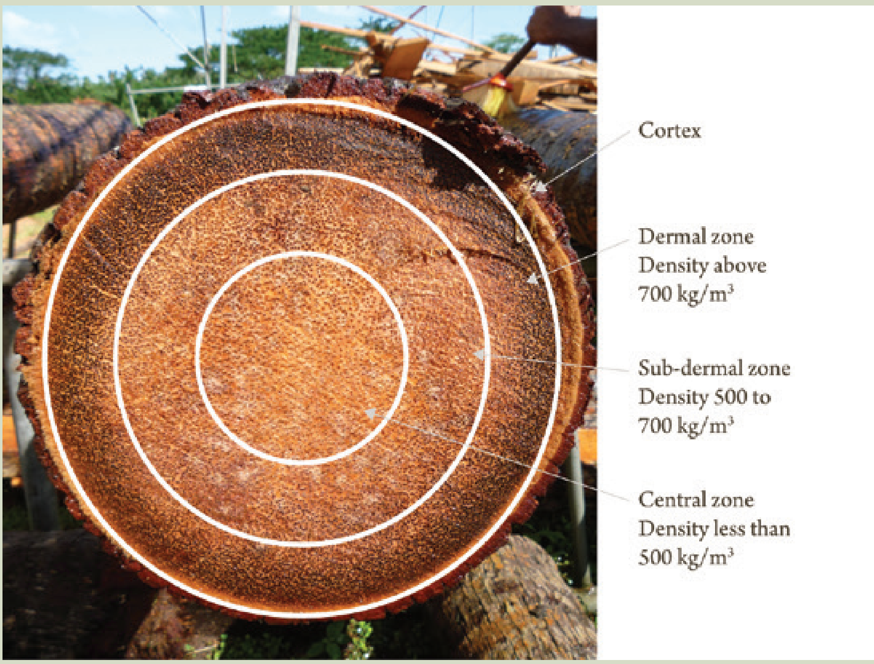

Figure 3.2. Cross-section of a coconut palm stem showing the concentration of vascular bundles increasing radially from the centre to the periphery, corresponding to increasing density.

Figure 3.3. Hard cortex covering a coconut palm stem.

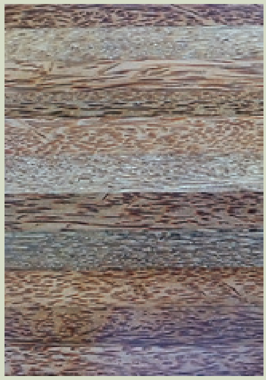

Figure 3.4. Many vascular strands in the high density zone are leaf traces, anchoring the palm frond to the stem.

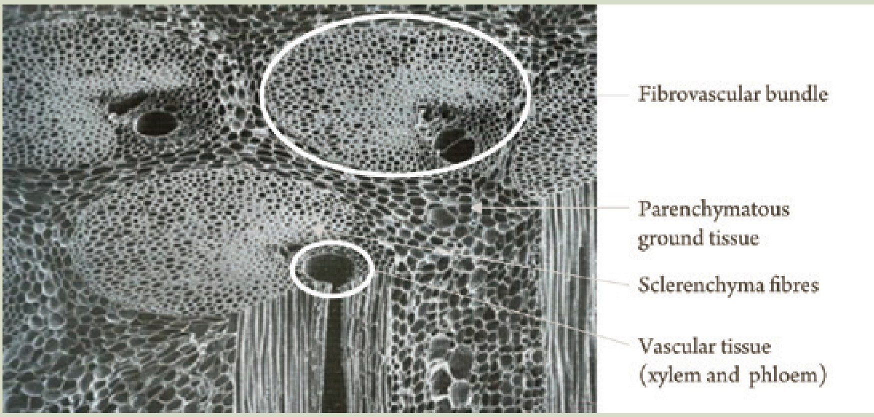

Figure 3.5. Vascular bundles embedded in parenchymatous ground tissue (120×). Source: Butterfield et al. (1997).

The ground tissue contains specialised tannin cells that hold polyphenols and raphide sacs and can include random strands of pectin. Each vascular bundle consists of xylem, phloem, axial parenchyma and sclerenchyma fibre elements. The bundles are arranged in a multi-helix formation up the stem. The helical pathways rotate approximately one-quarter of the stem circumference per 15 cm length along the stem (Figure 3.6). This architecture can result in distortion and low strength in sawn boards and rotary veneer.

Figure 3.6. Photos show the grain angle after a coconut palm log disk has been split with a straight blade.

Lateral growth of dicots originates in the vascular cambium which makes the tree grow in the radial as well as in the axial direction simultaneously. After cell differentiation, which includes the degeneration of the initial cell materials, there is no further increase in cell dimensions and wall thickness. Coconut palms have very different physiological growth processes and structural composition, and therefore different material attributes compared to woody dicots. Palms do not contain a vascular cambium, that is, the vascular system is totally closed, without a secondary vascular cambium, and the cells stay alive, continuing to evolve over the life of the palm. For the first five years or so, the stem grows mostly in the radial direction with little increase in height, followed by an extended period of growth in the axial direction with little further radial growth. As the palm stem increases in height, additional layers are added to the cell walls in the vascular bundles, increasing their density and mechanical properties towards the periphery of the stem. Within the coconut palm stem, there is a density gradient that can range from 100 kg/m^3 to more than 1,000 kg/m^3, with denser material towards the base and periphery of the stem.

The diameter of the stem increases slightly with age as the cell walls increase in thickness. Indeed, additional secondary layers are added inside the lumen to the existing secondary wall, made of cellulose fibres in a matrix of lignin and hemicellulose. The cellulose fibres are typically oriented at different angles in each secondary layer and the layers may differ in thickness. As the stem ages and grows taller, the increased load is resisted by increasing the thickness of the cell walls. The concentration of the vascular bundles, as well as the relative quantity of fibres within the bundles, is greater at the periphery of the stem than in the central zone. Cell wall thickening is also more pronounced in the peripheral tissue than in the central core tissue (Figures 3.7 and 3.8). A radial density and longitudinal stiffness distribution develops, with denser and stiffer tissue at the base and periphery of the stem, where the bending stresses on the stem are greatest (Gibson 2012).

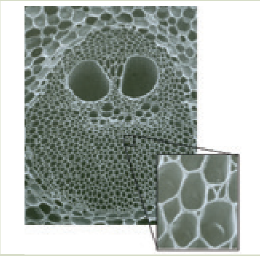

Figure 3.7. Fibrovascular bundle from a young palm stem or the centre of an older stem characterised by thin fibre walls and large lumens (big photo 100x, small photo 1300x). Source: Butterfield et al. (1997).

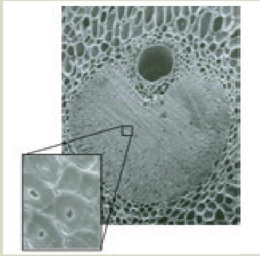

Figure 3.8. Fibrovascular bundle from the periphery of an old stem characterised by thick fibre walls and small lumens (big photo 90x, small photo 1900x). Source: Butterfield et al. (1997).

The bundles typically do not grow parallel to the stem axis. Investigations on bundle angle, applying a procedure developed by Bailleres and Mahnert (Mahnert 2009), showed that the bundle angle changes within the cross-section of the coconut stem. The colour map (Figure 3.6) displays the three interlocking bundle helices along the axis first described by Bailleres (2009) from analysis of 54 senile palms from different Pacific islands. Further analysis on the same coconut palm samples was performed by Gonzales et al. (2014b), resulting in the modelling of the bundles forming three helices across the radial axis. The average maximum fibre orientation was found to range from ±6.20° to ±9.15°, depending on the palm height. The typical radius at the bottom of the coconut palm was found to be 158 mm, decreasing gradually, following a proposed neloid shape, to 80 mm at 25 m height. Basic density distribution of the cocowood was found to best follow a parabolic curve that varies axially and radially from 'low' to 'high' density, with average density ranging from 100 kg/m^3 to about 900 kg/m^3.

Table 3.1 summarises the main anatomical differences between dicotyledon and monocotyledon plants that affect wood properties.

Table 3.1. Comparison of the main anatomical features in dicotyledon and monocotyledon plants (Gonzalez (2015), summarised from Butterfield et al. (1997)).

Dicotyledon woody plants (hardwoods and softwoods)	Monocotyledon plants (e.g. palm, bamboo, grass)
Vascular cambium, secondary growth	No vascular cambium, no secondary growth
Increase in diameter with age	No significant increase in diameter with age
May produce annual rings	No annual rings
Most trees produce heartwood	No heartwood
Wood contains radial ray cells	No ray cells
Knots within wood as a remnant from branches	No branches, no knots
Uniform distribution pattern of fibres	Scattered fibrovascular bundles
Completely separated bark, easy to remove	Bark is not demarcated from wood, hard to remove

PHYSICAL AND MECHANICAL PROPERTIES OF COCONUT PALM WOODY TISSUE

Coconut palms have neither heartwood nor annual growth rings, and lack branches and therefore contain no knots in the processed material. There is also no radial parenchyma tissue. Senile palms (>60 years old) are markedly heterogeneous with a soft, low-density central core transitioning towards an outer ring of hard, dense tissue. Nevertheless, cocowood can be processed using similar equipment and tools to those used for the processing of traditional wood.

Moisture content

In the timber industry, moisture content is expressed as a percentage and indicates the proportion of water to the oven-dry weight of wood material. The moisture content of coconut wood at the time of harvest varies markedly, ranging from 50% to over 400%. Moisture content increases with stem height and from the stem periphery radially inwards to the core. This pattern is strongly correlated with the proportion of parenchymatous ground tissue which holds more water than the vascular bundles. The combination of high moisture content and tropical conditions in the Pacific region provides a favourable environment for fungal contamination and growth, and therefore harvested logs need to be processed rapidly to minimise degradation or decay.

Density and hardness

Density is the mass per unit volume of a material. In the timber industry, density is expressed in kilograms per cubic metre (kg/m³), usually at a specified moisture content such as 12% (air-dry density, ADD). The central zone of coconut palm stems is characterised by very low to low density, between 100 and 500 kg/m³ ADD. The subdermal or intermediate zone has medium density material usually between 500 and 700 kg/m³ ADD. The dermal or outer wood zone has very high density, above 700 kg/m³ ADD and often between 800 and 1,100 kg/m³. Figure 3.9 illustrates the density profile within a stem.

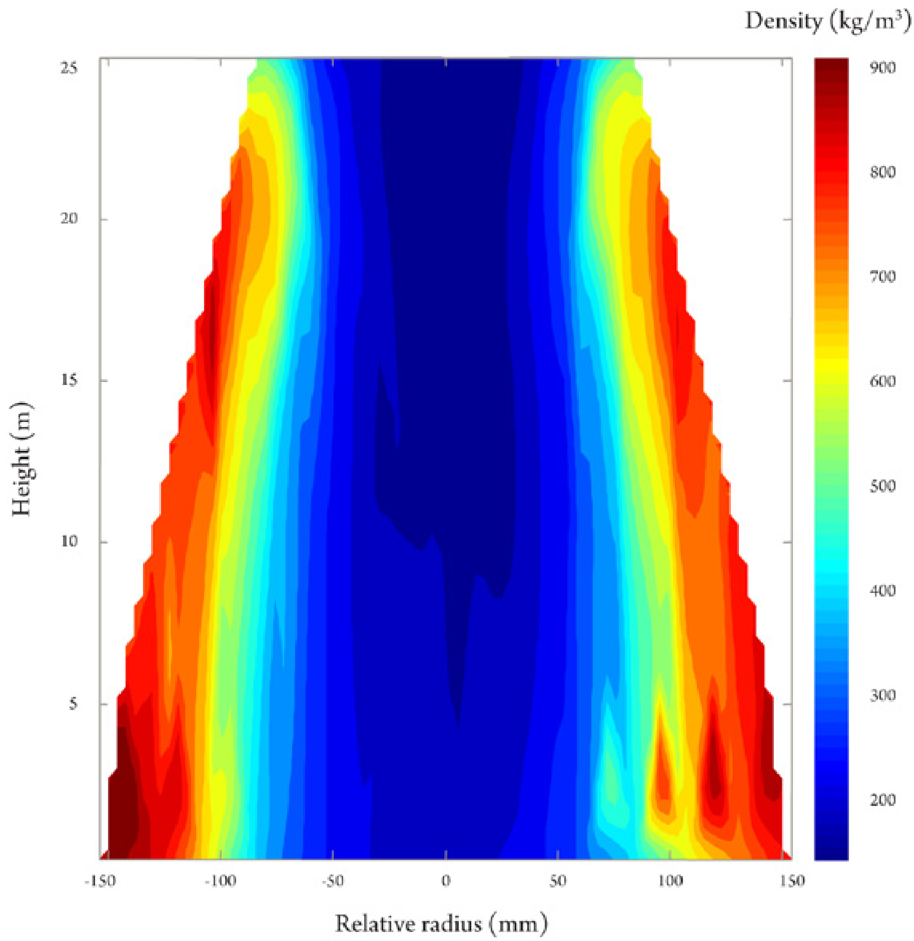

Figure 3.9. Typical air-dry density profile of a senile coconut palm stem (not to scale).

The diameter of the bundles decreases both from the base longitudinally towards the growing top and from the core radially to the cortex of palm stems, though the range of variation in fibre wall thickness is larger in the longitudinal axis. The number of bundles per unit of surface area increases with the height of the palm, as the bundle diameter decreases. As a result, cocowood with similar densities can display quite different visual patterns (Figure 3.10). Cell lengths are shorter in the higher density outer wood than in the central core. Fibre walls are essentially comprised of several layers, with wall thickness increasing with age. Tall varieties of coconut palm older than 60 years have a higher proportion of high-density fibre than younger palms. Despite the high-density cocowood representing a high proportion of log volume, much of this material is lost to waste if processed using traditional sawmilling equipment, whereas rotary peeling can maximise recovery of this valuable part of the palm stem.

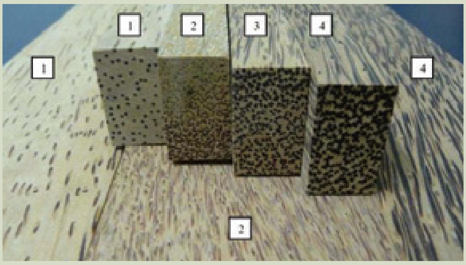

Figure 3.10. Appearance of cocowood. (1) Low density from central zone at 3–6 m stem height; (2) medium density with high density variation from periphery at 12–15 m stem height; (3) high density from periphery at 6–9 m stem height; (4) high density from periphery at 0–3 m stem height. Source: Tschupp (2009).

Hardness is an expression of a material's resistance to indentation. The Janka hardness quantifies the resistance of a sample of wood to denting and wear. The standard test measures the force (kN) required to embed an 11.28 mm (0.444 inch) diameter steel ball halfway into a sample of wood. A common use of Janka hardness ratings is to determine whether a species is suitable for use as flooring. An outer ring of hard cocowood (approximately one-fifth of the radius) provides Janka hardness values between 5 and 13 kN depending on the age of the palm. These values are within the recommended range for applications requiring resistance to indentation such as flooring and benchtops.

A non-linear correlation has been demonstrated to exist between hardness and density, and the relationship between these two parameters in cocowood is comparable to traditional wood up to a density of 700 kg/m^3. At a higher density, cocowood tends to have a higher Janka hardness than traditional wood (Figure 3.11).

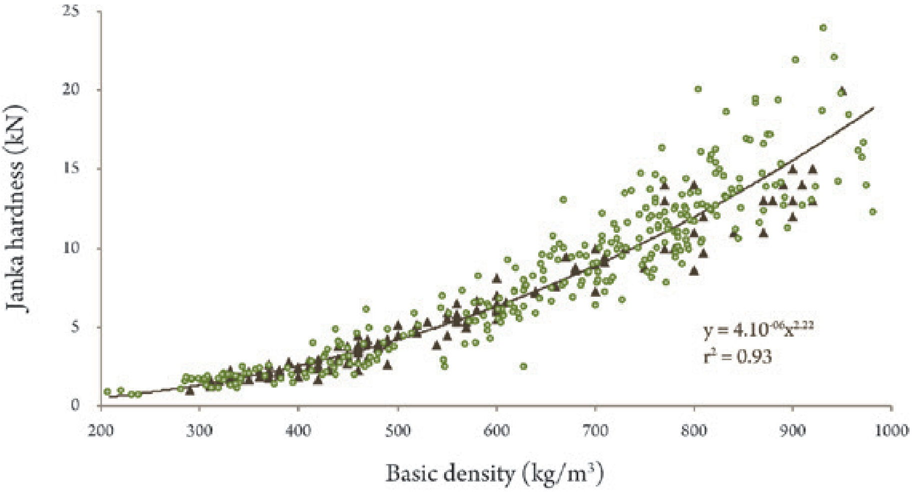

Figure 3.11. Janka hardness across a wide range of basic density for cocowood and traditional wood. Circles represent cocowood; triangles represent traditional wood. Non-linear regression is displayed for cocowood.

Shrinkage

An advantage of coconut palm over traditional wood is that the anisotropy coefficient for shrinkage (tangential shrinkage to radial shrinkage) is close to 1, compared to a range between 1 and 2 for traditional wood. This can be explained by the absence of radial parenchyma in woody monocots which is likely to restrain the shrinkage in the radial direction. The presence of rays in woody dicots contributes to their anisotropy, where shrinkage in the tangential plane can be up to double that in the radial plane causing cupping deformation of board cross-section when drying.

In coconut palm, shrinkage generally increases with an increased proportion of vascular bundles per unit volume. Shrinkage from green to air-dry (12% moisture content) is on average 4% in both tangential and radial planes for cocowood, compared to approximately 6% (tangential) and 4% (radial) for spotted gum (*Corymbia* spp.), a commercial species in Queensland that is processed in high volumes.

Unit shrinkage is the percentage change in dimension associated with each 1% change in equilibrium moisture content below about 25% moisture content. There is a high level of linear correlation between basic density and unit shrinkage of cocowood as displayed in Figures 3.12 and 3.13. The range of tangential unit shrinkage is like many commercial hardwood species, whereas the radial unit shrinkage is approximately twice the average of many commercial hardwoods (Ross 2010). The ratio of tangential to radial unit shrinkage is around 1 up to 500 kg/m³ ADD. Above this density, the ratio increases to 1.2 due to a higher proportion of vascular strands anchoring the palm frond to the stem in the radial direction.

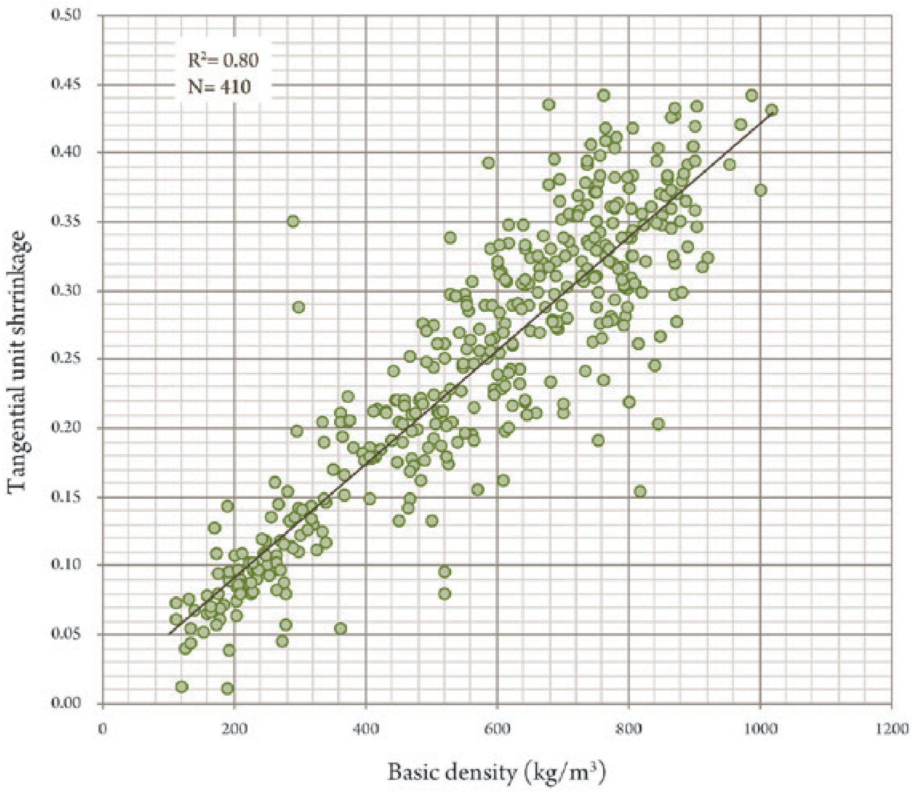

Figure 3.12. Tangential unit shrinkage versus basic density from samples of 54 senile palms from different Pacific islands.

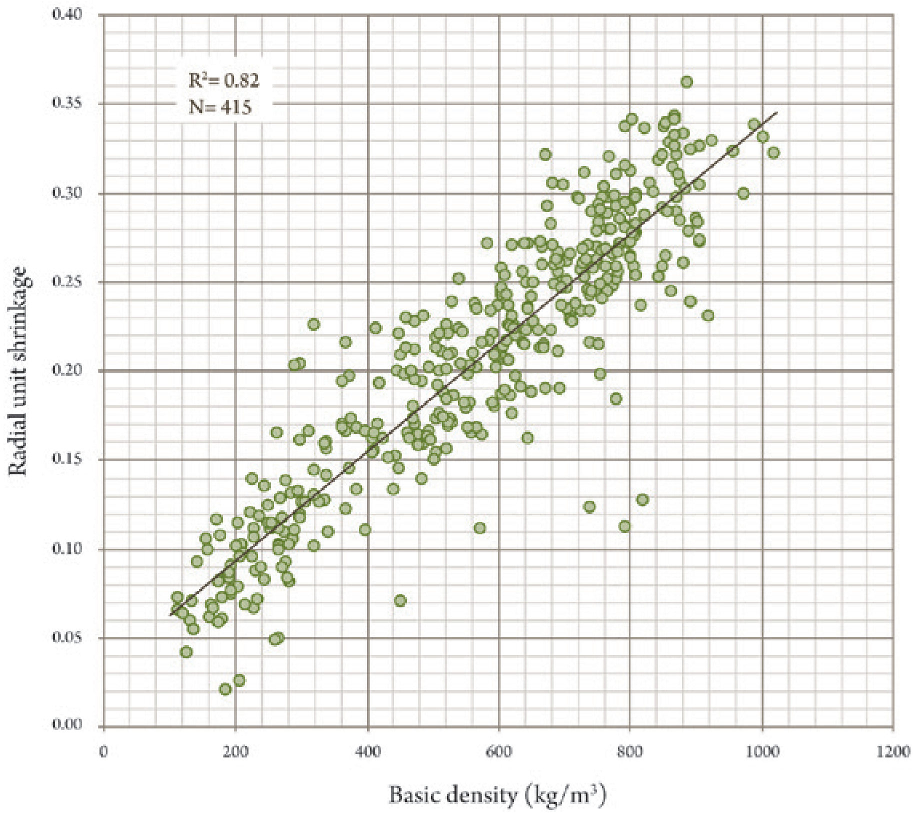

Figure 3.13. Radial unit shrinkage versus basic density from samples of 54 senile palms from different Pacific islands.

Stiffness and strength

Two of the key material mechanical properties of interest to product designers, specifiers and engineers are the modulus of elasticity (MoE) and the modulus of rupture (MoR). The former denotes a material's dimensional response under load and is measured by bending tests to determine deflection. MoR is the measure of the ultimate short-term load-carrying capacity when the load is applied slowly. Both properties provide a standard indication of suitability of a material for structural applications.

For a density between 500 and 1,200 kg/m³ (ADD), the cocowood MoE ranges from 5,000 to 18,000 MPa and the MoR from 30 to 160 MPa (Figures 3.14 and 3.15). The linear correlation between density and these mechanical properties is moderate with a significant dispersion. For the same span of density, common commercial hardwoods display an MoE of between 8,000 and 24,000 MPa and an MoR of between 70 and 170 MPa. This is about 30–40% higher than cocowood. The reason for this discrepancy lies in the high grain angle deviation and the low shear properties of cocowood.

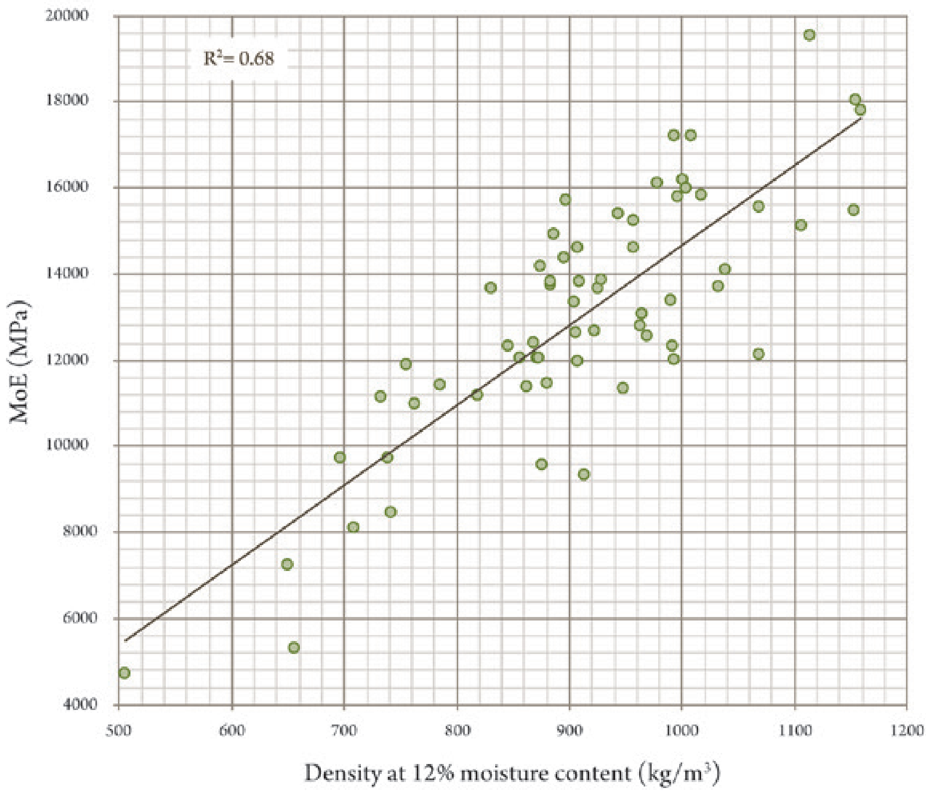

Figure 3.14. Cocowood modulus of elasticity (MoE) measured from four point bending tests on 62 specimens, 400 × 20 × 20 mm.

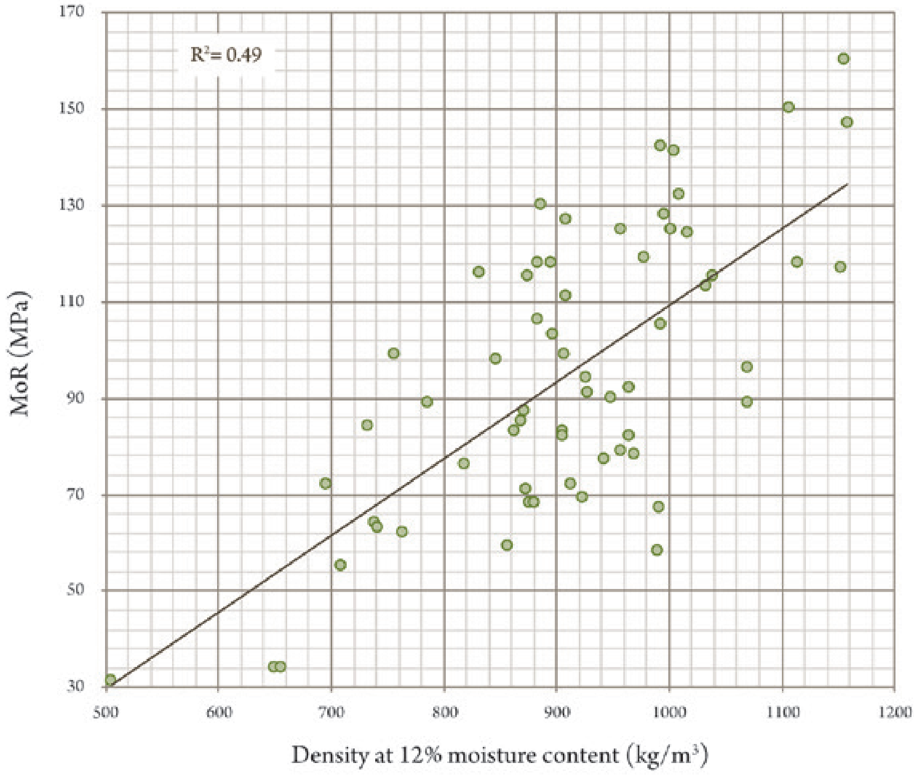

Figure 3.15. Cocowood modulus of rupture (MoR) measured from four point bending tests on 62 specimens, 400 × 20 × 20 mm.

The main characteristics of coconut palm woody tissue are summarised in Table 3.2.

Table 3.2. Summary of coconut palm woody tissue characteristics.

Characteristic	
Physical properties (units)	**Range (low–high density fibre)**
Density—basic (kg/m^3)	100–1020 [a]
Density—air dry (kg/m^3)	200–1170 [a]
Density for flooring products (Janka hardness >7 kN) (kg/m^3)	>700 [a]
Specific gravity	0.26–0.59 [d]
Shrinkage: tangential, green to dry (%)	3.0–6.0 [b,c,d]
Shrinkage: radial, green to dry (%)	2.7–7.4 [b,c,d]
Unit shrinkage: tangential	0.05–0.42 | high density: 0.32–0.38 [a]
Unit shrinkage: radial	0.05–0.34 | high density: 0.24–0.3 [a]
Workability	Firm to hard; use sharp tools
Mechanical properties (units)	
Modulus of elasticity: dry (GPa)	2–25 [a] | high density: 11.4 [c]
Modulus of rupture: dry (MPa)	28–205 [a] | high density: 104 [c]
Maximum crushing strength: dry (MPa)	19–57 [c] | high density: 40 [a]
Janka hardness: dry (kN)	0.7–23.9 [a]
Chemical properties (units)	
Inorganic pure ash (%)	0.75 (0.25–2.4) [a]
Silica (%)	0.07 (0.01–0.2) [a]
Lignin (%)	25.1 [d]
Holocellulose (%)	66.7 [d]
Pentosans (%)	22.9 [d]
Starch (%)	4.3–4.6 [e] (>6 months old; starch reduces with age)
pH	6.2 [e]

Characteristic	
Durability, susceptibility to pests and staining	
Natural durability above-ground (averaged over all densities)	Class 4; life expectancy 0–7 years [f]
Natural durability in-ground (averaged over all densities)	Class 4; life expectancy 0–5 years [f]
Susceptibility to *Lyctus*	Not susceptible [b,f]
Termite resistance (averaged over all densities)	Not resistant [a]
Staining	Susceptible to staining [b]
Wood seasoning	

Kiln drying schedule, up to 60 °C (dry bulb) over 10–14 days

Moisture content change points (%)	Dry bulb temperature (°C)	Wet bulb temperature (°C)	Relative humidity (°C)	Equilibrium moisture content (°C)
Green – 85	49.0	44.0	78.0	13.0
85 – 58	53.0	47.0	75.0	11.5
58 – 35	56.0	48.0	64.0	10.0
35 – 28	58.0	49.0	51.0	9.0
28 – 19	62.0	48.0	43.0	6.5
19 – 12	60.0	43.0	40.0	5.5
Equalisation – 48 hrs	60.0	55.0	55.0	8.0

Monitoring moisture content. Recommended: use sample boards in the stack and the oven-dry method for monitoring moisture content during drying. Or, use resistance type meters (accurate only at moisture content <25%) and moisture correction factors provided.

Moisture correction factors for drying cocowood (for resistance meters calibrated to *Pseudotsuga menziesii*)

Meter reading (% moisture)																		
6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Corrected moisture content (% moisture)																		
—	—	—	—	8	8	9	9	10	11	11	12	12	13	13	13	14	14	15

a Department of Employment, Economic Development and Innovation (DEEDI), Brisbane, Australia. Unpublished data: Improving the value and marketability of coconut wood. ACIAR project No. FST/2004/054.
b Alston (1982).
c Arancon (1997).
d Gibe (1985).
e Poulter and Hopewell (2010).
f Keating and Bolza (1982).

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4 Log specifications, grading and pre-processing

A successful veneer operation depends on three main criteria:

- a supply of suitable logs
- the use of appropriate processing techniques
- an effective sales and marketing program.

In order to sell veneer logs, a transferable and comparable grading system is needed. This gives buyers confidence that the graded logs meet their manufacturing and quality requirements. The purpose of grading veneer logs is to sort material into groups that match the best utilisation and price/value category. This price/value relationship is set not only by the aesthetics and physical properties of the wood, but also by the demand for particular qualities and species. Most veneer peeling processors buy logs based on log volume, log quality and species.

Factors affecting the veneer quality of peeler logs can be attributed mostly to species, genetics, silviculture, growing conditions and tree health. These include age, growth rate (slow and uniform generally equates to more desirable quality), stem form, knots and limb-related defects (size and location), decay and insect damage. It is important that there is an exchange of information between managers of veneer production facilities and forest managers to develop an understanding of forest management practices that impact on the yield and quality of peeler logs.

The three main criteria used to assign a value to a hardwood peeler log destined for veneer production are species, available volume and grade. Some species are more prized than others due to their rarity, ultimate suitability for a particular end use, or reputation in the market. Available volume considers not only the volume of recoverable veneer from a log but also the scale and long-term supply potential of suitable logs from the forest. Grade refers to a combination of log attributes (beneficial or non-beneficial) that will determine a log's suitability for veneer production.

Factors affecting the veneer quality from coconut palm logs include age, density profile, colour, diameter, form, presence of decay, mechanical damage and insect damage. A good understanding of veneer quality requirements will assist with an improved understanding of how forest management practices will impact the yield of veneer-quality logs.

GRADING A PEELER LOG

Log grading systems exist for many traditional wood species and although they vary internationally, the principles are essentially the same. The process aims to:

- identify grade-limiting defects
- measure and/or assess those defects
- identify grade-enhancing characteristics
- determine other important aspects such as size
- assign a grade to the log.

Grading a log destined for veneer production entails evaluating the log quality and hence the quality of the veneer that can be peeled from that log. Log grading is based on a visual assessment of specific log features that are set out for each grade classification. Ideally, the grading rules should be easily understood so they can be applied quickly and accurately. However, it should be noted that different interpretation of the rules can lead to small differences in opinion and sometimes written rules are not adequate to describe all scenarios. Then it is for the experienced grader to use their discretion.

Factors to consider when grading a peeler log are:

- the dimensions of the log (length and diameter)
- the form of the log (the degree to which the log deviates from a true cylinder) including sweep, taper and ovality
- the presence of defects or grade-enhancing characteristics in the log (external and internal).

A log grading system for coconut peeler logs is yet to be established, and will be needed as the cocoveneer industry develops. Peeler log grading systems are well developed for traditional wood species, but these will not be directly transferrable to coconut peeler logs. For example, coconut logs are devoid of knots and also have a low occurrence of log splitting which are common defects found in traditional wood peeler logs. Coconut peeler logs may have some additional grading requirements for density, colour and mould/discoloration. Some synergies potentially exist with log size, shape, decay, insect attack etc.

Grading a eucalypt peeler log—an Australian example

In Australia, each state forest agency has developed specifications for the logs sold within its jurisdiction. Sales between private growers and wood processors use the same grade definitions or others derived from the specifications developed by the state agencies. Although the general principles are the same throughout Australia, the precise definitions of grades vary. The specifications used by Forestry Tasmania (2015) for grading eucalypt regrowth and plantation peeler logs that are destined for veneer production are given as an example in Table 4.1.

Table 4.1. Peeler log specifications for eucalypt regrowth and eucalypt plantation in Tasmania (2015).

Grade factors	Criteria
Length	Minimum length is 3.4 m. A minimum length of 2.2 m can be accepted if suitable arrangements can be made for handling and transporting the peeler logs.
Small end diameter (SED)	Minimum 18 cm
Large end diameter (LED)	Maximum 70 cm
Knots and limbs	For logs with an SED < 35 cm, the maximum diameter of any knot or limb is 10 cm. For logs with an SED ≥ 35 cm the maximum diameter of any knot or limb is 20 cm. There is no limit to the number of knots or limbs allowed as long as they do not exceed the maximum diameters.
Bumps	A log may contain no more than one significant bump in each 1 m of log length. A log may contain any number of bumps that are not classed as significant bumps.
End-splitting	The end of the log may contain minor cracks no more than 5 mm in width.
Scars and evidence of borers	A log may contain scars, provided that the log is sound and there is no evidence of any rot beyond the scar itself. A log may contain evidence of insect borers.
Roundness	Neither end of the log can have a major axis that is more than 20% greater than the minor axis at the end. A log with an irregular or 'fluted' circumference is not allowable.
Sweep	For logs < 5.4 m in length, the maximum permissible sweep is 25% of the SED. For logs ≥ 5.4 m in length, the maximum permissible sweep is 50% of the SED.

Grading a hardwood peeler log—a Vietnamese example

Vietnam is currently in the advanced stages of introducing a standardised veneer log grading system for small-diameter hardwood peeler logs. The development of the grading system was supported by the ACIAR project FST/2008/039, 'Enhancement of production of acacia and eucalypt peeled and sliced veneer products in Vietnam', led by the Queensland Department of Agriculture and Fisheries (DAF).

The proposed grading system for Vietnam includes two grades, A and B, where grade A is of higher quality. For a log to meet grade A classification, all criteria must meet grade A standard. For instance, if one criterion is grade B standard, then the log is classed as a grade B log. If a log displays a defect below grade B standard, it is considered a reject log, that is, not fit for peeling. Special consideration may be given to accepting reject logs, depending on the company and client specifications. Table 4.2 sets out a summary of the proposed peeler log grading system for Vietnam.

Table 4.2. Proposed grading system for hardwood peeler logs in Vietnam.

Criteria	GRADE A	GRADE B
Knot	Maximum diameter ≤ 10 cm	Unlimited
Bend	Maximum 3%; no multiple bends	Maximum 4%; no multiple bends
Total end-split	Total split ≤ 10% log length	Total split ≤ 20% log length
Holes/insect holes	Maximum diameter ≤ 5 mm	Maximum diameter ≤ 20 mm
Decay	Not permitted	Permitted
Mould	Not permitted	Permitted
Metal objects	Not permitted	Not permitted

The metal objects criterion is included to prevent peeling logs that have imbedded metal objects such as nails or fencing wire, which can cause severe damage to the lathe and injury to machine operators. There is no minimum diameter and/or log length proposed in the log grading specifications because this is subject to the limitations of the machinery and should be specified separately by the processor or log buyer. For example, log specifications will vary depending on whether the lathe is spindled, spindleless or a hybrid type.

LOG STORAGE

Logs should ideally be processed as soon as possible after harvesting. Timely log processing is especially important for coconut peeler logs, to maintain their quality.

Logs should be transported to the log or holding yard as soon as possible after felling to minimise damage by insects, mould and decay. Once in the log yard, the logs must be stored in a way that minimises defects associated with shrinkage, splitting and end-checking, and reduces exposure to wood-decaying fungi, bacteria and insects (Figure 4.1).

Figure 4.1. Harvested coconut logs waiting to be processed in a log storage yard.

Veneer logs can be kept in good condition for some time as long as they are suitably stored. With poor storage, logs can deteriorate due to drying and cracking in the log ends and other exposed surfaces; development of mould; attack by insects; or development of undesirable odours or increased porosity due to attack by bacteria. Mould, fungal staining and decay can rapidly establish in coconut peeler logs.

Log quality degradation is often related to the weather the stored logs are exposed to, and the impact that this has on log drying rates. Wet weather and low temperatures are more favourable for maintaining log quality than hot, dry conditions (although some wood fungi thrive in wet conditions). Shrinkage-related defects should be minimal during cold, cloudy and wet conditions and insects and fungi become inactive or die at very low temperatures. A combination of hot and humid conditions, often encountered in the Pacific region, can be ideal for rapid fungal and insect attack.

Best practice for coconut peeler logs waiting to be processed in the log yard includes:

- minimising storage time prior to processing
- storing logs on bearers off the ground in well-drained areas cleared of plant growth, and free from dirt, stones and other contaminants that can cause processing problems
- sorting and storing logs according to receipt date, size, grade and intended veneer products
- ensuring sufficient space for loading and unloading logs and that the log storage area remains trafficable in all weather conditions
- protecting the logs from harsh weather conditions

- taking care when handling the logs to prevent mechanical damage
- ensuring workplace health and safety guidelines are adhered to including the use of personal protective equipment and mitigating the risk of log pile collapse.

If logs are to be stored for long periods in warm or hot weather, then a sprinkler system may be used if available (Figure 4.2). This will help to minimise end-splitting and end-checking of the logs and will slow the deterioration caused by insects, fungal stain and decay, although it may not eliminate them. Log drying and associated problems can also be reduced by:

- end-sealing the logs
- storing logs close together
- covering logs with shade cloth or storing in the shade
- orientating logs to minimise exposure to wind and sun
- using wind breaks if wind is an issue.

The logs can also be treated with a registered fungicide and/or insecticide prior to the end-seal to reduce fungal stain and insect attack. Despite best efforts, logs can still deteriorate rapidly when in storage so this time should be kept to a minimum. Ideally the first logs into storage should be the first out.

Figure 4.2. Using water sprays in a log storage yard prevents excessive or rapid drying and deters insect and fungal attack.

DEBARKING

The protective, outer layer of a tree is the bark. The equivalent layer in coconut stems is called the cortex. This layer prevents the loss of moisture, inhibits insect attack and decay organisms, and is a barrier to fire and mechanical damage. The bark (or cortex) often includes grit and extraneous materials that can damage or blunt veneer lathe knives. The process of removing bark at the time of harvest or in the mill is termed debarking or sometimes barking.

Debarking peeler logs from traditional wood species is relatively easy and is undertaken at the time of harvesting, at the start of storage or immediately prior to processing. In small operations debarking may be done manually with a bar or axe (Figure 4.3), however the most common method is to use mechanical debarking systems.

Figure 4.3. Removing bark from a hardwood log with the cutting face of an axe.

When to debark depends on several factors. Debarking in the forest at the time of harvesting has many advantages. It reduces the volume of waste material transported from the forest to the veneer mill. The bark is also much easier to remove immediately after harvesting. Removing the bark may render the billets less susceptible to insect attack, depending on the insect species. Leaving the bark in the forest can also benefit the soil nutrient cycle. On the other hand, retaining the bark can partially protect the billet from mechanical damage and also reduce drying while the billet is transported and stored. Even short delays (as little as 12 hours) in debarking can cause the bark to tighten, making it more difficult to remove, especially with manual methods. Debarking is generally easier when trees are harvested in the growth periods of spring and summer. During dry periods it is usually more difficult to remove the bark.

By comparison, the removal of the cortex layer from a coconut peeler log is more difficult. Undertaking the process manually is extremely slow and challenging. The suitability of traditional mechanical debarking systems for coconut peeler logs is unknown at this stage.

It is not uncommon for operations using spindleless veneer lathes to use the same equipment for both the debarking and peeling of logs. This is an effective method for removing the cortex of coconut peeler logs; it is relatively easy and requires minimal capital investment. However, debarking using a lathe frequently damages the veneer knife (e.g. causing chipping and dulling) which results in reduced veneer quality, machine down-time (due to additional knife replacements) and increased knife sharpening.

Many spindleless lathe manufacturers now make dedicated debarkers that are based on the spindleless lathe system (Figure 4.4). This prevents premature damage to the veneer lathe and boosts productivity. These debarkers are usually simpler in design than the lathe and are more robust. Debarking using this method can also provide a round-up function, preparing the billet for immediate peeling.

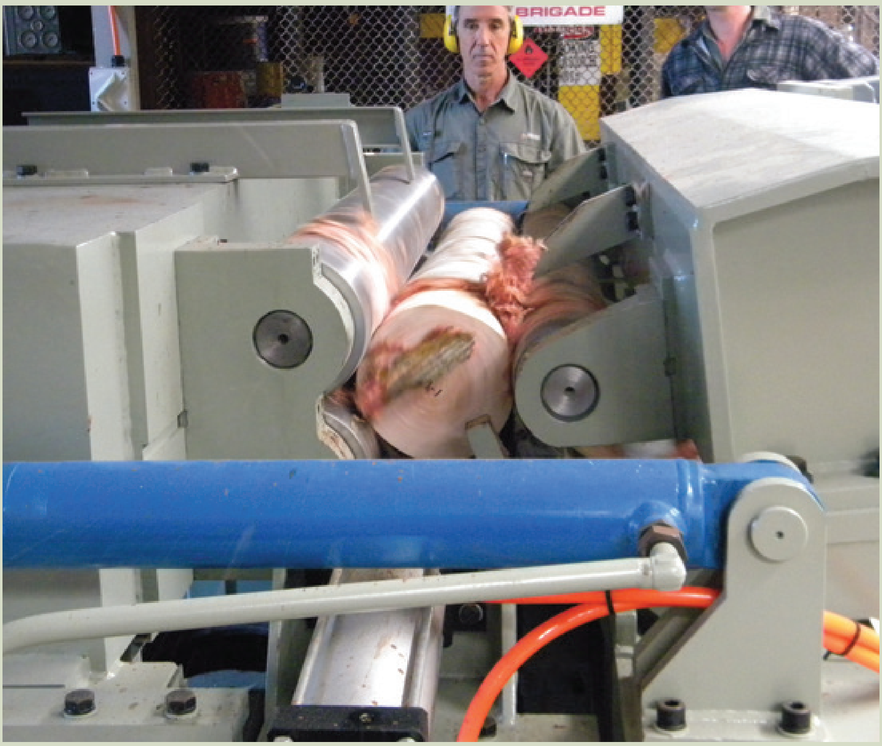

Figure 4.4. A spindleless lathe debarker rounding up a hardwood billet.

LOG PRE-CONDITIONING

Depending on the peeling equipment, log species and the required peeled quality, log pre-conditioning may be carried out. Pre-conditioning is highly recommended for coconut logs, and is critically important where the density exceeds approximately 600 kg/m^3 ADD. Pre-conditioning normally involves heating with saturated steam or hot water (soaking and/or spraying) to soften (plasticise) the wood (Figures 4.5 and 4.6). These treatments are designed to heat the full radial depth of the log without drying it. Pre-conditioning has advantages and disadvantages.

Potential advantages of pre-conditioning are:

- reduced energy requirements for the peeling process
- reduced loading on the veneer lathe (reduced wear and tear, less maintenance)
- improved veneer quality (smoothness, tightness)
- the ability to recover veneer from high-density logs
- fewer split sheets and greater full sheet recovery
- reduced veneer thickness variation
- reduced knife damage and wear (chipping, blunting)
- the ability for veneer colour modification (which could also be a disadvantage).

Potential disadvantages and risks include:

- over-softening, particularly in the lower density core, resulting in premature peeling failure (e.g. spindle holding failure, billet collapse)
- a need for specialist heating equipment and associated costs
- hot water, steam and hot billets can be a safety hazard
- veneer colour modification
- reduction in output (as pre-conditioning is the slowest part of the peeling process it can be logistically difficult to have sufficient pre-conditioned stock ready for peeling to keep pace with the productivity of the lathe)
- environmental management issues with the disposal of waste water.

The preferred wood temperatures (across the full radius) are as follows:

- coconut stems with an air-dry density less than 600 kg/m^3: approximately 50–70 °C
- coconut stems with an air-dry density over 600 kg/m^3: approximately 70–90 °C
- softwoods: approximately 50–60 °C
- hardwoods with an air-dry density 500–700 kg/m^3: approximately 50–70 °C
- hardwoods with an air-dry density over 700 kg/m^3: approximately 70–90 °C.

Figure 4.5. Log pre-conditioning using saturated steam.

Figure 4.6. Coconut peeler billet pre-conditioning using a steam chamber.

The time required to pre-condition billets depends on the density (higher density wood generally requires longer heating times), billet moisture content (up to approximately 30% moisture content, i.e. fibre saturation point), billet diameter, pre-treatment method (steam versus water), infrastructure capacity, veneer quality requirements, and temperature of the hot water bath or steaming chamber.

LOG ROUND-UP

Ideally, billets presented to the lathe should be cylindrical or as close to cylindrical as possible. Ovality, taper, sweep and bumps affect the peeling process, particularly by lowering productivity and increasing wear on machinery. These defects also have a negative impact on recovery. It is therefore desirable to trim or round-up the log (Figure 4.7). Log round-up makes the subsequent peeling more efficient, but the process does not necessarily continue until a perfect cylinder is attained. The operator decides when to stop the round-up phase by estimating when it is worthwhile to recover short lengths and/or widths.

Figure 4.7. Cylindrical coconut logs after round-up and ready for peeling.

Ideally, to protect the main veneer lathe and increase productivity, the round-up process is performed using a separate machine. The process removes foreign debris from the billet periphery thus extending the life of the knife on the main lathe and also providing a better quality veneer surface. As a rule of thumb, the round-up lathe should peel the log until at least 50% of its surface is dressed.

LOG POSITIONING

To maximise recovery using spindled lathes, spindles need to be positioned as close as possible to the geometric central axis of the billet. This ensures that the maximum diameter cylinder is provided as the starting point for peeling and the highest recovery is achieved. For this reason positioning tools are also known as optimisers. Methods to find the central axis include:

- operator's visual judgement with or without aids (Figure 4.8)
- manual measurement and marking
- use of mechanical devices
- computerised scanning equipment.

High-volume peeling facilities use scanning equipment that collects and sends geometric data to an optimisation computer. The computer determines the spindle x–y positions for both ends of the log and sends the data to the programmable logic controller (PLC) that operates the equipment to implement the centering (spindle locations) and peeling solution (Figure 4.9). Where a scanning apparatus is used, dimensions of the log are measured along at least two different planes.

The opportunity to improve veneer recovery through optimised billet positioning is not possible with spindleless technology. Billet positioning using this technology is influenced by the external dimension and shape of the billet.

Figure 4.8. Visual aids such as a light stencil can assist the lathe operator in positioning the lathe spindles.

Figure 4.9. Log scanning ensures logs are positioned in the lathe spindles at the optimal location.

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Rotary peeling

5

Rotary veneer production involves using a lathe to remove a continuous thin ribbon of wood from the periphery of a peeler billet. The billet is rotated against the knife using a drive mechanism that varies in design and approach, depending on the lathe technology being used. In close proximity to the knife is a nose bar (or pressure bar) which applies a localised zone of compression just before the point of cutting. This helps to improve veneer quality by preventing splits forming ahead of the knife that can cause roughness on the veneer surface (Figure 5.1).

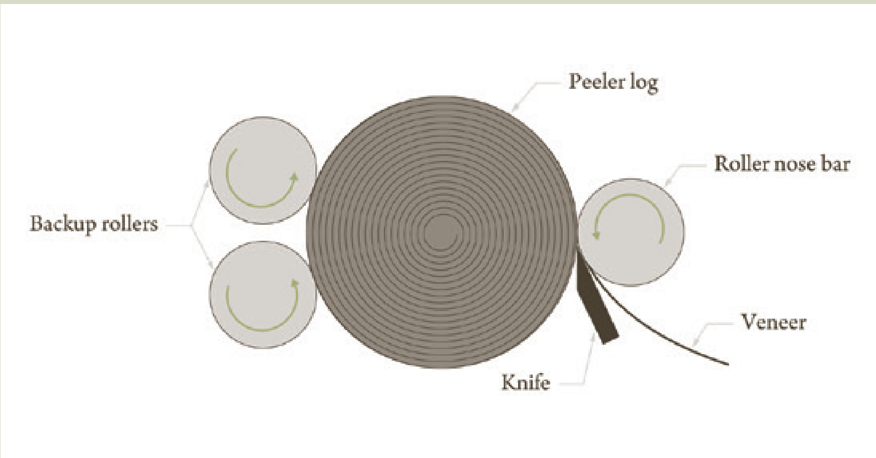

Figure 5.1. Illustration of rotary peeling using a spindleless lathe.

Traditionally, the rotary veneer industry received premium quality logs that were large in diameter and high in quality. To match the resource, rotary veneer lathes and other processing equipment were designed and built to be large and robust. To accommodate the changes in available resource and to improve efficiency, technology has evolved in several key areas. While initial development was focused towards improving efficiencies through increasing production speeds, in recent decades focus has been on improvements in resource recovery through minimising waste, and systems that better accommodate smaller diameter and suboptimum quality billets. The three major lathe types are presented below—spindled, hybrid and spindleless.

SPINDLED LATHES

The traditional method of rotary veneer production uses a spindled lathe (Figures 5.2 and 5.3). This type of lathe uses spindles or 'chucks' to hold the log in position and to rotate the billet against the knife. This method has proved very reliable and a very effective way to produce high-quality veneer from traditional wood species, even at very high production speeds.

This technology is not suitable for coconut palm stems as the spindles are not able to provide sufficient holding forces due to the very low density core in coconut peeler logs. Failure to provide sufficient holding capacity leads to 'spin outs', where the spindles lose grip on the billet and the billet cannot be peeled further.

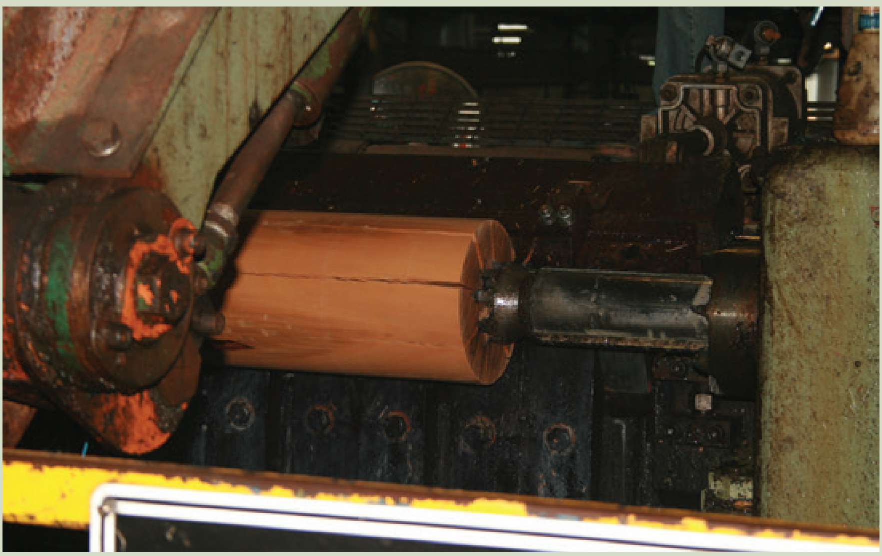

Figure 5.2. An example of a spindled lathe.

Figure 5.3. 'Chucks' or spindles on a spindled lathe.

HYBRID SYSTEMS

An alternative to the spindled lathe has been developed by Meinan, a Japanese company. Spindles are used to position the billet and provide rotary drive, however the spindles are completely retracted once the billet diameter is close to the spindle diameter. Additional drive is provided through a sectional nose bar that contains a series of spiked gang roll segments. Two in-feed brace rolls (similar to backup rolls) are used. These combine with the gang roll drive to allow the peeling process to continue after the spindles have retracted. This allows further processing until the peeler core is released at diameters below 75 mm. These lathes are well suited to large-scale, high-throughput operations.

While this technology has not been trialled with coconut palm peeler billets, it would not be expected to be appropriate given the reliance on spindles during the early stages of peeling.

SPINDLELESS LATHES

Spindleless lathes were originally designed and developed for further processing of peeler cores produced from conventional spindled lathes. Spindleless lathes are also referred to as 'chuckless lathes' or 'centreless lathes'. While the approach has existed for decades, commercial adoption remained very low due to their reputation for producing poor quality veneer, mainly due to variation in veneer thickness.

In the last decade or so spindleless lathe technology has developed quickly, with wide adoption in some countries, prompted by the rapidly growing availability of small-diameter forest resources, particularly from young fast-grown hardwood plantations. While spindleless lathes were originally developed to process the already pre-rounded peeler cores, many of the spindleless lathe operations today successfully use the lathes to directly process small-diameter unrounded billets (Figure 5.4).

Figure 5.4. An example of a spindleless lathe.

Spindleless lathes, as the name suggests, have no spindles. Rotary drive is provided through powered backup rollers and often with support from a driven roller nose bar. While spindleless lathes still produce peeler cores, their diameters are small, usually in the order of 20–60 mm. Figure 5.5 compares a peeler core produced from a standard rotary veneer spindled lathe and a coconut peeler core produced from a spindleless lathe.

Without the reliance on spindles to hold the billet in position, and the damage to billets from the stresses created within a relatively concentrated zone, spindleless lathes are proving to be very successful in processing logs of quality below that previously accepted. This processing approach enables coconut peeler logs to be successfully processed where more traditional approaches have failed (Figure 5.6).

Figure 5.5. A 45 mm coconut peeler core (left) produced from a spindleless veneer lathe, compared with a 130 mm softwood peeler core produced from a standard, commercial spindled lathe.

Figure 5.6. A coconut log being peeled with a spindleless lathe.

OPTIMAL LATHE SETTINGS

The quality of the veneer is heavily influenced by the lathe settings. Optimal settings are determined by a range of conditions and parameters including the lathe capacity, supporting infrastructure (e.g. capacity of equipment used for billet pre-conditioning), species, log size, log quality, wood density, speed of production and actual veneer quality requirements (including target thickness and acceptable thickness tolerance). Some of the common variables for lathe settings include knife angle, knife grind angle, knife height, pitch angle, nose bar position (horizontal and vertical), nose bar design and feed rate.

For spindled lathes, there is widely available documentation supported by many decades of research that provides lathe settings specific to commercial timber species and target veneer qualities. The vast majority of published settings and approaches to improve veneer qualities are transferable between spindled lathe manufacturers and models. For hybrid lathes, such as Meinan, documented settings are usually provided by the supplier and are very specific to the individual operation.

While a very large number of spindleless lathes now exist, there are few examples of documented lathe settings. In addition, the vast majority of spindleless lathe designs have targeted simple, lean designs with minimal capacity to change settings. This means the opportunity to optimise settings to suit a particular operation is limited. There are also several variations to lathe design and operational methods that result in major differences in lathe settings between manufacturers and models. For example, while nose bar designs on spindled lathes are relatively similar, a much larger range of designs exists for spindleless lathes. They are almost always a roller style, but diameters range from 30 to 150 mm, and they can be power driven or free spinning, segmented or full width, smooth or grooved. The design of the nose bar, along with other design features, has a large influence on optimum position of the knife height and knife angle.

The feed rate is also very different on a spindleless lathe compared to a spindled lathe. With the latter, the knife carriage is moved towards the spindle at a uniform rate relative to the billet rotation. The rate of advance influences the veneer thickness per log revolution. With a spindleless lathe there are two common approaches, both of which move the billet towards the knife. The first approach uses hydraulic pressure against the driven feed roller to move the billet towards the knife. The other approach uses a mechanical system to move the feed rollers towards the knife. Later mechanical versions use screw drives (similar to the mechanism that moves the knife carriage on a spindled lathe). While the latter probably has better control, all approaches can lead to veneer thickness variation, especially if there is a wide variation in wood properties within the billets being peeled. Ongoing developments are quickly overcoming these limitations.

Another major difference between spindled and spindleless lathes is the control of the knife pitch angle relative to the billet surface. On spindled lathes, the knife carriage changes the knife pitch angle during peeling as the billet diameter is decreased to maintain an optimal angle. With the exception of a couple of very recent spindleless lathe models, the knife angle is set and then remains constant during the peeling operation. This means that the optimum settings are potentially compromised for a significant part of the billet peeling.

The large range of spindleless lathe designs and the capacity to influence settings explains why optimum lathe settings are not published. Although some basic lathe operation principles apply, optimum lathe settings are specific to lathe model, the resource being processed and the target end product.

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Veneer clipping and drying

6

CLIPPING

Veneer clipping is usually done as part of the peeling operation. As the veneer ribbon leaves the lathe, it is transported along a conveyor to a clipper that clips (cuts) the veneer, parallel to the grain, into smaller, more manageable veneer sheet widths. Alternatively, the veneer ribbon is coiled or reeled immediately after the lathe and is moved to a separate clipping station. Regardless of approach, any clipping strategy should aim to recover the highest amount of veneer of a dimension and quality that aligns to the target end products (Figures 6.1–6.3).

Figure 6.1. Hardwood veneer sheets being clipped manually by a guillotine in Vietnam.

Figure 6.2. Veneer being coiled in preparation for a separate clipping operation.

The simplest clipping systems are manual operations that utilise hand- or foot-operated guillotines. These are relatively slow and rarely adopted given the availability of relatively cheap, more automated systems.

The next level of technology utilises a mechanical clipper system, normally activated on a time interval. This means that the sheet width is determined by the speed that the veneer ribbon is traveling through the clipper and the time interval between the clipper knife being activated. Often with these operations, the clipper knife is fixed to a rotating shaft meaning that the knife blade clips the veneer at each revolution. This is a simple, low capital cost approach that is much more efficient than hand-operated guillotines; however, it provides little opportunity to maximise the recovery of specific grade qualities. This is because the clipping strategy does not consider veneer quality (e.g. defects such as splits) and focuses on veneer width only. This approach can result in a low-grade recovery as unacceptable defects remain in the veneer sheets. While these defects can be removed during follow-up processes, this can lead to less than desirable and variable veneer sheets widths, and added costs.

Figure 6.3. Coconut veneer clipped and ready for drying.

Advanced systems incorporate veneer scanning technology that can be programmed to detect and measure defects within the veneer as it travels between the lathe and clipper. Using this information, unacceptable defects (e.g. fishtails and insect attack) can be limited to narrow strips of veneer that can be clipped out and rejected. The remaining veneer ribbon is clipped to sheet widths that best suit the end product. This approach maximises the recovery of veneer with acceptable qualities, operates at speeds that equal the lathe operating speeds, and also produces more accurately sized veneer sheets.

DRYING

The main reason for drying veneer is to remove excessive moisture so that the veneers are prepared for adhesive application and product manufacture. Drying soon after clipping is preferred, to prevent mould, veneer distortion (e.g. buckling) and other degradation. Practical objectives are to dry at low cost, with short drying time, and to achieve appropriate quality.

Veneer drying approaches have evolved over time. The simplest and lowest cost approach is to air-dry veneers (Figure 6.4); however, this gives little control over drying time and quality. There are various types of mechanical drying systems, with the most common in larger commercial operations being the conveyor-type jet-box drier (Figure 6.5). With this system, veneers are fed along a conveyor into the dryer and passed through a series of chambers where hot air is blasted across the veneers. Temperature and conveyor speeds are adjusted to ensure the veneer exits the dryer with the appropriate moisture content and suitable quality. A number of moisture monitoring systems are commercially available that identify under-dried (wet) veneers at the drier exit, allowing these veneers to be separated and re-dried.

The most important and common form of avoidable degradation during veneer drying is out-of-range and uneven moisture contents. The target moisture content and acceptable range both between veneers and within a veneer depend mainly on the adhesive to be used to manufacture the final product, but the species and the manufacturing process also have an influence. A common target moisture content is 6% with a range of 3–10%.

Drying-induced defects include buckling, splitting and surface modification. All these defects affect the veneer recovery, and the aesthetics and mechanical qualities of the final product. These defects are generally more common if excessively high temperatures are used or if the veneer has been over- or under-dried.

The variables that effect drying time are veneer thickness, wood species, initial moisture content, drying temperature, air velocity and relative humidity. Air-drying may take several days or weeks whereas a jet-box drier can dry veneer within minutes. Better utilisation of the dryer is achieved by batching veneer to take account of large variations in initial moisture content.

Cocoveneer can be dried following similar practices and protocols used for traditional wood veneer species.

Figure 6.4. Air-drying hardwood veneer sheets in Vietnam.

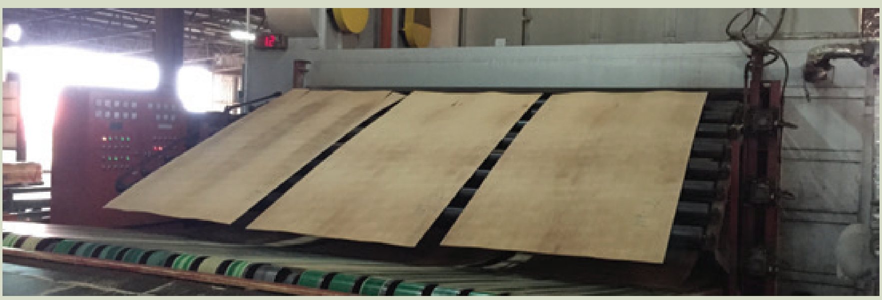

Figure 6.5. Dried cocoveneer exiting a jet-box veneer dryer.

7 Veneer grading and upgrading

Veneer sheets are graded so that they can be segregated into categories that reflect their best use and price/value. This price/value relationship is set by the aesthetics and physical properties of the veneer. A transferable and comparable grading system gives buyers confidence and reassurance that the veneers will meet their manufacturing and quality requirements.

The standards or rules for grading veneer may be set by the industry or by individual companies based on sound knowledge and understanding of market and consumer requirements. Veneer can be graded for different uses such as for face veneer, substrate veneer, plywood, laminated veneer lumber (LVL) and formply. The grading system applies a set of rules (grade criteria) to classify material into different grade classes. Grade criteria can include natural wood features or defects and/or process-induced defects caused when peeling or handling the veneer. Grade classes are usually assigned either a letter (A, B, C etc.) or number (1, 2, 3 etc.), where the best grade class is 'A' or '1' and subsequent grades reflect lower quality veneers.

While many veneer grading systems have been developed for traditional forest resources, a new or modified grading system may be necessary to suit the uniqueness of cocoveneer.

Veneer can be graded visually by an experienced grader, or using automated grading equipment. When done visually, the grader assesses the sheet against the grade criteria and the predominant defect or feature determines the grade class that is assigned to the veneer sheet. In large-scale production lines, automated grading processes are often used based on cameras and scanners, linked with optimised clipping and sorting systems to segregate veneer into grade classes.

Apart from visual defect grading, veneer may also be segregated into grade classes based on mechanical properties where structural products are targeted. Mechanical grading is an automated process based on the veneer dynamic modulus of elasticity. Ultrasonic grading is widely used in large-scale plywood manufacturing mills.

COCOVENEER CHARACTERISTICS

The qualities and characteristics of cocoveneer are often very different to veneer from traditional wood species, therefore existing veneer grading systems may not be suitable for cocoveneer. Veneer characteristics that need to be considered when grading cocoveneer will depend on the target end-product, and may include:

- density
- colour (Figure 7.1)
- roughness
- splits (Figure 7.2)
- brittleness
- fungal decay (Figure 7.3)
- holes and tear-out
- flatness/waviness (Figures 7.4 and 7.5)
- wane
- insect tracks.

Figure 7.1. Example of the range in colour of cocoveneer.

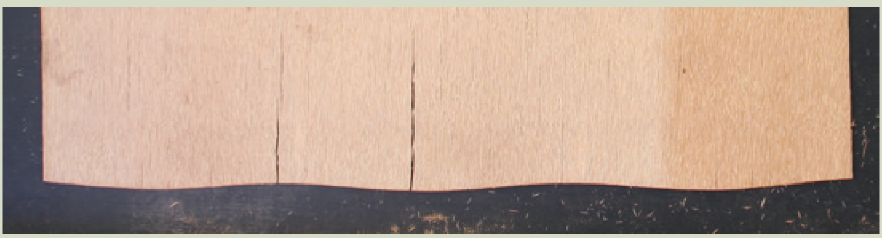

Figure 7.2. Splits in cocoveneer.

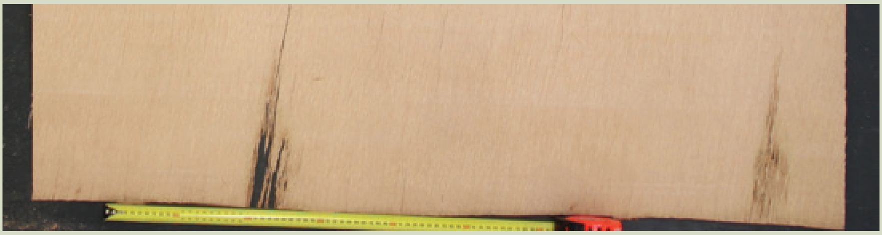

Figure 7.3. Fungal decay in cocoveneer.

Figure 7.4. Waviness in hardwood veneer.

Figure 7.5. Waviness can cause an overlapping when pressed flat

AUSTRALIAN AND NEW ZEALAND STANDARD AS/NZS2269.0:2012

The Australian and New Zealand standard AS/NZS2269.0:2012 is an example of an existing industry standard which provides minimum performance requirements and specifications for manufacturing structural plywood that are acceptable to users, specifiers, manufacturers and building authorities in Australia and New Zealand. The standard is applicable to both hardwoods and softwoods, and may have some relevance for cocoveneer.

There are five veneer grades specified, A, S, B, C and D, with F a reject grade.

- A-grade veneer is a high-quality appearance grade veneer suitable for clear finishing. This grade should be specified for the face veneer in plywood where surface decorative appearance is a primary consideration (Figure 7.6).
- S-grade veneer is a similar specification to A-grade veneer, but some characteristics (not permissible for grade A) are allowed when specified as decorative features. These include knots, holes, discoloration, hobnails and other characteristics as agreed between manufacturer and customer.
- B-grade veneer is an appearance grade veneer suitable for high-quality paint finishing. This face veneer quality should be specified for applications requiring a high-quality paint finish (Figure 7.7).
- C-grade veneer is defined as a non-appearance grade veneer with a solid surface. All open defects such as knot holes or splits are filled. Plywood with a C-grade face is intended for applications requiring a solid non-decorative surface. An example is plywood flooring that will be overlaid with a decorative surface (Figure 7.8).
- D-grade veneer is defined as a non-appearance grade veneer with permitted open imperfections and is the lowest veneer grade. It is intended for structural applications where decorative appearance is not a requirement, for example, structural plywood bracing (Figure 7.9).
- F-grade veneer is defined as reject grade, that is, sheets not meeting the minimum requirements of the above grades (Figure 7.10).

Figure 7.6. A-grade hardwood veneer.

Figure 7.7. B-grade hardwood veneer.

Figure 7.8. C-grade hardwood veneer.

Figure 7.9. D-grade hardwood veneer.

Figure 7.10. F-grade hardwood veneer.

UPGRADING

Veneer grade can be improved if the defects which are limiting higher quality grades are removed from the veneer. Upgrading can be achieved through patching or composing. In patching, a machine is used to remove the defect in a veneer sheet and a patch of clear wood or plastic of the same size is used to fill the space. Patching cocoveneer may prove much more difficult than traditional veneer species due to the coarse and potentially brittle veneer structure.

Veneer composing takes narrow random width veneer pieces and joins them into a full-size sheet. This can be done manually using a veneer splicer (Figure 7.11), or can be automated through the use of a veneer composer machine (Figure 7.12), which combines the steps of piece preparation (i.e. clipping square straight edges), jointing and docking joined sheets to the required final width into one process, enabling greater production speeds and efficiencies. Splicing and composing, while adding labour cost and extra handling, result in improved grade recovery, increased veneer quality and can improve final panel quality.

Figure 7.11. Veneer splicing.

Figure 7.12. Veneer composer.

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8 Veneer quality control

Quality control is a system of process and product monitoring that aims to ensure procedures and protocols are being followed to produce a consistent product of the required quality. Such systems help to identify issues quickly and correct the manufacturing process if necessary. Optimised quality control systems also help to reduce manufacturing costs by reducing rejects and downgraded products, reducing repair and reprocessing costs, increasing recovery and reducing waste, and increasing productivity.

The objectives of quality veneer production are to:

- maximise veneer recovery
- produce long and straight veneer ribbons
- minimise buckling and waviness
- minimise veneer breakage/splitting
- ensure a smooth surface
- produce uniform thickness.

While there are a number of steps involved in the production of veneer that affect veneer quality (e.g. pre-conditioning, peeling and drying), peeling has the most influence on the quality. For this reason many quality control checks are necessary immediately after the lathe, so that any set-up issues are identified and rectified quickly (Figure 8.1).

Figure 8.1. Assessing veneer quality.

QUALITY ISSUES RELATED TO PEELING

Ribbon mis-tracking

The ribbon should leave the lathe in a straight line onto the conveyor belt producing a consistent, cylindrical peeler core (Figure 8.2). A straight-tracking ribbon will produce a peeler core with the same circumferences at each end and at its centre. Mis-tracking occurs if the ribbon tracks in an arc to either the left or the right side of the conveyor, depending on which end of the knife leads into the cut (Figure 8.3). The effect of mis-tracking becomes accentuated as the diameter of the peeler cores becomes smaller and might only be noticeable when peeling large diameter billets.

Figure 8.2. Examples of straight tracking.


Figure 8.3. Examples of mis-tracking.

The conveyor belt is designed to take the ribbon away from the lathe in a straight line and mis-tracking can cause splits along the concave edge of the ribbon and waviness (see above), especially if the veneer ribbon is physically straightened. The ribbon can break or split into unfavourably sized sections, thus reducing the overall veneer recovery. Mis-tracking can also cause the clipper to jam.

Mis-tracking indicates the need to realign the lathe settings (e.g. knife, nose bar, rollers). Multiple adjustments and fine tuning might be necessary to achieve straight tracking.

Waviness

A veneer ribbon is considered flat if the ribbon sits even and parallel with the conveyor belt and exhibits minimal gaps between the veneer and the belt's surface. The presence of waviness in a freshly peeled veneer ribbon indicates an issue with the lathe settings. Waviness within the ribbon may be linked to barrelling or cotton-reeling which is generally accompanied by thickness variation.

Thickness variation

If all peeling parameters are optimised (e.g. billet pre-conditioning and lathe settings) the green veneer thickness should have minimal variation. Uniformity in thickness (within and between veneer sheets) directly affects the manufacturing process, and ultimately, the quality of the final product. In order to achieve efficiency in gluing and finishing, minimal variation in the panel thickness is required. Excessive thickness variation can cause the following problems:

- variation in the amount of adhesive spread on the veneers resulting in poor bond quality of the finished product—for instance, thinner veneers will tend to have more glue spread on their surface than thicker veneers with the same machine set-up

- variation in platen pressure in the press during product manufacture
- undesired variation in the product thickness causing the product to be outside specifications
- low pressure areas which cause poor localised bonding and can increase the blow rate.

Variation in thickness of green veneer can be monitored by using a hand-held dial thickness gauge (Figure 8.4). To minimise measurement error, it is important for the operator to calibrate the gauge and use the same method for each assessment. Thickness measurements should be taken along both edges of the ribbon at opposite points. The frequency of measurement will vary depending on standards, production and product requirements; however, good practice would be to select a random subsample of veneer sheets and measure at 300 mm intervals on both sides along the veneer sheet edge (parallel to the grain) with measurements taken on areas free of pronounced grain deviations, decay and other major defects (Figure 8.5).

Figure 8.4. A hand-held dial gauge used to measure veneer thickness.

Figure 8.5. Routine checking for veneer thickness variation.

Thickness tolerances

Several international veneer quality standards exist that outline allowable thickness tolerances for rotary veneer produced from traditional veneer species. While they vary slightly, each allows a maximum tolerance of approximately 5% of the nominal dried veneer thickness. One of the key reasons for maintaining a low thickness tolerance in veneer is to reduce the thickness tolerance in products manufactured from combining several veneers.

When peeling coconut logs with standard processing protocols using spindleless lathes with factory settings, a range of veneer thicknesses larger than traditionally acceptable can be expected. This is because of the large radial variation in wood density of coconut palm logs, and the strong correlation between veneer sheet density and thickness at a particular lathe setting.

The impact of veneer thickness on the end-product thickness is further influenced by density, as varying densities will perform differently during product manufacture where large forces are applied during pressing. Targeting a low veneer thickness tolerance across the wood density range of coconut palms may result in an unacceptable product thickness tolerance. It may in fact be necessary to peel lower density wood thicker than higher density wood to achieve the same veneer thickness post product manufacture (i.e. low-density veneer will compress more than high-density veneer).

Tightness and looseness

Veneer is characterised by the presence of small checks or fissures commonly referred to as lathe or peeler checks. These checks form on the underside of the veneer that is in direct contact with the knife as the veneer passes between the knife and the nose bar as it is being cut from the billet and flattened out (Figure 8.6). The underside of the veneer containing the lathe checks is referred to as the 'loose' side and the upper side is referred to as the 'tight' side. Veneer that has many deep lathe checks is termed 'loose-cut' while veneer having shallow infrequent checks is termed 'tight-cut'. Lathe checks will affect the veneer quality significantly; and a balance is required between tightness and looseness.

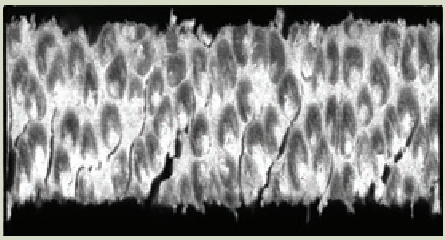

Figure 8.6. Peeler checks in cocoveneer.

Veneer with optimal tightness has only small and fine peeler checks, and has little tendency to curl, buckle or split during drying. Fewer peeler checks mean greater strength across the grain and tight-cut veneers are less likely to rip or split during manual handling. Tight veneers are associated with superior weathering properties and exhibit less finishing faults. However, veneer that is too tight can cause pressing problems if the veneer has not dried flat. Deep peeler checks and rough surfaces significantly increase the surface area of the veneer (up to three times), leading to excessive absorption of adhesive and/or surface coatings and distorted reflection of light (relevant for appearance grade).

Surface roughness

Surface roughness results from factors such as excessive peeler checks, splits and grain tear-out. Roughness originates from splitting ahead of the knife edge during the peeling process due to cleavage action of the knife. The direction of splitting in relation to the cutting path determines the severity of the roughness. The development of roughness in the peeled veneer is also dependent on and intensified by inherent lines of weakness within the wood (mainly influenced by the slope, size and frequency of fibrovascular bundles), pith eccentricity and non-uniform grain.

The two main disadvantages of surface roughness are the reduction in veneer grade class and manufacturing complications (e.g. increased adhesive usage to compensate for the increased surface area and reduced bond quality due to an increased tendency for glue lines to dry out).

Optimal lathe settings, combined with appropriate pre-conditioning of the billet, are effective methods to minimise surface roughness.

QUALITY ISSUES RELATED TO VENEER MOISTURE CONTENT

Veneer moisture content has an important influence on product quality. The veneer must be at the right moisture content for the following reasons:

- so that it can be glued successfully
- to avoid biological degradation including fungal (stains and decay) and insect damage
- to ensure that the veneers are pre-shrunk prior to product manufacture
- to ensure product dimensional stability and therefore prevent veneer and panel distortion, for example, waviness and warpage
- to avoid splits and checking
- so that it is compatible with production processes such as the closed and open assembly times.

The target moisture content of the veneer is dependent on the adhesive and manufacturing protocols, however a common target moisture content is 6% with a range of 3–10% (e.g. for most phenol formaldehyde resins). Urea formaldehyde resins are often more tolerant of higher moisture content and wider variation.

The two most common methods of measuring moisture in veneer are with a resistance meter or a capacitance meter.

Resistance meter (pin-type meter)

A resistance moisture meter uses two or more pins that penetrate the veneer at a desired depth (Figure 8.7). Direct current travels between the pins through the wood and the resistance is measured. Dry wood allows only little current to pass whereas wood with higher moisture content permits more. The meter reads how much resistance there is to the current and correlates the resistance to wood moisture content. This type of meter becomes less accurate as the moisture content increases. Pin-type meters are more accurate and effective in determining the moisture gradient within wood (the difference between shell and core moisture content) than other types of meter as the operator can control the pin depth.

Capacitance meter (electromagnetic field meter)

A capacitance meter measures the moisture content of wood without penetrating the wood (Figure 8.8). A sensor emits electrical waves that create an electromagnetic field. This field behaves differently depending on how much moisture is in the wood and the wood density. Capacitance meters measure the capacity of the wood to store energy (capacitance), the amount of power the wood absorbs from the field (power loss) or the wood's resistance to the field (impedance). This pinless meter is less effective in measuring the moisture gradient within wood than a resistance meter. Also, readings provided by a capacitance meter are determined more by surface moisture, so that readings for material beneath the surface veneer are generally less accurate. Readings are also affected by surface roughness. However, capacitance meters are easy to use and do not damage the veneer surface.

Table 8.1 compares the two types of moisture meters and the influence of physical factors and other features.

Table 8.1. Factors affecting the use of capacitance and resistance moisture meters.

Factor	Capacitance meter	Resistance meter
Temperature	No	Yes
Chemicals	No	Yes
Grain orientation	No	Yes
Moisture gradient	Yes, in some models (but less effective than resistance meters)	Yes
Wood species	Yes*	Yes*
Wood density	Yes*	No
Surface texture	Yes	No

* Both require species correction which is broadly related to density. Resistance meters also require temperature conversion.

Hand-held resistance moisture meters provide quick access to moisture content information, are relatively easy to use in small-scale operations, and are especially useful to determine the moisture content of sheets outside the production line. Commercial plants producing veneer on a large scale often install in-line moisture measurement systems as part of their production line (Figure 8.9). These systems usually use the capacitance method. They are often combined with automatic grading systems and form an essential part of a highly automated process.

Figure 8.7. A hand-held resistance moisture meter.

Figure 8.8. A hand-held capacitance moisture meter.

Figure 8.9. In-line veneer moisture measurement.

FURTHER READING

APA–Engineered Wood Association. 1996. PS-195. Construction and industrial plywood (with typical APA trademarks). Reproduced from copy furnished by the Office of Standard Services, National Institute of Standards and Technology.

Colombia Forest Products. At <http://archive.constantcontact.com/fs058/1102117931485/archive/1102890340140.html>, accessed April 2015.

9 Veneer recovery

The calculation of veneer recovery is important to provide guidance on the efficiency of the veneering operation, to compare and evaluate forest resources, and to establish fundamental economic information. There are different methods to calculate veneer recovery, and it can be useful to calculate recovery in several different ways to obtain information such as where losses are occurring within the process. However, it can be confusing to compare between reported recovery values unless details of the methods used are known.

Four recovery calculation methods are provided below: green veneer recovery, gross veneer recovery, net veneer recovery and graded veneer recovery.

Green veneer recovery (GNR) provides a measure of the maximum recovery, taking into account log geometry (sweep, taper, circularity) and lathe limitations (e.g. peeler core size). GNR disregards internal log quality. GNR (%) for a batch of veneer billets can be calculated as follows:

$$GNR = \left(\frac{L \times \Sigma_{veneer}(GT_{mean} \times GW)}{\Sigma_{billet} V}\right) \times 100$$

where GT_{mean} is the average green veneer thickness (m), GW is the green veneer width (m) perpendicular to the grain (as measured prior to clipping and excluding any major defects, e.g. wane or undersize thickness, that are present at the beginning or end of the veneer ribbon), L is the veneer length (m) parallel to the grain, and V is the billet volume (m^3).

Gross veneer recovery (GSR) provides a measure of the maximum recovery of dried veneer that meets the relevant quality specifications (e.g. AS/NZS 2269.0:2012). This recovery includes the losses accounted for in GNR but also includes additional losses from visual grading (i.e. veneer that failed to meet grade) and the drying process (e.g. veneer shrinkage, splits). GSR (%) is calculated as follows:

$$GSR = \left(\frac{L \times \Sigma_{veneer}(DT_{mean} \times GRW)}{\Sigma_{billet} V}\right) \times 100$$

where DT_{mean} is the mean dry veneer thickness (m), GRW is the width (m) perpendicular to the grain of dried veneer that meets the grade requirements (e.g. A, B, C and D grades in accordance with AS/NZS 2269.0:2012), L is the veneer length (m) parallel to the grain, and V is the billet volume (m^3).

Net veneer recovery (NR) provides a measure of process efficiency, as it identifies the saleable product, taking into account the product manufacturing limitations. NR includes the losses accounted for in GSR but also includes the additional losses due to the trimming of veneer before, during and after product manufacture. The loss incurred when veneer sheets are reduced in width to the final product size is known as a trimming factor. While this varies between operations, an example is provided of a trimming factor of 0.96. This corresponds to reducing the veneer sheet width perpendicular to the grain from 1,250 to 1,200 mm. In the following example, the veneer sheets are also reduced in length (parallel to the grain) from 1,300 to 1,200 mm. For this example, which relates to the manufacture of 1,200 × 1,200 mm final product, the NR (%) can be calculated as follows:

$$NR = GSR \times 0.96 \times \frac{1200}{1300}$$

thus $NR = GSR \times 0.88615$

Graded veneer recovery for an individual grade can be calculated using the same method as for NR but using the veneer volumes that meet the specific grade (e.g. A, B, C or D grades in accordance with AS/NZS2269.0:2012).

FURTHER READING

McGavin R.L., Bailleres H., Lane F., Blackburn D., Vega M. and Ozarska B. 2014. Veneer recovery analysis of plantation eucalypt species using spindleless lathe technology. BioResources 9(1), 613–627.

Standards Australia 2012. AS/NZS 2269.0:2012 ‘Plywood—Structural—Specifications’. SAI Global Limited. At <www.saiglobal.com>

10 Case study: Cocoveneer processing research and product testing

BACKGROUND

This chapter summarises results from research activities undertaken in Australia, Fiji and France on senile coconut palm material to determine optimum lathe settings, veneer and veneer-based product properties and borer insect resistance. This research was performed during the ACIAR co-funded project 'Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities' (FST/2009/062) which evolved from the recommendations of a preceding project, 'Improving value and marketability of coconut wood' (FST/2004/054).

The earlier project established a comprehensive understanding of the properties of coconut wood, the variation of properties, and their distribution both within individual palm stems as well as across the Pacific's plantation estate. The project then investigated a range of processing methods, mainly focused on sawing, to determine the quantity and quality of wood that could be recovered from coconut palm stems. The recovered wood underwent extensive evaluations before being used to develop a range of products including a composite engineered flooring product. The need to maximise the recovery of the high-density wood located towards the periphery of senile coconut palms was clearly identified, in order to capitalise on more attractive and profitable markets. One of the disadvantages identified with applying traditional sawing techniques to coconut palms stems was the inability to recover high quantities from this part of the stem. A recommendation made at the completion of this project was to pursue rotary veneer processing as a possible means to maximise the recovery of the highest density wood from the log periphery.

Conventional rotary peeling techniques use a spindled lathe. This equipment suspends the log between two opposing spindles which turn as a knife is pushed against the log to peel a continuous ribbon of thin veneer from the log periphery towards the core. This design generally works well for normal woody stems; however, coconut palm has a very different structure to normal wood and traditional spindles are unable to grip the soft inner core of the coconut stem sufficiently to enable peeling of the hard outer material.

Also, spindled lathes are relatively inefficient in processing small logs as they leave a residual core of at least the diameter of the spindle.

A spindleless lathe is an alternative to a spindled lathe. These lathes use periphery drive rollers to grip, turn and push the log against the blade for peeling. Without the restrictive spindles, spindleless lathes can peel small logs efficiently down to a residual core of 60 mm or less. Spindleless lathe technology has been available for many years but their use and availability was limited until about a decade ago. This processing technology formed the basis for the project, 'Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities' (FST/2009/062).

Peeling coconut palm logs with a spindleless lathe offers greater efficiency, recovery and utilisation of the stem when compared to sawing. The log is quickly converted into a long ribbon of veneer down to a small core, and approximately 50–60% of log volume can be recovered. The resulting veneer can then be dried and glued together to make valuable products such as plywood panels or laminated veneer lumber (LVL).

The following details findings from a series of peeling trials undertaken with increasing levels of operational scale and technical understanding, each building on the results of the previous stage. First, an exploratory study was undertaken at the laboratory scale on coconut discs sourced from over 40 palms sent from Fiji to a specialist laboratory in France. Following this trial, 23 palm logs were peeled on a semi-industrial processing line which included a spindleless lathe that had been extensively modified specifically for peeling coconut palm. A selection of the resulting veneers were dried and shipped to Brisbane, Australia, to enable the development of a grading protocol and to determine physical and mechanical properties. A third trial was undertaken within an industrial setting in Labasa, Fiji, using commercial-scale equipment; 153 billets were processed totalling 25.1 m^3. The resulting veneer sheets were dried and shipped to Brisbane for product manufacturing and evaluation.

OPTIMUM PARAMETERS FOR PEELING COCONUT PALM

Compared to typical wood from forest trees, the stems of senile coconut palms contain a wide variation of density, with sharp gradients extending radially from the centre to the periphery. This feature, combined with the unique anatomical structure of the material, makes its processing a very different proposition to conventional wood. The project activity described here had the objective to determine the fundamental processing parameters for rotary peeling coconut palm stems.

In addition to knife and pressure bar selection, the key processing parameters that result in high-quality veneers include an optimised combination of billet temperature, pressure and knife angle. Comparative quality between different combinations is determined by examining the incidence and severity of peeler checks in the resulting veneer, assessment of variation in veneer thickness, and assessment of veneer roughness. For the trials, 43 Fijian coconut palms were selected to provide 25 mm thick discs from four palm heights. These were supplied to the Ecole Nationale Superieure d'Arts et Metiers (ENSAM) in France for testing.

At ENSAM, a micro-lathe equipped with extensive control and instrumentation systems including displacement and force sensors, was used to investigate various processing parameters. This was followed by visual assessments and digital image analysis using the Système de Mesure de l'Ouverture des Fissures apparatus (SMOF; open checks measurement system).

The peeling parameters and veneer qualities studied were:

- billet heating temperature
- pressure bar type and compression ratio
- cutting forces
- veneer quality assessment
- veneer thickness variability.

The methods used in the trials and the results obtained are summarised below.

Heating temperature

Pre-conditioning treatments are commonly used in peeling processes because of beneficial effects such as improved deformability, reduced cutting forces and reduced damage (Lutz 1960; Baldwin 1995; Yamauchi et al. 2005; Marchal et al. 2009; Dupleix et al. 2012). The discs were heated in a water bath to 50 °C, 60 °C, 70 °C or 80 °C. Control samples were peeled at ambient temperatures.

The discs peeled at ambient temperature did not produce any veneer due to the excessive cutting forces. After the first two or three revolutions, the veneer ruptured and damage (chipping and blunting) was sustained to the knife's cutting edge due to the hardness of the vascular bundles within the coconut palm structure (Figure 10.1). The force measured on the pressure bar was substantially reduced when peeling discs pre-conditioned at higher temperatures. For example, an increase in pre-conditioning temperature from 50 °C to 80 °C resulted in a reduction of force of almost 50%. A minimum of 70 °C and preferably 80 °C is recommended when peeling high-density coconut palm material. Based on the results, a peeling temperature of 80 °C was used for the subsequent trials.

Figure 10.1. Chipped knife edge caused by a high-density vascular bundle during peeling at ambient temperature.

Pressure bar type and compression ratio

An angular fixed pressure bar as commonly used for traditional homogeneous forest woods, and a roller pressure bar potentially more suitable for heterogenous material such as coconut palm, were trialled. Three compression ratios, expressed as a percentage of the veneer thickness (that is, 5%, 10% and 20%), were used in combination with five vertical gap settings (0.1 mm, 0.4 mm, 0.7 mm, 1.0 mm and 1.26 mm).

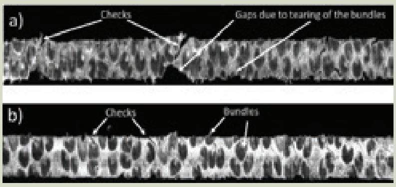

Figure 10.2. Comparative grade quality of veneers produced using (a) an angular pressure bar and (b) a roller pressure bar.

The roller pressure bar which is commonly used on spindleless veneer lathes was found to yield significantly better results for continuity of ribbon, check depth, check frequency and surface quality than the angular pressure bar (Figure 10.2). Subsequent trials were performed only with the roller pressure bar.

Cutting forces

The cortex was removed from the 25 mm thick discs and they were rounded to remove any eccentricity before testing. Cutting forces were recorded for two axes, tangential and radial, for both the knife and the pressure bar. Cutting force was shown to be a relevant predictor of veneer quality, with a decrease in cutting forces corresponding to an increase in veneer quality. Cutting with a lower compression ratio improved veneer quality and reduced variability of the results. These results highlight the different approach required when peeling coconut palm compared to traditional forest woods. That is, when peeling homogeneous wood, high compression ratios can be used to minimise crack propagation and reduce surface roughness. Although a low compression ratio provided the best results in this trial, the optimum compression ratio for a given lathe would be influenced by the diameter of the roller pressure bar. The use of a knife encompassing a micro-bevel sharpening approach may assist with improving knife service life and potentially reduce cutting forces although this was not trialled.

Veneer quality

Veneers were graded for roughness using a visual system with four categories ranging from 1 (low grade, fragmented, rough or fuzzy) to 4 (high grade, continuous, smooth, polished). Veneers assessed as grade 2 or higher were then assessed using the SMOF apparatus, which gave thickness profiles and peeler check characteristics through use of a video camera and dedicated evaluation software. Peeler checks were recorded then analysed for depth and frequency along the veneer ribbon.

Based on the visual scoring system, the best quality veneer was produced using a compression ratio of 5%. The SMOF results indicated that average check depth was not significantly affected by compression ratio, however the best result for frequency of checks was obtained at 10% compression ratio.

Veneer thickness

Seven common veneer thicknesses in half millimetre increments between 1.0 mm and 4.0 mm were tested. It proved challenging to produce veneer less than 2.0 mm thick due to high levels of checking and surface roughness. This result was a function of the anatomical structure of coconut palm, in particular the diameter and hardness of the vascular bundles embedded in the softer, fragile parenchyma tissue. A minimum target thickness of 2.5 mm is recommended.

SEMI-INDUSTRIAL AND INDUSTRIAL-SCALE PEELING TRIALS

Two separate peeling trials were conducted on coconut palm logs in Fiji. The first trial involved processing 23 logs in the Fiji Government's Timber Utilisation Department experimental facility at Nasinu near Suva on Viti Levu. The second trial involved peeling of 153 logs in a commercial ply mill in Labasa in northern Vanua Levu. Dried veneers from these trials were shipped to the Queensland Department of Agriculture and Fisheries' Salisbury Research Facility in Brisbane, Australia, for development of grading protocols, property testing and product manufacturing and testing.

In Nasinu, logs were merchandised to 1.3 m lengths to suit the semi-industrial spindleless lathe, then rounded up to form close to cylindrical geometry. Logs were pre-conditioned in a steam chamber for between 14 and 18 hours, then peeled at 40–55 °C (Figure 10.3). The low temperatures compared to the recommended settings as determined during the laboratory trials were due to equipment limitations. Logs were peeled down to a residual core of approximately 60 mm diameter. The veneer ribbons were clipped at 1.3 m widths, producing a total of 249 sheets, which were dried in a gas-assisted solar kiln to a target moisture content of 10%. Gross recovery of veneer was 61% of original log volume.

Figure 10.3. Spindleless peeling trial in the experimental facility at Nasinu, Viti Levu, Fiji.

The Labasa trial was conducted within a commercial veneer processing facility, and included a recovery study, then testing of the resulting veneers (grade quality, borer insect susceptibility), followed by plywood and LVL manufacturing trials. Logs were delivered to the commercial mill in 6.0 m lengths, then merchandised to produce two smaller 2.7 m billets for peeling. This provided 153 peeler billets with a total volume of 25.1 m^3. Billets were heated to a target temperature range of 80–90 °C. Billet debarking and rounding were undertaken in a dedicated spindleless round-up lathe prior to peeling in a spindleless lathe (Figure 10.4).

Figure 10.4. Spindleless peeling trial in the commercial ply mill at Labasa, Vanua Levu, Fiji.

The veneer ribbons were clipped at 1.35 m widths and dried in a jet-box drier to a target of 6% moisture content. Gross veneer recovery was 50% of the original log volume and 65% of the total billet volume after rounding up to cylindrical geometries. The lower recovery compared to the results in Nasinu was mainly due to the different log length, where the longer logs (2.7 m as used in the commercial ply mill) tend to include higher levels of taper and lower levels of straightness than the shorter 1.3 m billets peeled at Nasinu.

The advantage of peeling compared to sawmilling is evident by comparing the results from these peeling trials with data published by Hass and Wilson (1985) for a sawmilling trial on coconut palms—with 68% of the recovered veneer volume having a density of 500 kg/m^3 or higher, compared to 14% of the sawn board volume.

VENEER PROPERTIES

Assessment of density and stiffness (modulus of elasticity) on test specimens cut from veneers produced during the Fiji peeling trials was conducted in the Salisbury Research Facility, Brisbane, Australia. The Nasinu palms were estimated to be younger than the Labasa palms. Seventy per cent of the Nasinu veneer samples tested (n = 47 veneer sheets) had air-dry density values between 400 and 700 kg/m^3 and only 4% had density greater than 800 kg/m^3. The stiffness testing results for both trials are summarised in Table 10.1. The mean stiffness values and level of variability were similar between both trials, but the older palms used in the Labasa trial produced some veneer sheets with higher stiffness properties which indicates the potential for higher product value.

Table 10.1. Veneer stiffness (modulus of elasticity) results from two peeling trials in Fiji.

	Modulus of elasticity (MPa)	
	Nasinu (semi-industrial lathe, log length 1.3 m, n = 47 sheets)	Labasa (commercial lathe, log length 2.7 m, n = 247 sheets)
Minimum	940	1,013
Mean	5,290	5,352
Maximum	11,936	16,883
Standard deviation	2,674	2,896

VENEER QUALITY

Like sawn wood products, veneers are normally sorted into batches of similar grade (quality) during production in readiness for manufacturing or marketing. The grading process involves assessment of a veneer sheet using qualitative (appearance, distortion, dimensional tolerances, machining imperfections) and/or quantitative criteria (physical or mechanical properties, severity of defects) against specific limits provided in a specification.

For most commercial forest product feedstocks, grades have been established over time as either industry-wide standards or specific product standards agreed between the producer and the customer. These standard-defined grades provide an enforceable definition of product performance and denote suitability for particular end products. Grades are also used in the market to assign value to batches of material with desirable characteristics, with high-grade products attracting a price premium.

The veneer grading standards for traditional timber species do not apply to coconut palm due to the vastly different material structure, qualities and properties. To be marketed effectively, a standard quality grading system is required specifically for coconut veneer.

The material supplied from Fiji was used to develop a visual grading specification. Three different grades were devised: superior (grade 1), high (grade 2) and standard (grade 3). These nominal grades provide an indicative spread of qualities when all veneer characteristics are evaluated together and may provide a useful benchmark for the future development of a commercial grading standard for coconut veneer.

The grades are defined by a combination of density, with a score based on visual assessment of processing, and natural defects such as surface roughness, splits and holes. The results for the veneer sheets produced during the trial in the commercial ply mill in Labasa, expressed as percentage of sheets attaining the prescribed grade, and a list of grading parameters used in the specification, are given in Table 10.2. Eighty-four per cent of the veneers attained grade 3 or better; of these 50% attained grade 2 or better and 15% attained grade 1. Sixteen per cent of the sheets failed to meet the minimum grade quality requirements developed for the trial.

Table 10.2. Grade recovery and quality specifications for coconut palm veneer. Parameter scoring is described below the table.

	Grade 1	Grade 2	Grade 3
Recovery	15%	50%	84%
Density	≥600 kg/m^3	≥450 kg/m^3	No restriction
Roughness	≤3	≤5	≤7
Splits	≤3	≤6	≤6
Brittleness	≤2	≤3	≤7
Collapse	≤3	≤4	≤6
Decay	1	≤5	≤7
Holes and tear-out	≤2	≤4	≤7
Compression	1	≤2	≤4
Handling splits	≤4	≤7	≤9
Wane	1	≤2	≤2
Insect tracks	≤2	≤2	≤3

Roughness: 1 = smooth surface to 8 = very rough surface.
Splits: 1 = none to 10 = severe.
Brittleness: 1 = robust veneer to 10 = very fragile veneer.
Collapse: 1 = none to 10 = large proportion.
Decay: 1 = none to 10 = large proportion.
Holes and tear-out: 1 = none to 10 = large/frequent.
Compression: 1 = minimal/none to 4 = severe.
Handling splits: 1 = none to 10 = severe.
Wane: 1 = none to 3 = excessive.
Insect tracks: 1 = none to 3 = high frequency.

PRODUCT TESTING

A range of plywood panels and LVL beams, with different construction strategies based on density combinations (see below), were manufactured and tested. All veneers were conditioned in a controlled environment to a moisture content of approximately 9% before veneer selection and product manufacture.

A phenol formaldehyde resin system was applied to both faces of each core veneer at a spread rate of 200 gsm (grams per square metre) using a double roller glue spreader (Figure 10.5). The face and back veneers were fed through the spreader while at the same time concealing the surface to be exposed on the product, ensuring that adhesive was applied only to the inner surfaces of these veneers.

The laid-up veneers had an open assembly time limited to a maximum of 5 min prior to pre-pressing for 15 min at 1 MPa (Figure 10.6). A 25 min closed assembly time preceded a final hot-press at 135 °C and 1.2 MPa. The final hot-press time was 12 min and 30 min respectively for the plywood and LVL.

Figure 10.5. Coconut palm veneers being passed through the glue spreader in preparation for plywood manufacture.

Figure 10.6. Cocoveneers being pressed into a panel product.

Plywood panels

For plywood, four construction strategies were trialled to produce the following range in 15 mm 5-ply:

- type A ply panels: low-density veneers (<450 kg/m^3)
- type B ply panels: medium-density veneers (451–600 kg/m^3)
- type C ply panels: medium- to high-density veneers (601–750 kg/m^3)
- type D ply panels: high-density (>750 kg/m^3) face/medium-density core veneers.

All mechanical property tests were conducted within Queensland DAF's National Association of Testing Authorities (NATA)-registered engineering laboratory located at the Salisbury Research Facility. A Shimadzu AG-X universal testing machine was used to conduct the static bending, shear and hardness tests (Figure 10.7).

The suite of testing included modulus of elasticity (MoE, stiffness) parallel and perpendicular to the face veneer grain, modulus of rupture (MoR, strength) in flexure parallel and perpendicular to the face veneer grain and shear MoR parallel and perpendicular to the face veneer grain. The combination of these provides an indication of the structural characteristics of the products. In addition, Janka hardness tests were performed to compare the resistance to indentation capacity between panel types. Bond quality was also assessed.

Figure 10.7. Mechanical property testing of cocoveneer products.

The plywood static bending and panel shear test samples were prepared and tested in accordance with AS/NZS 2269.1:2012 'Plywood structural—Part 1: Determination of structural properties—Test methods' (Standards Australia 2012c).

Hardness was tested using the Janka hardness test as described by Mack (1979). With this test method, a steel ball with a diameter of 11.28 mm is pressed into a test piece until the ball has penetrated to a depth equal to half its diameter. This test was completed on the face of plywood samples measuring approximately 150 × 85 mm.

Bond quality was tested in accordance with AS/NZS 2098.2: 2012 'Methods of test for veneer and plywood – Method 2: Bond quality of plywood (chisel test)' (Standards Australia 2012a). A subset of plywood samples (measuring 150 × 75 mm) from each construction strategy was evaluated to A-bond criteria (6 h steaming at 200 kPa). This test involves the forceful separation of veneers along the glueline and the subsequent evaluation of the ratio of wood fibre and glue failure on the separated sections (Figure 10.8).

Figure 10.8. Bond testing using the chisel test.

A subset of test results follow; more detailed results and discussion are presented in McGavin et al. (2016).

As expected, the stiffness and strength properties generally improve incrementally when comparing type A through to type D construction strategies (Figure 10.9)

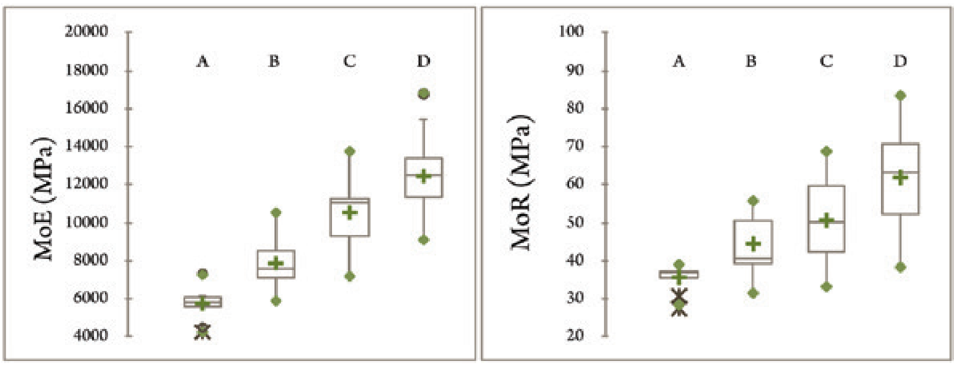

Figure 10.9. Left: Comparison of modulus of elasticity (MoE) parallel to the face veneer grain for each panel type. Right: Comparison of modulus of rupture (MoR) parallel to the face veneer grain for each panel type. *n* = 65 samples: 10 type A, 15 type B, 20 type C and 20 type D.

In the shear test, there was improvement from the type A low-density panels to type B medium-density construction and again to type C panels, however no further improvement in shear properties for type D compared to type C (Figure 10.10, left). The Janka test results showed an increase in hardness from low-density type A panels to type B and type C, but no advantage was offered by the type D panels with high-density face veneers (Figure 10.10, right). Type B to D panels generally performed as well as many softwood and lower density hardwood panel products in terms of resistance to indentation in the Janka hardness tests.

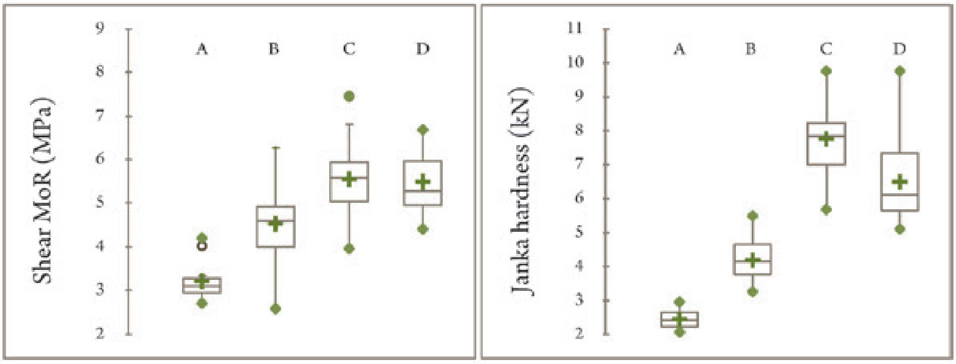

Figure 10.10. Left: Comparison of shear modulus of rupture (MoR) parallel to the face veneer grain for each panel type. *n* = 64 samples: 10 type A, 15 type B, 19 type C and 20 type D. Right: Comparison of Janka hardness for each panel type. *n* = 65 samples: 10 type A, 15 type B, 20 type C and 20 type D.

Bond testing revealed that 93% of the samples passed the requirements for an 'A bond'. Type A bonds are intended to withstand prolonged exposure to severe exterior conditions without failure of the glueline. Type A bonds are normally suitable for weather-exposed, structural and marine applications where rigidity and durability are required. They have a design durability life of more than 50 years in fully exposed situations and indefinite durability in semi-exposed and interior applications.

Laminated veneer lumber beams

For the LVL, construction strategies based on veneer density similar to the plywood panels were adopted to produce 33 mm thick beams. Testing was performed using a Shimadzu universal testing machine. Due to the density variation and corresponding compressibility differences, some beams were constructed from 13-ply and others from 12-ply as summarised below:

- type A LVL beams: 13-ply, low-density veneers (<450 kg/m^3)
- type B LVL beams: 12-ply, medium-density veneers (451–600 kg/m^3)
- type C LVL beams: 12-ply, medium- to high-density veneers (601–750 kg/m^3)
- type D LVL beams: 12-ply, two high-density outer veneers on each face (>750 kg/m^3)/ eight medium-density veneers in the core.

The LVL static bending and shear test samples were prepared and tested in accordance with AS/NZS 4357.2:2006 'Structural laminated veneer lumber (LVL)—Part 2: Determination of structural properties—Test methods' (Standards Australia 2006).

A subset of test results follow; more detailed results and discussion are presented in McGavin et al. (2016).

LVL stiffness and strength properties improved from type A to type B to type C (Figure 10.11, left). Fourteen type D beams were tested and showed lower stiffness properties on average than the 21 type C beams. The benefit of type D construction strategy was more evident in the testing 'on flat'. MoR results for type D were within the range achieved by the type C panels, but with less variation and higher mean and median values (Figure 10.11, right).

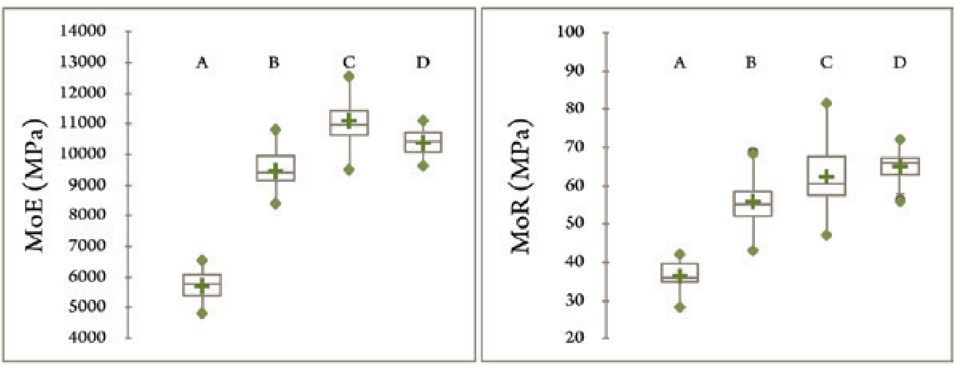

Figure 10.11. Left: Comparison of modulus of elasticity (MoE) in flexure, on edge, for each beam type. Right: Comparison of modulus of rupture (MoR) in flexure, on edge, for each beam type. *n* = 77 samples: 21 type A, 21 type B, 21 type C and 14 type D.

LVL shear strength was tested in both edge and flat orientations, with the edge test results showing sharp improvements from type A to type B to type C. The mean shear strength result for type D was similar to type C, but type D displayed a higher degree of variation than type C beams comparing the edge test results (Figure 10.12, left). In the comparison of shear strength results from testing 'on flat', there were again sharp improvements in results from type A to type B to type C, but in this test type D results dropped to approximately halfway between those achieved by the type B and type C panels, implying that the addition of high-density face veneers has minimal improvement on flatwise shear properties (Figure 10.12, right).

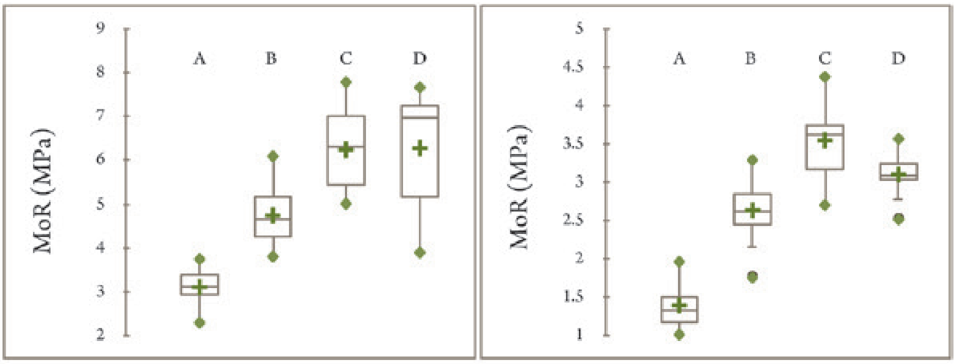

Figure 10.12. Left: Comparison of shear strength on edge for each beam type. *n* = 55 samples: 15 type A, 15 type B, 15 type C and 10 type D. Right: Comparison of shear strength on flat for each beam type. *n* = 58 samples: 15 type A, 15 type B, 14 type C and 14 type D.

Architectural products

For many non-structural applications, it has been common practice to use reconstituted wood-based panel products such as medium-density fibre boards (MDF) or particle board combined with a surface layer (or layers) of veneer. This construction strategy can maximise the veneer utilisation and value, while reducing the final product costs.

Options exist to manufacture flat overlay panels or manipulate the surface quality to suit particular markets such as VJ wall panelling (Figure 10.13). The visual appearance of cocoveneer products can also be manipulated or standardised through colour staining (Figure 10.14).

Figure 10.13. Veneer overlay panel using medium-density cocoveneer on medium-density fibre boards (MDF).

Figure 10.14. VJ style wall panelling using medium-density cocoveneer on medium-density fibre boards (MDF). Surface finishes included red (left), golden, clear (middle), dark brown and light brown (right) stains.

It is not common to use rotary veneer as the exposed surface for engineered flooring systems due to the market demand for a solid wood look, which is often lost in a rotary veneer from traditional timber species. However, due to the anatomical structure of coconut wood, the surface appearance of cocoveneer is very similar to that of sawn coconut (cocowood). This presents a potential competitive advantage for cocoveneer in engineered flooring products. Figure 10.15 shows engineered flooring using cocoveneer for the exposed face, combined with more traditional and readily available forest resources.

Figure 10.15. Engineered flooring combining cocoveneer with other forest resources.

Multilaminar wood provides an opportunity to use a wide range of veneer qualities to produce a range of products that can have high aesthetic appeal. Using the large manufactured veneer block as feedstock, sawn sections of various sizes can be produced and depending on the processing approach, a range of appearances can be achieved. This includes more classical appearances when sawn longitudinally either at 90° or at various angles (Figure 10.16), or a quite unique appearance when sawn across the grain to expose the ends of the vascular bundles (Figure 10.17). The veneers and the manufacturing protocols can be manipulated to change, for example, patterns and colours and influence the visual qualities of the end product. Sawn sections of multilaminar wood are well suited to furniture and joinery applications. In addition to sawn sections, turned articles can also be produced from multilaminar wood (Figures 10.18 and 10.19).

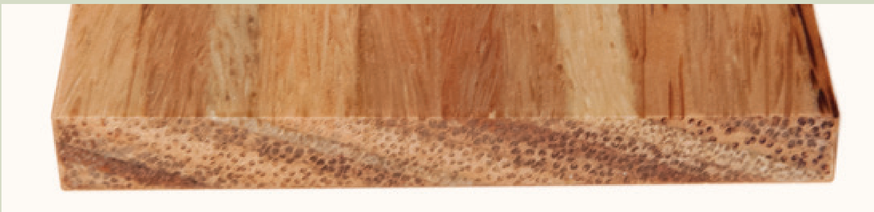

Figure 10.16. Multilaminar wood section sawn across the grain at 20° to the veneer direction.

Figure 10.17. Multilaminar wood section sawn across the end grain at 45° to the veneer direction.

Figure 10.18. Table legs made from cocoveneer multilaminar wood. Surface finishes include golden (left), clear (middle) and dark brown (right) stains.

Figure 10.19. Speciality handles made from cocoveneer multilaminar wood. Surface finishes include golden (left), clear (middle) and dark brown (right) stains.

Beetle and borer insect susceptibility

In addition to the physical and mechanical property testing, empirical data on the susceptibility of processed coconut palm stem material to beetle and borer insect attack (but not termites) was undertaken. Potential insect pests of seasoned coconut palm material include the powder-post beetle (*Lyctus* spp., principally *L. brunneus*) and bamboo borer (*Dinoderus minutus*). Over 200 blocks of coconut palm, covering the range of densities, were exposed along with control samples of known susceptible timbers (spotted gum (*Corymbia* spp.), blackbean (*Castanospermum australe*) and bamboo). The experimental design included exposure to wild populations (Figure 10.20) and contained colonies in the laboratory. At the completion of the trial, no evidence of attack by powder-post beetles or bamboo borer was detected in the coconut palm material, despite infestation of the control species.

Figure 10.20. Left: Wild exposure trial—cocowood blocks alongside powder-post beetle-infested hardwood. Right: Wild exposure trial—cocowood blocks alongside bamboo borer-infested rings.

Based on these results, it is likely that coconut palm veneer and veneer-based products do not require prophylactic treatment to protect against beetle and borer infestation. Termite resistance was outside the scope of this case study. Preservative treatment is required to protect against decay fungi (rot) where cocoveneer products are to be used in weather-exposed applications.

SUMMARY

The processing trials demonstrated that senile coconut palm stems can be successfully peeled and dried to produce veneer as long as optimal processing settings are deployed. Robust equipment is required due to the high density of the outer cylinder of the coconut palm stem and the abrasive effect of the vascular bundles present within the material.

The resulting cocoveneer can be assembled using available adhesives into a range of products that satisfy market performance requirements. Products using only cocoveneer or a combination of cocoveneer and traditional wood feedstocks include:

- structural products, such as plywood and laminated veneer lumber LVL
- architectural products, such as appearance veneer on board substrates, engineered flooring and multilaminar products.

With a sensible target product mix, and intelligent product construction strategies, all the high-quality veneer produced during processing could be used. Low-quality veneer may be used for core material.

Structural assessment focused on common veneer-based wood products, while appearance grade material was assembled and used in design trials. These assessments confirmed that cocoveneer's unique material properties present advantages and constraints across the product range.

Testing showed that there was a wide variation in the mechanical properties across the assembled plywood and LVL, mainly due to the construction strategy employed. Panels assembled from lower density veneers achieved low mechanical properties in general, while panels assembled from higher density veneer returned mechanical properties more in line with market expectations for structural products. However, the veneer and product MoE results were generally low compared to commercial wood species of similar density.

Improved performance levels may be achieved by blending coconut and timber veneers in a product or by making thicker coconut veneer products that deliver the same performance as thinner timber products. While not a disadvantage in some markets, increased weight is undesirable in many structural applications due to lower site productivity and increased concerns about workplace health and safety with manual handling.

While the material properties of cocoveneer constrain its performance in many structural products, its hardness, colour and visual appeal are advantages for many appearance products.

Hardness is a useful indicator of a timber's ability to resist wear and indentation and the higher density cocoveneers fall within the hardness range considered suitable for applications where this resistance is critical. Hard cocoveneer can be used as a surface for engineered flooring, and provides an alternative to thin sawn laminate. Advantages including higher recovery of surface area from the coconut log, reduced variation in quality, and reduced feedstock preparations. With the anatomical structure of coconut palm stems, the link between hardness and wear resistance should be further explored. It is possible that cocoveneer's wearing properties are better than indicated by the Janka hardness test.

Re-sawing appearance and colour graded coconut plywood, LVL or multilaminar blocks offer a wide range of uses for joinery, lining and furniture. Veneer arrangement may also be manipulated by colour or orientation to broaden the range of options offered to the market. A lightweight, joinery plywood with a dense, dark outside face over a light, pale core is an example.

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