

# Sustainable possibilities from waste timber

Henry Skates, Ian Underhill and Benoit Gilbert

Griffith University, Gold Coast, Australia

**ABSTRACT:** Plantation timber forms an integral part of the future of timber industries, but in its production, significant quantities of timber is lost as waste in the form of plantation 'thinnings' (plantation thinnings are the sub-standard or poor quality trees that are removed prior to trees reaching full rotational age and have no to low commercial value). This paper reports on and promotes a more sustainable approach to the use of plantation timber and in particular the normally waste plantation 'thinnings'. The holistic approach is achieved by developing methods not only for processing but also for the manufacture of products that utilize the plantation 'thinnings' for structural and architectural applications. More specifically, the paper reports on the development and testing of a number of concepts and structural and architectural prototypes and speculates on proposed applications in the construction and other industries. Topics covered include economic, social and environmental benefits and the key focus - the potential uses as a sustainable construction material. Plantation timbers offer social, financial and environmental benefits if correctly managed by governments and growers. By staggering timber harvesting, an endless supply of timber is possible. Environmental benefits include the reduction of dry-land salinity, reduction in greenhouse gasses and in aiding carbon sequestration.

Conference theme: Construction technology and materials

Keywords: Timber thinnings, Veneers, Lamination

## INTRODUCTION

Australia is the world's smallest continent with a total landmass of 769.2 million hectares. Of this total, 149.4 million hectares (or 19%) is classified as forests, which are dominated, by more than 700 different species of Eucalyptus. Currently around two million hectares or 0.25% of these forests are managed as plantations (Bureau of Rural Science, 2010). Of the two million hectares of plantation forests grown in Australia, roughly 49% contain hardwood species. These plantations are dominated by Blue Gum (*Eucalyptus saligna* 62%), Shining Gum (*Eucalyptus nitens* 19%), Flooded Gum (*Eucalyptus grandis* 4%), other Eucalyptus species - 11% and other hardwoods - 4%. The remaining 51% of the two million hectares are softwood species (Boland et al., 1992, Bureau of Rural Science, 2010). In the 2007-2008 period, 68% of the timber sourced from Australia's forests came from plantations, with the remaining 32% sourced from native forests (Plantationfacts com, 2010). State Governments were the major plantation owners prior to the early 1990s, however since then most of the investment in new plantations has been in the private sector. The Victorian, Tasmanian and Queensland Governments have sold, or are in the process of selling plantations to private investors. Private ownership of plantations has therefore increased from about 30% in 1990 to about 62% in 2009. (Bureau of Rural Science, 2010). In addition to the privatisation of plantations, in 1997 the Australian Government developed a range of Regional Forestry Agreements (RFA's). These 20 year agreements, which cover the main native timber producing forests in Australia, were designed to integrate and balance the commercial, social and environmental requirements for the conservation and sustainable management of Australia's native forests (DAFF, 2010). Plantation forests have increased by approximately 51% in the last 10 years. This equates to a dramatic increase of 150% for hardwood plantations and an 8% increase for softwood plantations and can be attributed predominantly to changes in government policies (Bureau of Rural Science, 2010). Commercial utilisation of sub 15-year-old plantation hardwood thinnings is only deemed viable for low-value pulpwood if located less than 100km from a port or pulp mill or can be integrated with other harvesting operations. No other viable markets have been identified due to the lack of research and economic concerns pertaining to this material (McGavin et al., 2006).

**Table 1. Composition of harvest (% of harvest merchantable volume)**

Log type	Commercial thinning age (12 years)	Clear-fall (age 25 or 30)
Pole	0	20
Sawlog	0	60
Low-value Log <sup>a</sup>	100	20

*Note* <sup>a</sup> Low-value logs include material suitable as salvage sawlogs, pulp, fibreboard, treated posts, pallets and palings. (Venn, 2005)

The lack of mid-rotation revenue associated with subtropical hardwood plantations is a key impediment in attracting new investment into this sector of the industry (McGavin et al., 2006). With the absence of mid-rotation products, the first harvest in sawn log hardwood species is around 25 - 30 years which when added to production risk (Pest, disease and fire) creates a challenging economic business model.

The research relating to hardwood plantation thinnings, their material properties and potential applications has highlighted potential applications in the round-wood form such as vineyard posts (McCarthy et al., 2005) and potentially as logs for the building and landscaping industry (Nolan et al., 2005), but only if the current problems with excessive splitting and checking as depicted in Figure 1 can be reduced (McGavin et al., 2006).



(McGavin et al., 2006)

**Figure 1. Splitting of Hardwood Plantation Round wood logs**

When a new hardwood plantation is established, the current recommended stocking rate for unimproved energetic stock is around 1000 trees per hectare (Qld DPI, 2009). The reason for this is rapid site capture so as to negate the impact of weeds. At between 1.5 - 3.5 years of age depending on the growing conditions the first thinning takes place. The aim of the first thinning which usually entails the removal of 500 - 600 trees per hectare is to remove substandard or poor quality trees before they become dominant, thus improving the growing conditions for the remaining trees by increasing the amount of light, moisture and nutrients available. At between 10 - 15 years, inter-tree competition for available resources again becomes a problem and a second thinning is recommended. It is this second thinning which is the focus of this research. This thinning reduces the stock rate down to 150 - 200 trees per hectare. The remaining trees are allowed to reach maturity and are clear felled between 25 - 35 years of age (Geoff et al., 2006, Qld DPI, 2009). Costs for the above plantation activities are shown in Table 2.

**Table 2. Establishment and Post-establishment expenses for hardwood plantations (Venn, 2005)**

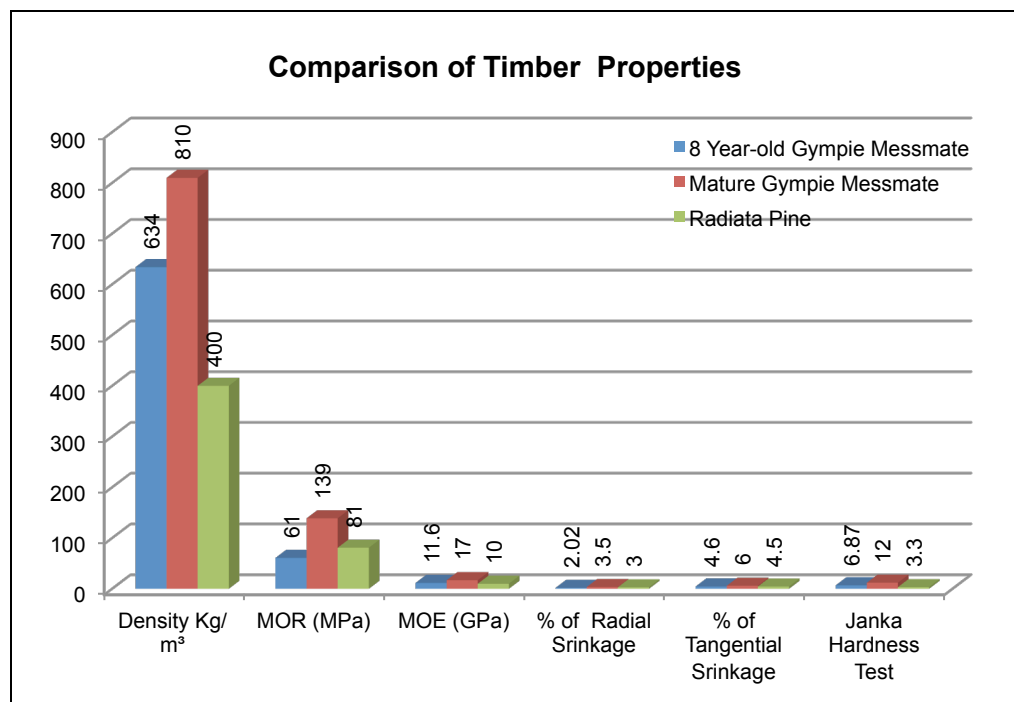
Year	Item	Amount (\$/ha)
1	Total establishment expenses (excluding cost of land)	1900
2	Weed control	170
2	Fertilise	130
3	Non-commercial thinning	280
3	1 <sup>st</sup> prune	450
5	2 <sup>nd</sup> prune	350
12	Marking of thinnings	50
12	Contingency for commercial thinning cost incurred by landholder	130
25 or 30	Inventory and analysis prior to clear fall	70
25 or 30	Contingency for clear-felling expenses incurred by Land holder	130
Annual	Management cost	60

## 1. MAXIMISING UTILISATION

### 1.1. Solid Wood Products

The research in this paper is concerned primarily with the utilisation of Gympie Messmate. Gympie Messmate, is a large hardwood species found throughout Southern Queensland. It predominantly occurs in tall open-forests or woodlands and inevitably is the dominant species in the stand. Under ideal growing conditions the species can attain 55m in height with diameter at breast height (dbh) of 2m. The heartwood is yellow-brown, of even texture with a density of around 810 kg/m<sup>3</sup>. By way of comparison, softwood timber has a density of 400 kg/m<sup>3</sup>. Established uses for large section Gympie Messmate timber, when durability and strength are key requirements, include railway sleepers, mining timbers and bridges, etc. (Bootle, 1983, Boland et al., 1992, NAFI, 2004).

While a great deal of research has been conducted on the material properties and commercial applications for mature Gympie Messmate sourced from plantation and native forests, little research has been conducted on the < 15 year-old juvenile Gympie Messmate. Of the available research, the Queensland DPI reported (2006) some of the disparities between the juvenile and mature species (Figure 2). The data shows that Gympie Messmate plantation thinnings while lower in strength, hardness and density had more favourable shrinkage and stability results over mature Gympie Messmate from native forest. In addition this report aimed to show that the properties of the juvenile Gympie Messmate thinnings are still favourable when compared to common softwood plantation species.



(McGavin et al., 2006, Bootle, 1983)  
**Figure 2. Comparison of Timber Properties**

While timber is still extensively used in its solid form in many industries, the use of solid timber has obvious limitations. Two major limitations are availability and the length of natural timber sections that cannot meet the spans required for modern building components. (Bootle, 1983). Coupled with inherently wasteful milling processes where significant losses occur as sawdust and off-cuts, the need for a more complete utilisation of the raw material is required. This has the potential to alleviate some of these inherent shortfalls. Training and Further Educations (TAFE) students have investigated the use of hardwood plantation thinnings for solid wood applications with successful trials in the fabrication of furniture. For industrial applications, similar trials were conducted where sawn timber, roof trusses and pallets were successfully tested. Within the trials, high rates of rejection (> 50%) were reported due to defects in the material or processing (McGavin et al., 2006). This high rate of rejection makes the economics of using plantation thinnings for sawn timber questionable.

## 1.2. Engineered Wood

Engineered Wood products on the other hand address some of the above shortfalls by utilizing more of the available resources with minimal waste. Engineered woods are predominantly wood-based materials that have been reengineered to improve the performance of the final product. The standard approach when developing engineered woods is to utilize smaller sections of timber which are more readily available in the form of veneers, small chips / flakes or fibres. These small elements are then reconstituted with the appropriate binding agent to form an array of products that are designed to meet application-specific requirements. One of the underlying problems when using some of the denser (>700kg/m<sup>3</sup>) eucalypt species, is the variable level of extractives which can represent 5% to 30% of the dry wood mass (Bootle, 1983). These chemical extractives, which can be removed with solvents, play an important part in the wood structure as they contribute to the overall colour, density and durability of the timber. The presence of high levels of these extractives can also have an adverse effect on gluing when forming engineered wood products (Ozarska, 1997b). Overall, plantation thinnings generally exhibit a higher percentage of sapwood, lower strength, hardness and density compared to fully-grown hardwood timbers. Plantation thinnings do however display lower shrinkage rates (McGavin et al., 2006).

### 1.2.1 Veneers

Timber veneers are thin slices of timber that usually range between about 0.3mm to 6.0mm in thickness depending on the application and selected timber species. They are generally produced in one of three ways: rotary peeling; slicing; or by sawing - a process which is seldom used today (Bootle, 1983). Before cutting veneers either by rotary peeling or slicing, the logs need to be preconditioned. This involves debarking and docking the log to the desired



length, then pre-softening by water-spraying, immersion in hot water (50°C - 90°C) or the application of steam generally for up to 36 hours depending on the density of the species (Ozarska, 1997a). The preconditioning ensures the logs are at a high, consistent moisture content between 40-140% depending on the species, thus allowing the veneers to be peeled more readily with less tearing and splitting. The rotary peeling process involves the continuous rotation of a log against a fixed knife. This process produces an unbroken continuous veneer that peels or unrolls off the log. The log can be either rotated between 'centres' or via a 'centre-less' process. The centre-less process involves a number of external rotating rollers which apply pressure and rotate the log against the knife. (PAA, 2010b, Ozarska, 1997a). Early work on the peeling of low quality, small diameter eucalypt logs such as thinnings, highlighted problems when traditional peeling technology was used (Ozarska, 1997b). Some variability in material or processing could have created these problems because subsequent reports have shown the general suitability of Eucalyptus plantation timber including Blackbutt (*Eucalyptus pilularis*) for structural LVL applications (Nolan et al., 2005) and (Carrick and Mathieu, 2005). The Queensland DPI also reported that engineered wood products, namely plywood sheets and LVL beams were successfully made and tested from Gympie Messmate (*Eucalyptus cloeziana*), Blackbutt (*Eucalyptus pilularis*) and Red Mahogany (*Eucalyptus pettita*) (McGavin et al., 2006). For plantation thinnings to be more widely utilised, more research is required into the material properties, gluing methods and potential end uses along with increased awareness and understanding by the relevant industries (Wolfe, 1999, McGavin et al., 2006). This paper explores potential end uses for what would otherwise be considered a waste material.

The Gympie Messmate logs used in this study were sourced from plantations in the Gympie region, South East Queensland. These logs, once harvested, were shipped to DEEDI's Salisbury Research Facility for processing. The processing involved steam preconditioning of the logs at 80°C for 24 hours prior to the centre-less peeling process. The veneers were peeled at a nominal thickness of 1.5, 2.0, 2.5 and 3.0mm, then docked into 1.2m lengths as per Figures 3 and 4.



**Figure 3. Centre-less Peeling Lathe at DEEDI Salisbury QLD**



**Figure 4. Peeling of 2.0mm thick veneer from <12 year-old Gympie Messmate**

An initial visual inspection of the Gympie Messmate veneers revealed a marked variation in the visual quality, with some veneers exhibiting clusters of knots and gum pockets, whilst other veneers were visibly free of all defects (Figure 5).



**Figure 5. Variation in Veneer Quality of Centre-less Peeled Gympie Messmate**

The composition of the test samples was sourced from random veneers, including from different logs and from different radial positions. For aesthetic reasons, only high-grade veneers were then selected as the face veneers on the test samples.

## **2. STRUCTURAL SECTIONS**

### **2.1. Circular Hollow Sections**

Circular hollow and tapered structural sections have been developed that have a variety of potential applications such as power distribution networks (power poles), street lighting, decorative columns, and exposed elements in lightweight building structures. This work builds upon earlier research undertaken by Sasaki and Kawai 1993, Farny 1942, and Botten and McGuire 2005. The new process developed in this project involves the forming from veneers of circular hollow structures that consists of four 'C' sections or half round sections. Each section is formed separately around one of two different diameter mandrills, depending on their position within the structure. This produces an inner and outer pair of 'C' sections which are then cut to the appropriate size and bonded together in one 'glue-up' using a two-part thixotropic epoxy gel to form the hollow structure as shown in Figures 6 and 7.

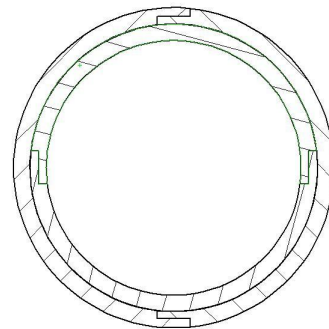
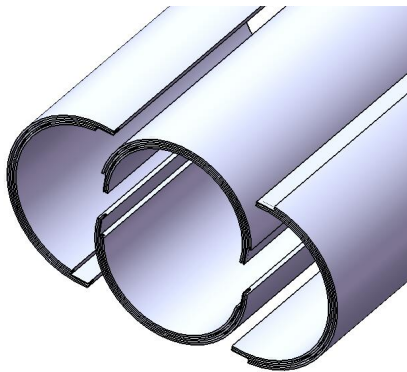
Potential benefits of this process include:

- The ability to control the position of the veneers so that poor quality veneers can be dispersed throughout the material, thus retaining high quality veneers as face veneers
- Ability to form long lengths in a continuous process
- Ability to precondition veneers, such as preservative treatment on underlying veneers, thus leaving face veneers free from chemicals. This has potential benefits for external applications such as play equipment, handrails and furniture etc.





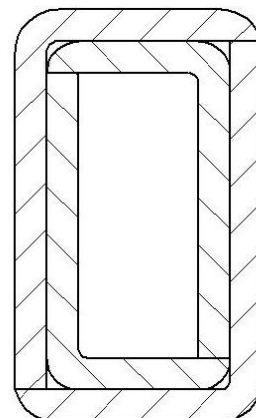
**Figure 6. Interlocking Circular 'C' Section**



**Figure 7. Second Iteration - Interlocking Circular 'C' Section**

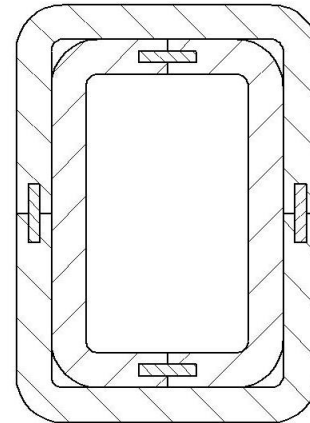
## **2.2 Rectangular Hollow Sections**

By gluing inter-locking segments together rectangular hollow sections have been developed that have potential uses in structural applications. In the first iteration, the hollow section material was fashioned by butt joining and bonding together four 'L' shape segments, again with a two-part thixotropic epoxy gel. These segments were bonded firstly as an inner-pair over a fixed mandrill. After curing, the outer-pair was then bonded to the inner structure, so that the edge joints were positioned perpendicular to the inner joints. This is demonstrated in figure 8.



**Figure 8. Rectangular Hollow Section First Iteration - Inter locking 'L' Sections**

In the second iteration of this concept, four inter-locking 'U' sections were used to form the rectangular hollow section material as illustrated in figure 9. This hollow section material was glued together in one set up over a fixed mandrill. For proof of concept the sections were butt jointed together, but further research will investigate open floating tenon joints and finger joints.



**Figure 9. Rectangular Hollow Section Second Iteration - Inter locking 'U' Sections**

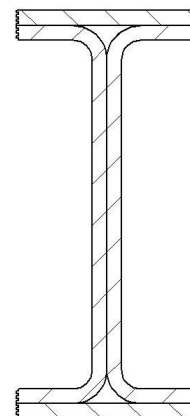
Potential advantages of the interlocking 'U' section concept include:

- The material could be manufactured in standard lengths and marketed in conjunction with a range of 'click-lock' fittings that could be used to join a number of lengths together in a range of different positions, or for attachment to other building elements.
- The 'click-lock' fittings and hollow rectangular sections will be reusable with the hollow central void potentially being used to accommodate services such as electrical, gas or water.
- This overall system could allow the rapid assembly and disassembly of either pre-designed building elements such as house frames, roof trusses, emergency housing structures, DIY projects, or flat-packed custom designed building elements.

The ability to rapidly assemble and disassemble flat-packed custom or predesigned building structures with minimum equipment has immense benefit. This benefit is both as a versatile building material within the building industry, and as a complete building system where immediate temporary housing is required.

### 2.3 I-Section Beam

Laminated I-beams have been produced that are both structural and visually appealing for exposed architectural applications. The normal configuration when constructing composite timber I-Beams involves a web element that is made from oriented strand board or plywood, with solid timber or LVL top and bottom flanges. Whilst this configuration performs well structurally, it is somewhat lacking aesthetically, and is often concealed within the building envelope. The I-beam developed in this project is formed in a radically different way. To create the I-beam, two identical 'U' shape sections that are formed in a continuous process are bonded together to form the web and underside of the flanges. This web assembly is then bonded to a top and bottom LVL sheet in which the grain direction runs perpendicular to the long axis of the beam as shown in figure 10.



**Figure 10. Novel LVL I-Beam**

## CONCLUSION

Three new structural sections have been produced from hardwood plantation thinnings that could be the basis for new architectural structural systems.

The first new structural section developed is the circular hollow section utilising interlocking 'C' section which adapts some of the technology presented by Hara et al., 1994, and Sasak and Kawai, 1993 in the forming of curved structural members. Some of the methods in curing and joining as presented by Yang et al 2005 and the use of overlay materials as presented by Sarmento and Lacoursiere 2006 have also been incorporated in the design. Historically jointed circular hollow section structures have inherent weaknesses partly due to the joining of short lengths to form longer sections but also because the joints radiate from the inner core to the outer perimeter in a continuous path, creating a weak point. It is believed that by incorporating overlapping sections as proposed and the forming of continuous lengths, this failure mode can be reduced, thus producing a stronger material. Samples of this concept have been manufactured which have highlighted many potential applications. The concept could be scaled up for power distribution poles or structural architectural columns in which the columns are manufactured in continuous lengths or as standard lengths for handrails and balustrades or lightweight building materials.

Square hollow section laminated sections have been formed from interlocking 'U' sections - builds on a need highlighted by industry for large sections of hardwood for cross-arms in the power distribution industry. It is believed that this concept has many applications, far beyond the original scope that requires further investigation. An example of a new application of this idea is as a lightweight temporary building material that can be rapidly assembled and disassembled with minimal equipment.

I-beams have been fabricated in a novel way that has potential both structurally and decoratively. The I-beam has potential uses in residential and commercial buildings where architecturally exposed elements are desirable.

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