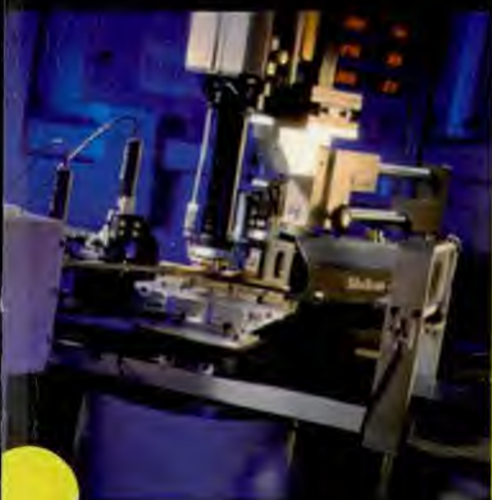
26th FOREST PRODUCTS Research Conference

June 19th-21st 2000

26th

Research Developments and Industrial Applications

Waste Wood Forum



CSIRO forestry and forest products

Clayton
Victoria
Australia

CSIRO

26th Forest Products Research Conference

"Research Developments and Industrial Applications"

and

Wood Waste Forum

19th-21st June 2000

Proceedings

CSIRO Forestry and Forest Products
Forest Products Laboratory
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Monday 19th June

8:00 Registration

9:00 Welcome: *Dr Glen Kile (Chief CSIRO Forestry and Forest Products)*

Opening Address: *The Hon. Wilson Tuckey (Federal Minister for Forestry and Conservation)*

Keynote Address: Carbon products and energy from wood
Mr Colin Stucley (ENECON) 6

10:00 Morning tea

10:30 Session 1: Wood protection-preservation and timber coatings.

12:10 Lunch

1:00 Session 2: Structural applications.

3:00 Afternoon tea

3:30 Session 2: Structural applications (continued).

Session 3: Reconstituted and composite wood products.

6:00 Institute of Wood Science – Pre dinner drinks and dinner
(Forest Product Laboratory)

7:30 Student Presentations - Forest Industries Program, School of Forestry, Creswick

Chemical modification of wood for wood composite products
Kristen Filcock

Chemical treatment of wood and its effect on wood-water interaction
Jeff Hann

Sequential pyrolysis of wood for value added compounds
David Butt

Tuesday 20th June

9:00 Session 4: Primary conversion, drying and utilisation.

10:40 Morning tea

11:00 Session 5: Growth for end use.

12:40 Lunch and posters

Posters (Presenters available)

1:30 Session 5: Growth for end use (continued).

3:10 Afternoon tea

3:30 Session 6: Optimal use of fibre resources.

6:30 Conference dinner
(West Banquet Room, 1st Floor, Campus Centre, Building 10)

Wednesday 21st June

Carbon products and energy from wood

C. Stucley

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Introduction

There is always strong interest within the timber industry to find commercial uses for as much as possible of the wood that is being harvested. There is therefore considerable interest at present in "new products" such as carbon products (charcoal and activated carbon) and energy. These are seen as possible alternative uses for mill wastes, export chip and forest residues. They are also seen as potential products to be made from trees planted for environmental benefits, or for new, product-specific plantations.

Enecon is an Australian engineering and project development company, with considerable experience in technologies for wood-based electricity and carbon products. In particular, Enecon holds the managing licence for technology developed by CSIRO Forestry and Forest Products, for the manufacture of carbon products and energy from wood or other feedstocks.

Charcoal

When charcoal is produced from wood, much of the energy in the wood feed is released as the volatiles are driven off. In simple batch kilns and similar plants this can actually contribute to pollution problems. However, in a carefully designed process, this energy can be recovered as hot air, or as steam for drying or power generation. Consider a simple energy balance: one tonne of dry wood (at 20GJ/t) will typically yield 250 kg of good quality charcoal (at 30GJ/t) after carbonising. Thus only some 40% of the original energy in the wood is captured in the charcoal product. The challenge is to usefully recover as much as possible of the remaining energy.

Forestry and Forest Products at CSIRO has developed a fluidised bed process for charcoal production, using wood chips or sawdust as feed and recovering energy for heat or electricity. Such plants offer the potential to provide a large saw mill with energy for kiln drying or power requirements, as well as providing a marketable, value-added product from mill waste. These charcoal/energy plants offer an excellent alternative to capital expense on new boilers or combustion equipment.

Enecon and CSIRO are also studying the manufacture of metallurgical charcoal using the CSIRO process. Our feasibility work indicates that a plant making 30,000 tonnes of charcoal each year can also generate up to 8MW of renewable electricity. Sale of this electricity at 7 c/kWh will realise $4.5 million per year. In contrast, sale of the charcoal at, say $350/tonne, will realise $10.5 million per year.

Activated Carbon
Activated carbon is produced when charcoal or other biomass carbons are activated at high temperatures with steam, or with chemicals such as phosphoric acid. Activated carbon is a powerful adsorbent, and some 700,000 tonnes are used worldwide each year, to clean water, air and other gases, in the food and beverage industry and for mining and other applications.

Over a number of years the Forestry and Forest Products Group at CSIRO has developed carbonising, processing and activation technology to make a range of charcoal and activated carbon products from wood feedstocks. Developed initially at the laboratory scale, CSIRO has also built and tested two pilot plants for carbonisation and activation trials. Enecon holds the managing licence for this technology, and over the past two years has been studying a variety of opportunities for its use around Australia. Tests by CSIRO with jarrah wood have yielded high quality activated carbons for gold industry applications. Tests with mallee eucalypts have yielded excellent, broad spectrum water treatment activated carbons. These latter tests have been combined with considerable study work in 1999 (co-funded by RIRDC and Western Power Corporation) to assess a mallee-based activated carbon industry.

Mallee eucalypts are being planted extensively through the Western Australian wheat belt to help control waterlogging and salinisation; problems caused by the water table rising after decades of tree clearing. Mallees were selected as a new tree crop for this low rainfall (sub 450mm/y) zone on the basis that eucalyptus oil sales would provide commercial returns for large scale plantings. This work has been driven by the Department of Conservation and Land Management and also by the Oil Mallee Company, which was set up by the many farmers planting mallee trees on their properties.

By combining the proposed use of mallee leaves for eucalyptus oil with the mallee wood as a feed CSIRO activated carbon technology, Enecon developed the concept of integrated tree processing. Whole trees will be harvested and brought to centralised processing plants, where the leaves will be processed for oil production and the wood processed for activated carbon. Leaves and wood both provide feed for energy generation. This concept has been carefully researched and work is now underway to build the first full scale demonstration plant, at Narrogin south east of Perth. Western Power Corporation is a major supporter of the plant, as are the Australian Greenhouse Office and Ausindustry. The plant will process 20,000 tonne/year of fresh whole tree feed and produce:

- 700 tonne of activated carbon
- 250 tonne of eucalyptus oil
- 1 MW of export electricity.

The success of this first plant will open the way for a number of larger plants built through the Western Australian wheat belt in coming years, providing commercial incentives for water and salinity control work and also major sources of employment and income for rural communities.

Comparative in-ground performance of pigment emulsified creosote (PEC) and high temperature creosote (HTC) after 11 years of field exposure

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Our oldest wood preservative, creosote, is amongst those receiving detailed attention in today's environmentally conscious society. In Europe, for example, specifications for creosote limit the benzo(a)pyrene (BaP) content on the basis that this compound is toxic to humans. The primary concern in Australia is not the BaP *per se*, but the fact that some of the compounds found in conventional creosote migrate to the surface of treated commodities where they polymerise into black, sticky deposits (referred to as "crud") which are unsightly and can also cause skin irritations.

In the early 1980's, CSIRO and the producer of creosote in Australia (Koppers Australia Pty Ltd) (2) commenced a research program to produce a clean version of the preservative. The strategy was to take conventional high temperature creosote (HTC), produced to Australian Standard AS1143-1973 specifications, and use it, unmodified, to develop a creosote preservative which stayed in the timber when used and which did not produce "crud" on treated commodities, especially poles and sleepers. In addition, the resultant preservative should perform like conventional creosote, exhibiting no loss of biocidal efficacy. Pigment emulsified creosote (PEC) was thus developed using HTC, emulsifiers, stabilisers and highly refined pigment (2). PEC contains up to 67 per cent HTC and can be formulated either as an oil-in-water or water-in-oil emulsion (preferred phase).

Shortly after the development of PEC, a field trial was undertaken in Australia to compare the in-ground performance of both HTC and PEC formulations when impregnated into the hardwood substrate, *Eucalyptus regnans* (Mountain ash). Three retentions (50, 100 and 200 kg/m^3) were targeted for each formulation. An additional retention of PEC formulation (308 kg/m^3), which contained 200 kg/m^3 of creosote, was also included in the trial. Specimens (25 x 50 x 300mm long) were treated by the full-cell Bethell process. After treatment, specimens were not subjected to any form of artificial weathering. Treated and untreated *E. regnans* sapwood specimens were exposed horizontally below-ground to a range of economically important species of subterranean termites and wood decay fungi at two tropical and one semi-arid test sites. Test specimens were installed using a randomised complete block design with five replications of each treatment per site. All specimens have been examined on an annual basis for both termite and fungal attack. Attack was rated according to the CSIRO system (4=sound, 3=slight attack, 2=moderate attack, 1=severe attack, 0=destroyed).

Within one to two years of field exposure, termites had destroyed all untreated control specimens. The combined data of termite ratings and decay ratings for all treatments (excluding the untreated controls) were subjected to analysis of variance (ANOVA). Results show there was a significant site by treatment interaction. Results also revealed that after 11 years of field exposure, specimens treated with 200 kg/m^3 of HTC and specimens treated with PEC containing 200 kg/m^3 of creosote continue to perform well. In addition, the field trial has demonstrated that PEC will perform comparably to HTC on an equivalent creosote retention basis. A range of wood destroying subterranean termites, including *Coptotermes acinaciformis* and *Mastotermes darwiniensis*, frequently encountered test specimens. Other termite species of lesser economic importance were often observed attacking the softened, fungal-infected surfaces of some of the treated test specimens. Soft rot was the dominant rot type present on treated specimens recorded with fungal degrade. The field trial continues.

References

1. Australian Standard AS1143. (1973). High temperature creosote for the preservation of timber. Standards Australia, Homebush, New South Wales, Australia.
2. Watkins J.B., H. Greaves, and C.W. Chin. (1983). Preservative composition. Aust. Patent No. 570984.

Some applications of inductively coupled plasma (ICP) spectroscopy in forest products research

K. J. Schmalzl

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ICP spectroscopy has been widely used in these laboratories for the analysis of metals and metalloids in preservative treated timber and associated leachates; the analysis of metals in wood, pulp and ash samples; and for the analysis of sulphur in composites and synthetic fibres. Many of these analyses can not be carried out conveniently by any alternative method and consequently the advent of ICP has opened up promising new areas of research.

GBC Scientific's Integra XM sequential ICP spectrometer is in commission. Typically a number of elements can be readily determined in the same analytical solution which constitutes a generic advantage of ICP when compared with alternative analytical systems such as atomic absorption spectroscopy (AAS). Sample solutions are aspirated and sprayed into the torch plasma. The resulting high energy ionic and atomic species emit light at characteristic wavelengths, thus facilitating identification and quantification.

Boron is an element of considerable interest in wood preservation research because of its biological efficacy against fungi and insects combined with relatively low mammalian toxicity. Work with commercial and experimental formulations has required accurate and rapid boron analysis of treated timber and leachates. Boron has two main transitions or emission lines at 249.773 and 249.678 nm, either or both of which can readily be used for quantification by ICP.

Copper-chrome-arsenic (CCA) treated timber samples can be conveniently analyzed by ICP spectroscopy of appropriate digests. Work has also been carried out on CCA content of barnacles growing on treated timber (1). Emission lines typically used for CCA analysis are 283.563 nm for chromium, 324.754 or 224.700 nm for copper and 193.696 nm for arsenic. The use of the most intense arsenic line at 188.979 nm should be avoided because of interference.

Analysis of a range of metals in wood, pulp and ash samples has been carried out. Iron, manganese, copper, chromium, calcium and magnesium have been widely requested. The first four metals of this group are important because of their discolouration potential in paper. For these four (Fe, Mn, Cu and Cr), the most intense lines can normally be used for quantification without saturation of the detector. The sequential measurement of calcium or magnesium in the same solution as the other four metals usually necessitates the use of a minor calcium or magnesium line. Alternatively, the analytical solution is diluted to avoid saturation of the detector by some of the more intense calcium or magnesium lines, which may be preferred for greater accuracy.

A most useful application of ICP spectroscopy is in the determination of sulphur content. Like boron, sulphur is difficult to measure conveniently by any other procedure. The most intense line at 180.731 nm can be used, although this is close to the lower wavelength limit for ICP spectroscopy. Two groups of analytical studies carried out in the Forest Products Laboratory were related to sulphate impurities in wood cement composites and, by contrast, in reconstituted cellulose fibres.

References

(1) Cookson, L.J., D.K.Scown and K.J. Schmalzl. 1996. Pile surface coverage and copper,chromium and arsenic content of barnacles growing on experimental mooring piles. Proceedings of the 25th Forest Products Research Conference, CSIRO Division of Forestry and Forest Products, Clayton, Victoria, Australia.

Strength of Tanalith E, CCA and Creosote treated *Pinus radiata* posts

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Most posts used for grapevine trellising in Australia are CCA-treated *P. radiata* (radiata pine) because they are relatively cheap and dry to handle. However, the mean bending strength of CCA-treated radiata pine posts is about 30% less than that of creosote-treated (commercially available) radiata pine posts. Breakage of CCA-treated posts during mechanical harvesting of grapes is a common occurrence in Australian vineyards.

To test the suitability of Tanalith E as an alternative to CCA, a trial was conducted in conjunction with Agriculture Victoria. The purpose of this trial was to compare the relative strengths of CCA and creosote treated radiata pine posts (from a separate trial) with Tanalith E treated radiata pine posts.

The mean strength of Tanalith E treated posts (57 MPa) and water treated control posts (55 MPa) was significantly higher (at the 5% level) than the mean strength of CCA treated posts (47 MPa). The mean strength of the Tanalith E treated posts and the water treated posts was significantly lower (at the 5% level) than the mean strength of the creosote treated posts (68 MPa).

Results of this trial indicate superior strength of posts treated with Tanalith E compared with the currently used standard CCA-treated posts. This indicates the potential use of Tanalith E as an alternative wood preservative for radiata pine posts for grapevine trellising.

Vineyard trellis posts from treated eucalypts

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Introduction

There are over 100,000 hectares of vineyards in Australia with approximately 10,000 hectares of new plantations installed each year. Typically, a vineyard will utilise 500-800 posts per hectare installed in-line as trellising. A significant number of these posts (as high as 15%) require annual replacement due to breakage by mechanical harvesters and fungal decay. Therefore, the annual demand for posts is in excess of 10 million.

In recent years, the conventional CCA and high temperature creosote (HTC) treated *Pinus radiata* post for grapevine trellising has been in short supply. Suitable new pine posts are available as a by-product from the smaller diameter trees when plantations are thinned or clear-felled. Consequently, their availability is governed by other timber demands. Post manufacturers forecast that this shortage will continue for the foreseeable future. Subsequently, vine growers and manufacturers have been forced to look for alternatives.

A number of eucalypt woodlots in the Mallee region and other areas of Victoria and New South Wales have been established to utilise industrial wastewater, treated sewage effluent or irrigation drainage water. These woodlots are grown for the safe disposal of wastewater, which would otherwise cause environmental degradation and water pollution. They have often been planted in wine growing regions, and as the wine industry continues to grow they could be used to supply posts to the local industry for use in grapevine trellises.

To test the suitability of eucalypt species as trellis posts, a number of trees from each species of *Eucalyptus grandis*, *E. globulus* and *E. camaldulensis*, fitting the diameter range for in-line posts, were harvested.

Manufacture of eucalypt posts

Trees were selected from seven year old *E. camaldulensis* woodlots in the Sunraysia\Riverland region of northwest Victoria (Mildura), five year old *E. globulus* woodlot in northern Victoria (Shepparton) and a three year old *E. grandis* woodlot in the Murray Riverina region of southern New South Wales (Deniliquin).

Selected trees were felled using a chainsaw and then docked to the required post length. The posts were then debarked by hand after bruising with the back of an axe.

The posts were removed from the woodlots as soon as possible after debarking and stacked in piles under cover to air-dry slowly. The stacks were covered with hessian to further slow drying. Young fast grown eucalypts need to be treated with preservative before they are suitable for in-ground application and drying of posts is required to facilitate preservative penetration. In addition, slow drying minimises splitting and checking prior to preservative treatment.

Preservative treatment

After three months air drying, the posts were transported to Koppers Timber Preservation Pty Ltd, Grafton, NSW and impregnated with pigment emulsified creosote (PEC). PEC is a highly stable emulsion of high temperature creosote and is capable of withstanding much of the stressing a preservative undergoes during its use for vacuum pressure impregnation of timber. It contains creosote, water, emulsifiers, stabilisers and a micronised pigment. The pigment, which is dispersed through both the oil and water phases of the emulsion, locks the creosote component into the wood structure. PEC-treated timbers usually exhibit dry, oil-free surfaces, making them more acceptable from a health and safety point-of-view (1). This treatment would be desirable in vineyard trellis where the mechanical arms of harvesting equipment can become contaminated by exudates on the posts.

After preservative treatment the posts were air dried for three months and then transported to Mildura. A sample of posts from each species were strength tested at Sunraysia Horticultural Centre and the remainder used to construct grapevine trellises at Lindeman's Winery, Karadoc, Mildura.

Strength testing and evaluation of surface defects

A portable test rig was used with a fixed post clamping facility to measure the strength of individual PEC-treated posts and then compare with the strength of CCA and HTC-treated pine posts (tested in a separate trial). The mean bending strength of *E. globulus* was significantly (at 5% level) higher than that for the CCA and HTC-treated pine posts and the two other eucalypt species (2). All eucalypt species tested were much stronger than CCA-treated pine posts.

Assessment of surface defects showed that no eucalypt post was rejected because of unacceptable knots, however 10% of *E. camaldulensis* and 7% of *E. globulus* posts were rejected due to unacceptable splits. Posts made of *E. grandis* were uniform with no rejections arising from splitting. Considering its age (only 3 years compared with a minimum of 5 years for others), quality and strength, *E. grandis* seems to be the most suitable eucalypt species for vineyard trellis posts amongst species tested.

References

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2. Mollah, M. R., K. J. McCarthy, D. K. Scown and L. J. Cookson 2000. Bending strength of vineyard trellis posts from treated eucalypts. Proceedings of Conference on Engineering in Agriculture. 2-5 April 2000, Adelaide, South Australia.

Termite hazard mapping

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Introduction
An important part of determining the durability of timber is to understand the hazard it will face in service. Before the Forest and Wood Product Research and Development Corporation funded project 'Design for Durability', there was no uniform measure of termite hazard across the country. Some localised termite surveys had been conducted. For example, termite incidence in Melbourne (1), Perth (2), and Sydney (3). Also, maps of each termite species were available (4), and while these provide guidance they indicate termite species distribution rather than hazard or termite pressure. The aim of this contribution was to determine the hazard faced by buildings in Australia to wood-feeding termites, as influenced by location and house construction type.

Methods
A 'Termite Tally' survey was conducted through CSIRO's Double Helix science club, producing data for 4194 buildings, from 248 students. Data for a further 145 houses were obtained by a CSIRO phone survey, targeting areas under-represented in the Double Helix data. An additional survey was conducted through an email survey to 'CSIRO All', resulting in 783 responses. Therefore, the total data set was 5122. A verification study of the Termite Tally survey was also undertaken to obtain an indication of the reliability of the data collected.

Results
The mean house age was 30 years, and the mean occupancy duration was 11 years. Lowest mean house age occurred in Darwin (result of Cyclone Tracey). Timber was the most common framing material in Victoria, Tasmania, Queensland, NSW and the ACT. Masonry framing materials predominate in WA, SA and NT. Steel alone accounted for only 5% of house framing, with the highest proportion in the NT. Timber is the most common flooring material in Tasmania, Victoria, NSW and the ACT. Concrete floors are most common in the NT, Queensland, SA and WA. Mixtures of floor type (timber and concrete) are more common than mixtures of frame type. The dominant factor affecting termite incidence inside houses was house age. The occurrence of termites inside a house was not significantly affected by house construction type (timber, masonry, concrete, steel or their combinations) (see Table). Termite eradication was most successful by soil or wood treatment. Least success was obtained by ignoring the problem, followed by simply disturbing the affected area. Termites inside houses were most often found in walls, flooring, house stumps, architrave and skirting boards, joists, bearers and window frames. Termites were less common in roofing timbers. Termites outside were most often found in wood piles/branches, live and dead trees, fencing, sleepers, dead tree stumps, and the garden shed. Termite presence was most often noticed by the damage caused to timber, followed by mud tube construction. A verification survey of Double Helix students showed that more than 95% of houses were targeted at random in relation to their construction type and termite history. The

ability to distinguish termite activity was also high, although obviously less than for trained specialists. Of 109 'termite' samples sent to CSIRO for identification, 106 were in fact termites. The relative information gathered was used to develop a termite hazard map. An agro-ecological map provided by The Agriculture Working Group on Ecologically Sustainable Development was used as the framework upon which the termite incidence data was applied. Maps illustrating termite incidence inside and outside were produced. From these maps was constructed a tentative termite hazard map for Australia. The hazard map suggests that the most important factor determining termite distribution is temperature, followed secondly by rainfall. Vegetation and soil type appear to play a more minor role within the dominant effects of temperature and moisture.

Table 1. Risk of Termites to House According to Frame Type

Frame type	**Sample size**	**% sample**	**Average age of house (years)**	**% termite inside**	**% termites inside adjusted to 30 y house**
Timber	3445	69.2	29.4	17	17*
Masonry	1071	21.5	34.6	18	16*
Steel	249	5.0	12.1	10	17*
Steel + masonry	7	0.1	27.7	0	Not detn
Timber + masonry	177	3.6	33.6	22	21*
Timber + steel	26	0.5	31.4	32	Not detn
Timber + steel + masonry	5	0.1	70.0	40	Not detn

*Not significantly different. Not detn = not determined due to low sample number.

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Acknowledgements

We would like to thank Dr John French for the concept and initiation of the Termite Tally Survey, Rebecca Scott for coordinating the survey through CSIRO's Double Helix Science Club, Berhan Ahmed for helping with the verification survey and data entry, and Arn Tolsma for further data entry.

Low-cycle fatigue of spruce loaded in compression parallel to grain

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Introduction

Structural wood systems fail during extreme events, such as hurricanes and earthquakes, which cause high-stress-level cyclic loads in members. Although an event may not last long, damage accumulation is a time-dependent process. The process is termed low-cycle fatigue (LCF). Microstructural change (damage) in softwood due to compression parallel-to-grain commences with formation of 'kinks' in the tracheid walls. This results from the reorientation of microfibrils in the S2 layer. This paper discusses the failure mechanism of spruce under cyclic compressive stress parallel-to-grain, and compares it with failure under static or pure creep stress.

Method

Failure mechanisms of small clear specimens (6 by 6 by 24 mm) of air-dry black spruce (*Picea mariana*) were investigated. There were 19 groups of density matched specimens, with five replicates per group. Seven groups of specimens were subjected to monotonic (static) loading at a cross-head movement of 0.1mm per minute. These specimens were used to elucidate the extent of damage at various points along the static stress-strain relationship. Four other groups of specimens were used to determine lifetime with square waveform cyclic loading having a peak stress of 90 percent of the static strength. The loading frequency was 0.5 Hz., duty ratios were 0.05, 0.5, 0.95 and 1.0 (pure creep), and the stress-ratio 9.0. Another four groups were used for pure creep tests where loading was halted after elapsed times of 10, 20, 80 or 320 seconds. The last four groups of specimens were used for cyclic load tests in which loading was halted after 5, 10, 40 or 160 cycles. Each specimen in the above tests had an end matched twin that was used estimate load corresponding to the target stress level. All specimens were examined after testing by 'dark-field incident light' microscopy. Specimens for which loading was halted were microtomed to produce R-L sections for 'polarised-light' microscopy. This permitted observation of damage and any change in shapes of cells.

Results

Deformation of creep specimens is larger than that of fatigue specimens, but relative creep is lower than the relative cyclic creep. Table 1 shows how the duty ratio influences the life of fatigue specimens. A previously established damage index for wood loaded in flexure was fitted to the data: $D = (T/Tcr)^{1.0} + (N/Nfat)^{0.02}$, Table 1. The index fits the data quite well ($D = 1.0$ for all duty ratios would be a perfect fit). There was no characteristic difference in macroscopic fractured appearance in the failed specimens subjected to static, creep and fatigue loads. Table 2 shows the relationship between time under load, or number of load cycles, and the number of kinks in tracheid walls (average: 3 sections x 3 specimens). Kinks tend to form in walls of latewood tracheid, while walls of earlywood tracheids tend to buckle. The kinks are more uniformly distributed in creep than other specimens. This is assumed to be due to greater time-dependent redistribution of stress. Damage accumulation in creep tests is predominantly the growth of a limited number of kinks formed during the initial loading period. By contrast, damage accumulation under cyclic load, after the first load cycle, is due to growth of existing kinks and formation of new ones. These observations help explain why the lifetime of a fatigue specimen is much shorter than that of a creep specimen. Accumulated deformations in either fatigue and creep tests is the result of kinks.

Conclusions

- The nature of compressive failure in softwood can be attributed to presence of kinks in latewood tracheid walls, regardless of whether the load is static, creep or fatigue.
- Damage accumulation due to static, creep and fatigue differs. Damage loci in creep specimens are mainly kinks formed during the initial loading. For fatigue specimens, new kinks are initiated during load cycling. New kinks are created continuously as the stress is increased during static loading.
- The number of kinks is a good damage indicator.
- Damage indices/models based on high-stress-level creep rupture tests with constant loading should not used to predict LCF.

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Table 1. Loading time and number of load cycles to failure

Duty Ratio	**Lifetime (sec)**	**T (sec)**	**N (cycle)**	$(T/T_{cr})^{1.0}$	$(N/N_{fat})^{0.02}$	**D**
1.00	33151	33151	0	1	0	1
0.95	1339	1272	670	0.03838	0.96422	1.00260
0.50	7055	3528	3528	0.10641	0.99680	1.10321
0.05	8281	414	4140	0.01249	1	1.01249

Note: Lifetime means the time to failure; T the total loading time to failure; N the total number of load cycles to failure; T_{cr} the pure creep lifetime; N_{fat} the pure fatigue lifetime; D the fitted damage index.

Table 2. Number of kinks at various stages of fatigue and creep tests

Test Type	**Number of Load Cycles / Duration (seconds)**			
	5 / 10	**10 / 20**	**40 / 80**	**160 / 320**
Fatigue	6	48	82	108
Creep	32	24	40	42

Factors controlling the moisture content of timber in the building envelope of houses in a number of climatic zones

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Introduction

As part of the FWPRDC sponsored product "Reliability based design method for durable timber structures", an extensive research program to develop a methodology of predicting the moisture content of timber in the building envelope of houses around Australia. As part of this program measurements of moisture content were made in houses in Tropical, Sub-tropical, Temperate and Alpine climatic zones. Two types of measurements were made, weight change of test samples and continuous electronic measurement of in-situ specimens. Weight change gives an accurate determination of changes in moisture content (MC) while the electronic measurements permit the cycles in moisture content to be determined. Samples were exposed on the façade and in the wall cavities and sub-floors of houses while electronic measurements were taken in the sub-floors. In addition microclimatic parameters (RH and temperature) were measured in the building envelope. The results permit an assessment of the factors controlling moisture content in the building envelope and the nature of cycles in moisture content. The results are compared with a computer programme developed to predict moisture content.

Experimental

Around twenty houses in Tropical, Sub-Tropical and Temperate zones at distances of 0 to 300km from the coast along the eastern seaboard of Australia, were monitored. Houses were monitored in Innisfail in far north Queensland, Brisbane, Sydney, Narrandera in central NSW, Mt Buller in the alpine area of Victoria and Melbourne.

Climatic and micro-climatic data was collected by datataking equipment at either 30 minute or 1 hour intervals over two years. Relative humidity, temperature was measured at the exterior of the house, in the sub-floor and in the wall cavities.

Sample timber boards of approximately 35x20x200mm were also located at the monitoring locations. These boards consisted of a number of species of timber including Radiata Pine, Mountain Ash, Douglas Fir, Spotted Gum and Treated Pine. The boards were weighed seasonally and dried at the end of the study to determine the moisture content through the study

Some pine sample boards (approximately 40x40x200mm) were instrumented with an internal relative humidity and temperature sensor and with a moisture sensor. Moisture sensors were also placed in some houses in the joists, beams, flooring and weatherboards.

Discussion

Previous work has derived a relationship between the Near Surface Moisture Content (NSMC) and the moisture content (MC) for a particular timber. The NSMC can be derived from temperature and relative humidity values. From the data derived from the climate and microclimate monitoring the estimated MC can be adjusted using micro-environmentally based factors to provide a prediction of the estimated MC in different positions in the building envelope. These factors include *solar radiation* for external positions, *climate* for the climatic zone the house is situated in and *micro-climate* for the particular building space.

From this modelling the moisture content in timber in various positions of a building have been generated. By using data from Meteorological weather stations, maps of the MC in particular positions of a building have been generated for the whole of Australia.

Instrumented timber samples were installed in some of the positions in some of the houses. The information gained from these samples was use to validate the use of the temperature and relative humidity in the MC models. By measuring the temperature and relative humidity inside a piece of wood the relationship between surface moisture and internal moisture could be seen.

The data from these boards showed that after the initial uptake of moisture the timber MC followed the fluctuations in microclimate in the immediate area. The amount of damping of the fluctuations due to the wood was also apparent. The values calculated for the internal calculated MC of the wood sample from the sensors shows the similar, although dampened, values as calculated from the sensors in the surrounding air. These values are also consistent with the MC values obtained from the weighed wood samples.

Conclusions

We have shown it is possible to produce models that can calculate the MC of timber in different parts of a building and apply this to Met data to produce Australia wide maps of building timber moisture content.

System effects and load-sharing in an L-shaped light-frame timber house

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This paper presents the details and results of pseudo-elastic lateral testing of a full-scale one-story L-shaped house. The nature and extent of tests are designed to generate data needed to develop and validate a whole building structural model of a light-frame structure. This particular test house is unique in that it is fully supported at its base by load cells, which measure loads in three principal directions. Under an applied load, we are able to see for the first time how the loads are distributed and shared through the walls. Results to date show that even at very low levels of loading (i.e. displacement within ±1.0mm or load of about ±10.0 kN), there is significant load sharing in the system. Both roof system and transverse end walls participate in distributing the loads. In the next phase of testing, the house will be tested to destruction.

Product design and development of the Hyne-I-beam

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Background

In 1996 Hyne and Son recognised a market potential for structural wood I-beams to complement its existing range of timber products available at that time. Investigations targeted upon implementation of a south-east Queensland I-beam manufacturing process. At that time one other local I-beam manufacturer was established in the Australian market. This was later to be complemented by at least three suppliers of imported products.

A decision to proceed with local manufacture of Hyne-I-Beam was taken in 1998 and work started in earnest on the associated product development. Hyne subsequently entered a license agreement with Canadian based Nascor Incorporated for purchase of manufacturing plant and technology. With a decision to proceed with product development and implementation, it was felt necessary to target products of superior structural performance to comparable products already established in the market.

Objectives

- Project objectives included:
- Analysis of structural performance of existing competitors' products in the market place
- Conceptual design and development of a structurally superior I-beam product
- Trial manufacture and testing of the proposed range of products
- Derivation of a suite of design properties for use in accordance with Australian timber design and application standards
- Recommendations for manufacture

Product design

Preliminary I-beam product design was carried out to determine an efficient timber flange material for use with oriented strand-board (OSB) used in the Nascor products in North America. Structural design and approximate span calculations led to the selection of finger-jointed 70x35 and 90x35 MGP15 slash pine flange material. It was expected the resulting product would exceed the performance (spanability) of equivalent depth I-beams already established in the market. A model based on a structural mechanics theory was used to predict a range of structural properties of the Hyne-I-Beam.

The proposed Nascor I-beam manufacturing plant utilised tapered web-flange connections requiring webs with profiled edge joints and "V" end joints. It was arranged to purchase pre-profiled OSB webs from Nascor as a cost effective means of manufacture at that time. Exterior rated adhesives were used for joining of all components.

Manufacture and testing

Comprehensive evaluation of the tension strength of MGP12 and MGP15 finger jointed flanges was carried out to ensure published tension strength values (1) could be achieved. Results are reported by Bolden (1998) (2) in a confidential Hyne and Son internal report. Some adjustments were made to visual grading overrides and manufacture procedures to ensure target tension strength was achieved. Manufacturing recommendations included implementation of in-line indicative proof testing of all flange stock to a one-percentile load level.

A trial consignment of flange stock was finger-jointed at the Hyne Glulam Plant in Maryborough, proof tested, and dispatched to Calgary, Canada for manufacture of I-beams and subsequent testing.

Pre-manufacture testing was carried out in accordance with ASTM D5055-1997 (3), which is generally in accordance with AS/NZS 4063-1992 (4), subject to independent inspection by Intertek Testing Services and observation by Hyne staff in Nascor's Quality Control Laboratory in Calgary. The tests carried out, with sample sizes for each beam type indicated in parentheses, were as follows:

bending rigidity EI_x (30), bending moment capacity M_k (30), shear capacity V_k (10), end bearing capacity N_{pe} - 30 mm bearing with no web stiffener (5), intermediate bearing capacities N_{pi} - 45 mm bearing, with and without web stiffeners - 65 mm bearing with no stiffener (5), compression/blocking capacity (5), shear capacity with web hole – various size combinations of round and rectangular web holes (5), mass (5), and creep performance (2). In total, 880 individual tests were carried out in Canada to determine Hyne-I-Beam structural properties. A further 400 individual tests were carried out by Hyne at the Virginia site after start up of the new Hyne manufacturing plant initial qualification.

Results

All test data was analysed and compared with predicted design values, or empirical fitted values to enable selection of the set of published design values presented in Table 1.

Joist Type	Joist Depth d	Joist Width b	Joist Mass m	Resistive Moment M_x	Bending Rigidity		Vertical Shear Vx	Torsional Rigidity GJ	Shear Rigidity G_wA_w	End Bearing N_{pe}	Intermediate Bearing Capacity N_{pi}		
					EI_x	EI_y				30mm	45 mm		65 mm
					$x10^9$	$x10^9$		$x10^9$	$x10^6$		no stiff	with stiff	no stiff
	mm	mm	kg/m	kN.m	$N.mm^2$	$N.mm^2$	kN	$N.mm^2$	N	kN	kN	kN	kN
HI 200 68	200	68	4.0	7.1	489	27.1	7.4	1.80	1.25	12.5	28.2	28.2	33.2
HI 245 68	245	68	4.3	9.3	792	27.1	9.4	1.80	1.68	12.5	28.2	31.8	33.2
HI 300 68	300	68	4.7	12.0	1270	27.1	11.9	1.80	2.20	12.5	28.2	36.1	33.2
HI 360 68	360	68	5.1	14.9	1920	27.2	14.8	1.80	2.77	12.5	28.2	40.9	33.2
HI 200 88	200	88	4.9	9.2	634	58.7	7.3	2.33	1.25	12.5	28.2	28.2	33.2
HI 245 88	245	88	5.2	12.1	1020	58.7	9.3	2.33	1.68	12.5	28.2	31.8	33.2
HI 300 88	300	88	5.6	15.6	1640	58.8	11.8	2.33	2.20	12.5	28.2	36.1	33.2
HI 360 88	360	88	6.0	19.5	2470	58.8	14.5	2.33	2.77	12.5	28.2	40.9	33.2

Table 1: Hyne I-Beam Australian Limit States Design Data - For use with AS1720.1 1997

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Use of wood from *Eucalyptus globulus* and *E. nitens* plantations for the furniture industry

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This project is a cooperative endeavor of the Universidad del Bío-Bío and Fundacion Chile, with Chilean (U. de Talca, U. de Chile, U. Austral) and foreign universities (U. of Stellenbosch), and the cooperation of the related industry (Forestal y Agricola Monteaguila S.A., Masisa, Pampa Union and Madel.

The objective is to research and develop methods to utilize wood of *Eucalyptus globulus* and *E. nitens*, in the production of sawn lumber, for its use in the remanufacturing industry (furniture, mouldings, others).

Chile has more than 350.000 ha of Eucalyptus plantations. *Eucalyptus globulus* is the most important species, (56%), followed by *Eucalyptus nitens* (40%). The main use of *Eucalyptus* plantations was to supply pit props, poles, transmission poles, fence posts, and firewood. Forest management used was short rotations and stump regrowth regeneration. A small proportion of *Eucalyptus* plantation was managed as even age stands and with long rotation, for saw logs and peeler logs production. At the end of the '80s, an export market for pulp chips and pulpwood developed, together with a domestic demand for short fiber. Thus, *Eucalyptus* plantation management was oriented towards pulpwood production, in short rotations (10 to 14 years).

The wood remanufacturing industry, specially furniture, has experienced a rapid growth, due mostly to the increase in exports and domestic demand, reaching sales volume of more than US$300 millions per year. *Eucalyptus* lumber is highly regarded by the furniture manufacturers, due to its good mechanical properties, workability and finishing properties.

Eucalyptus growers that manage their plantations for the production of pulp wood in short rotations, must be certain that all their production of saw logs and peeler logs, are usable by the industry, in order to manage their plantations towards a maximum return.

The main objective of this study, is to adapt existing technologies, so as to process *Eucalyptus* logs to produce kiln-dry sawn lumber, free of defects and of similar technological characteristics as lumber from adult trees.

Lumber from young trees (10-14 years old) presents different characteristics compared to lumber from adult trees. It tends to warps during use, changes colour, and develops severe drying defects. For high recovery factors, the sawmilling industry is interested in the production of flat sawn lumber, against quarter-sawn lumber, which is commonly produced.

Therefor, problems related to growth stress, collapse, and checks during the drying process should be considered. According to literature, *Eucalyptus nitens* is more susceptible to checking than other species during drying.

The above-mentioned problems, that do not permit the use of juvenile lumber, are not entirely solved. Important advances have been made in South Africa, Brazil, Australia and Holland. It is important to note that these advances are not entirely applicable to Chile, because the species and age classes are different.

The expected result of the project can be stated as an improvement in the economic results of growing eucalyptus; a reliable procurement of a valuable hardwood for the remanufacturing industry; incentives in growing and managing *Eucalyptus* plantations and an alternative land use.

The resulting knowledge of technological processes, its transfer towards forest growers, sawmills, remanufacture mills, and university professionals, represents an important impact, specially to the forest growers, and the medium size entrepreneur, which will be able to have access to a technology, in general now only accessible to large companies.

Current activities of the project include working on developing radial and tangential sawing techniques, for diminishing growth stresses, as well as investigating drying schedules in Chile and Australia. Physical and mechanical properties, varnishing, and adhesive junction from these solid products have been evaluated as well.

Research is being performed with Mr. Richard Northway at the Forest Product Laboratory (CSIRO), studying different drying schedules and conditioning of timber during drying. This research will generate more knowledge about the drying process of the *Eucalyptus nitens* and *Eucalyptus globulus* species.

The results obtained from drying process developed in the CSIRO laboratory, will be compared with results obtained in Chilean laboratories for the same species in the study.

For *Eucalyptus nitens of* eleven years old, diameter (DBH) of 43cm, we found that tangential cut samples gave 80% less spring compared to radial cuts. Differently, defects of bow and twist are less than tangential, 45% and 80% respectively. Also, it is been observed that spring in radial cuts increased from bark to the pith and bow has been diminished. In tangential cuts all wood defects diminished from the bark to the pith.

Favorable results have been obtained from preliminaries drying tests. Three thicknesses of wood have been tested (30mm, 16mm, and 8mm) and soft drying conditions (20 and 25°C). The 30mm dried boards have presented little checks; all 16 and 8mm boards have not presented checks. However, all tested boards, regardless of the temperature used, presented some collapse defect.

The 30mm boards from *Eucalyptus nitens* were dried, starting at 30°C, to 13% MC, from green wood at 140% MC, in 30 days. All boards were reconditioned. At the end of the process, from 60 samples, 19 presented internal checks, 3 boards presented surface checks, and 40 presented some degree of collapse.

Thank you to Richard Northway and Lincoln Teixeira for help me in redaction of this abstract.

Strength assessment of timber utility poles in Australia

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Preliminary investigations focusing on the development of assessment management systems for the power distribution industry have shown that the design and assessment methods that form current industry practices in Australia are imprecise and often unreliable. It was within this context that an FWPRDC sponsored project was developed for assessing the strength of new poles and remaining strength of in-service poles. Together the projects involve full scale destructive testing of some 2000 timber poles, both new and ex-service.

It is estimated that there are 5 million timber utility poles in Australia – with a current net worth of $10 billion. In South East Queensland alone, there are currently 500 000 poles in service (1). The cost per annum of maintenance to this asset (for this one electricity supply association) is $4 million. The annual cost of maintenance of timber poles across the three eastern states of Australia is $26 million. In addition to this cost, are the costs associated with risk obligations against failure, and lost income from disrupted supplies.

Optimisation of design criteria using a reliability-based philosophy, and an improved knowledge of the residual strength of poles, could potentially increase the level of reliability whilst reducing new pole costs. Significant potential savings in asset maintenance are also possible by refinement of inspection methods and development of more accurate techniques for assessing performance of in-service poles.

The project uses in-grade testing techniques and has three main areas of focus:

- The in-grade test results will establish characteristic design properties for new poles – both current supply and future resource plantation and regrowth material, through the use of full scale destructive testing.
- The same testing technique is used to establish the remaining strength in poles that have been removed from service. A separate project managed by EANSW (2) and undertaken by the University of Technology, Sydney will use remaining strength data from a further 350 poles to quantify degradation techniques and to assess commercial non destructive testing devices.
- Careful observation of the characteristics of the poles and correlations with performance will enable better grading processes to be developed. Design rules that truly reflect pole performance can also be derived from the test results.

For the utility pole producers, the improvement in design and grading criteria will allow greater flexibility in supply and would enable timber poles to compete more successfully with other manufactured pole products, such as those from concrete and steel. For example, if inefficient design of timber poles led to a loss of market of 2 percent per annum, this would equate to a $0.52 million per annum loss in market share.

The benefits of using reliability based design procedures for the pole supply industry, are based on the fact that many poles which fail to meet current specifications, can in fact be used quite satisfactorily. This benefit is only possible when the design is based on quantified performance criteria rather than the somewhat arbitrary assumptions of tip load capacity. This is because the characteristic strengths obtained from full sized 'in-grade' testing gives a much more accurate indication of pole performance than present strength assignment methods.

Both the electricity supply industry and the power pole supply industry will benefit from the improved knowledge of "life cycle" data for poles which will be generated from these projects.

The potential economic and risk management benefits from these linked projects accrue in two ways: - (1) simply by reducing the number of poles being replaced which are still capable of performing in service and (2), identifying more accurately those poles which constitute a risk to both system reliability and human life.

This would in turn see a continuing shift from "reactive" maintenance of poles, to "preventative" maintenance as a part of an asset management system. This improvement in the management of the pole asset will benefit electricity boards on a national level, with potential to reduce the cost of inspection and maintenance, and increase the level of system reliability. This could in turn benefit the pole supply industry, as the "life cycle" costs for timber poles are reduced, improving their cost competitiveness with other pole products.

Simple models for cost benefit analysis used by Electricity Authorities suggest that a ten percent improvement in assessment and structural analysis of poles, would equate to a \$2.5 - \$3 million per annual saving in the cost of maintenance.

On the basis of data collected and analysed to date, the following trends have been observed:

- There is a general deterioration of poles with time in service. This reduces the bending capacity and appears to reduce the fibre strength of the poles.
- For higher strength poles, there seems to be a fairly rapid reduction in strength at ground-line near the commencement of service. This may be associated with installation of the pole or other hardware, or may be a step reduction in strength after ground contact.
- For lower strength poles (near the 5%ile) the deterioration cannot be attributed to age of service alone. Correlation with the extent of degradation (loss of section), growth and service characteristics will enable the trends to be fully investigated.

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Mode I fracture behaviour of softwood

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Background

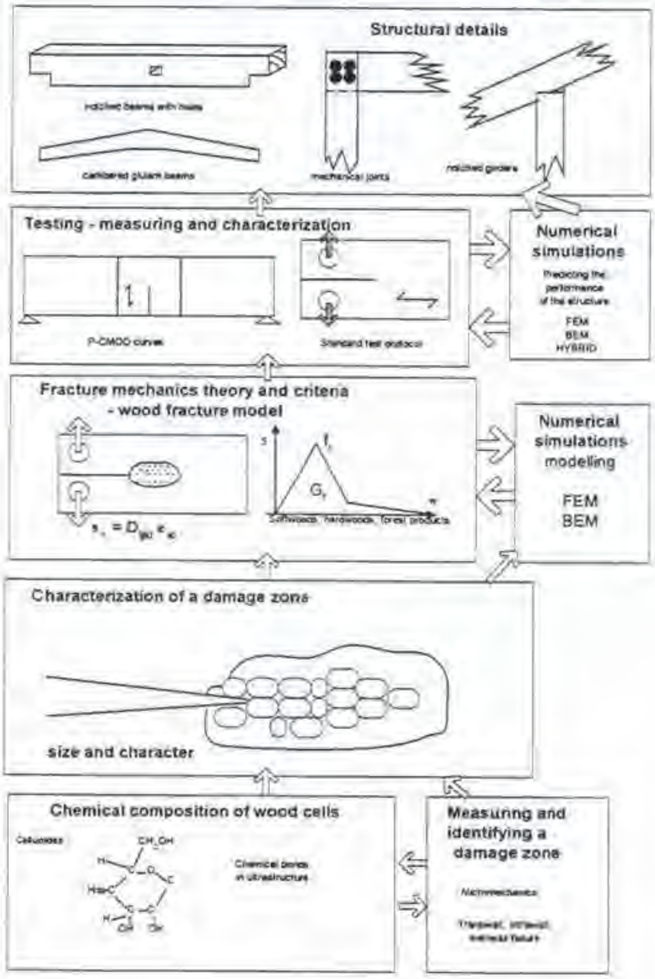
From an engineering design point of view wood is regarded as a brittle material, and structural members and connections often exhibit brittle failure. Whether or not wood actually is brittle depends upon a number of parameters, including the direction that stress is applied relative to the grown ring structure, the duration of loading and the moisture content of the wood. Because it is not an isotropic material, failures tend to occur preferentially in some planes. Interest centres on cracks induced by tension perpendicular to grain (Mode I fracture), cracks induced by shear parallel to the grain (Mode II fracture) and combinations of the two primary modes. The 'science' of fracture mechanics has been applied to wood since the early 1960's. To date, the approach has been to either assume the behaviour is perfectly brittle-elastic (Linear Elastic Fracture Mechanics_LEFM), or to assume material ahead of a crack-tip behaves in a non-linear inelastic manner. Non-linear models applied presume that wood's behaviour is the same as that of some other construction materials, notably concrete. Results are rather patchy regarding agreement between predicted and observed levels of load necessary to cause unstable crack growth (brittle failure) in wood members and connections. Attempts to verify applicability of modelling assumptions have been limited to what can be deduced via macroscopic observations as tests on structural components progress, and post mortem examination of fractured surfaces.

Recent studies

Work on failure of wood due to excessive stress or strain has been ongoing at the University of New Brunswick (UNB) for some time. Development and application of fracture concepts is an integral part of that effort. The diagram on the next page shows 'fracture mechanics levels' of wood characterisation. Understanding all levels is important if fracture mechanics is to become useful. Most work at UNB has been oriented towards opening mode (mode I) behaviour of softwood species with stress applied in the radial or tangential direction and crack growth in the longitudinal direction. Real-time observations have been of the fracture mechanism, and deformation in the vicinity of crack tips (1, 2). Small end-tapered 'double cantilever beam' specimens were loaded with the chamber of a Scanning Electron Microscope with direct measurement of the surface strain field in the vicinity of the crack tips during initiation and propagation. This led to the proposal of a new 'bridged crack' fracture model. The model mimics real behaviour and allows for bridging behind the crack tip. These represent restrain provided by partially delaminated cells. Ahead of the crack tip material behaviour is elastic. Bridging stresses have a non-linear dependence on crack opening displacement and fall to zero once the crack faces are sufficiently separated. The behaviour and model are completely different from what had been supposed to be right. Such precise modelling is only necessary in situations where crack tips are not remote from boundary conditions. Most important instances of this occur in mechanical connection systems. The new model has helped explain the so-called size effect on strength properties for lumber. Other work has characterised the fracture properties of wood and led to more appropriate routine test methods (3). In situations where crack tips are remote from boundaries, accurate modelling of crack tip behaviour is not important. Thus, simplified fracture-based design method can be employed for certain common problems. For example, a closed-form LEFM design equation was developed for predicting critical load levels for notched bending members (4). The method is incorporated in the Canadian wood design code.

Conclusion

Provided appropriate models are used, fracture mechanics is a valuable and reliable tool for engineering design in wood.



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Variation in the visual stress grading of slash pine

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Visual grading of wood products occurs at a number of points from the forest through to the end product. Traditionally, the visual grading process refers to human vision coupled with human data processing. This process is actually a combination of sub-processes each with some potential for variation, largely due the variation between human scanners and data processes. Managers of wood processing operations in general have some frustrations with the variations inherent in the visual grading process and are increasingly moving towards machine scanning systems which when coupled with modern data processing speeds can provide accuracy, consistency and speed improvements over traditional visual grading processes. The development of such automatic non-human grading systems in many cases attempts to emulate the traditional visual grading process. While the potential benefits of machine based grading systems are significant, they are currently at a relatively basic level. For instance in may cases traditional visual grading still needs to be carried out to grade wood features not specifically graded by a machine system, e.g. mechanical stress grading. An improved understanding of the visual grading process and the variables influencing its accuracy, consistency and speed can have a two fold benefit, firstly improvements in existing visual grading processes and secondly improved machine grading systems. While Australian Standards have attempted to unify the visual grading process for particular species and grades, the grading systems used in most wood operations are highly customized to the specific species, processing technology, human abilities and customer requirements. A model encompassing the variable associated with the visual grading process is presented.

Hyne and Son at their Tuan Softwood have a customized visual grading system in place. Maintaining an accurate and consistent system at commercial production speeds has necessitated the development of techniques for recording the grade decision of every grader and providing timely grading reports to assist in the maintenance and improvement of this system. An analysis of some of this data has given an insight into some of the variables influencing the quality of visual grading. These are reported in the presentation.

In conclusion,

1. An improved understanding of visual grading processes can lead to more accurate, reliable and faster visual grading.
2. Many variables which impact on the visual grading process are still not well understood and require further research.

The use of Glulam Cypress Durabeam in Victorian and overseas structural applications

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An outline of the research and development of value added laminated structural beams, from Australian white cypress (GL10 Cypress Durabeam), is presented. The beams are suitable for exterior and interior applications and meet high strength, appearance and durability requirements, including a high resistance to termites.

Durabeam is produced by Timber Engineered Structures (TES), a division of Laminated Timber Supplies, a wholly Australian owned company, operating from Bayswater Victoria.

Several examples of the use of Glulam Cypress Durabeam in both Victorian and overseas structural applications are described and analysed.

MDF Process Variables

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Introduction

A range of MDF process variables were investigated to determine their relative importance on panel properties. The variables studied included: blowline design (mainly resin injection position and blowline diameter); resin addition level; inlet drier temperature; furnish moisture content. Raw materials used for the study were a commercial E1 UF resin and spruce wood chips. The studies were undertaken on the pilot plant facility located at The BioComposites Centre. In addition, a computer based model was developed to analyse and predict flow conditions in the blowline.

Table 1: Summary of standard reference process variables used in MDF studies.

Refiner pressure	:	0.8 MPa
Resin solids level	:	57%
Resin addition level	:	12% (solids on oven dry mass of fibre)
Resin injection point		400mm from blowvalve
Wax (emulsion) solids level	:	60%
Wax addition level	:	0.8% (solids on oven dry mass of fibre)
Wax injection point	:	Refiner housing
Drier inlet temperature	:	150 - 160°C
Drier outlet temperature	:	77 – 82°C
Target fibre moisture content	:	10.0 – 11.0% (dry weight basis)
Hot-press platen temp.	:	180°C
Hot-press time	:	180 seconds (from start of press closure to opening)
Nominal panel area		100cm x 100cm
Target board thickness		12mm (after surface sanding)
Target board density	:	750 kg/m^3

Outline of Results

The major results of the study were:

Blowline modelling

- Temperature measurements made along the blowline showed excellent agreement with model predictions. It was demonstrated that the model could be used to predict steam flow and velocity, degree of turbulence, resin drop size, residence times and wall shear stresses.
- There was evidence that resin injection position influenced panel properties, and that this could be explained by model predictions.

Board Properties

- Furnish moisture content had a significant influence on panel properties.
- Panel properties were generally improved as resin addition levels increased.
- Inlet drier temperature had a significant effect, higher temperatures generally resulting in poorer panel properties.

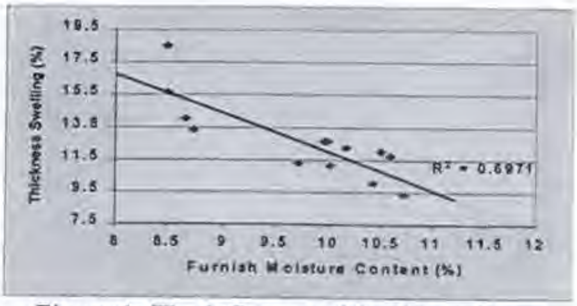

Figure 1: The influence of furnish moisture content on thickness swelling.

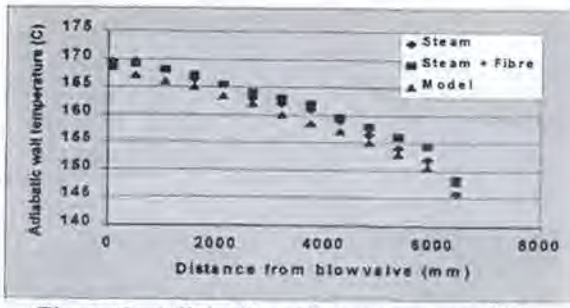

Figure 2: Adiabatic wall temperature of the blowline compared with model predictions.

It was concluded from the study that accurate control of furnish moisture content was likely to be of primary importance in maximising the efficiency of MDF mills.

Acknowledgement
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Will new advances in research lead to greater use of Phenolic Adhesives?

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Phenol-formaldehyde (PF) adhesives with over 50 years of full exposure history are still considered to be the most durable and lowest in-service formaldehyde emitting of all thermoset wood adhesives. Traditional PF adhesives as compared with the less durable and higher in-service formaldehyde emission adhesives such as urea-formaldehyde (UF) and melamine-urea-formaldehyde (MUF) are relatively slow curing. Composite board products such as medium density fibreboard (MDF) and particleboard (PB) bonded with PF adhesives whilst of high durability exhibit excessive thickness swelling in service due to the high alkalinity of the PF adhesive. Recent research results with newly developed PF's at CSIRO have shown that both improvements in curing speed and marked reductions in thickness swell of composite products are possible.

According to current Australian Standards fully structural composites such as plywood and laminated veneer lumber (LVL) are required to be bonded with PF adhesives. Over the last 10-15 years incremental advances in PF adhesive technology has resulted in an approximate halving of pressing time for 17mm structural plywood to 7-8 minutes and that of 63mm LVL being reduced from approximately 45-46 minutes to 42-43 minutes. Newly developed technology at CSIRO has shown that the pressing time of LVL can be reduced to approximately 35 minutes and that of 17mm plywood to 6 minutes or less.

Laboratory trials at identical resin loadings construction and density, which comprised a newly developed PF resin, a commercial PF and a MUF resin, were used for the production of 18mm particleboard. Whilst the new PF resin could not match the cure speed of the MUF it was at least 20% faster than the commercial PF. In comparison to the MUF resin the PF exhibited 40% less thickness swell, 5% greater Modulus of Rupture (MOR), 11% greater Modulus of Elasticity (MOE), 30% Surface Water Absorption (SWA) and identical Internal Bond (IB) strength. All of these results considerably exceed Australian Standards. The use of PF bonded composites "solves" the problem of in-service formaldehyde emissions, a vital factor for the continuing sale of composite panels to Japan. Further development in the near future is likely to result in even faster curing PF adhesives.

The role of vocational training institutes in forest products research

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With increasing pragmatism of both government and funding bodies regarding the application of research, a very strong symbiotic relationship can be developed between research organisations and vocational training institutes to ensure research outcomes are adapted and professionally delivered at an operational level to industry.

Communication and uptake of research results has been most successful when industry has an active role. This is demonstrated by the long-term successful interaction between CSIRO paper scientists and paper industry professionals. Over the last ten years the implementation of a formal training infrastructure for the sawmilling and furniture industries has at last provided a very successful interface between CSIRO researchers and industry through the Victorian Timber Industry Training Centre and the Timber Furniture Industry Training Centre.

Both centres have successfully collaborated with CSIRO Forestry and Forest Products in both FWPRDC and federal funded research and development projects, particularly in the development of processing practices and obtaining technical information on the end-use performance of high-value products from young, fast-grown trees. The two training centres provide state-of-the-art operational facilities which have been an invaluable addition to research facilities through to implementing outcomes in industry. The involvement of training staff in research projects has provided a closer industry link for researchers as well as the link to the industrial application of research results.

Microwave processing of *Pinus radiata* D. Don

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Microwave processing of green timber or round-wood can be used to increase the permeability of radiata pine by rupturing the soft radial tissue, thus providing penetration pathways for wood preservative. Wood prepared in this way can be successfully impregnated by the Bethell or Alternating Pressure Method processes. The provision of higher levels of microwave causes an expansion of the wood cross-section and the provision of micro-voids between ray tissue and tracheids. These micro-voids increase the permeability of wood very substantially and facilitate the rapid drying of radiata pine heartwood within a few minutes. The application of wood resins to the microwave modified wood followed by hot pressing results in the formation of a new solid wood material with superior wood quality attributes. These properties include increased strength, durability, dimensional stability and surface hardness.

Development of ultra high temperature drying of slash pine

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This abstract summarizes the development of improved drying systems for plantation grown Slash Pine (*Pinus elliotii*). The processing of plantation pine softwoods is largely a well understood science technology readily available from the northern hemisphere. For example, Hyne and Son's Tuan Softwood Sawmill utilizes European Technology in its Green Mill and North American technology in its Dry Mill. The one processing area not well developed internationally is the drying of plantation softwood. Off the shelf drying technology can be very expensive and does not always provide the drying quality required by pine users. In 1988 Hyne and Son was motivated to develop a drying system that provided improved product straightness and stability while also reducing capital and running costs. The objective to achieve these goals was to dry faster through higher kiln temperatures, improved handling systems and quicker heat delivery. The development strategy used was one of incremental improvement. Over six years investments in people, plant and research together with good management resulted in significant improvements to the drying system. Rigorous measurements of the process and the resulting products was critical throughout the development period and continues to be a key operational feature. The development process required a sustained management commitment and was underpinned by external and internal research. External research (CSIRO, QFRI and NZFRI) stimulated development ideas and provided some independent confirmation of the commercial improvements achieved. Internal research, primarily in the form of trials conducted by operational staff, proved to be the most effective way of moving forward. Hyne and Son is optimistic about the continued development of drying systems and believes the following areas should be pursued.

Increased drying temperatures – 300° C +
Improved handling systems
Improved sensors & control systems
Improved kilns construction
Continuous drying systems

This abstract and the associated presentation summarizes the application of commercially focussed research to the development of a cost effective quality focussed drying system. It also outlines ideas for ongoing research and development.

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An investigation into the theory of high temperature drying of boards

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Moisture profiles generated in some high temperature drying experiments using *Pinus radiata* showed a distinct plateau in the central region of the board which decreased in moisture content and in width as drying proceeded. The plateau appeared to decrease in width at a reducing rate so that at the end of the drying process a plateau, though of diminished width, is still present. It has been found possible to explain this occurrence from mass balance considerations and the result is a logarithmic profile for the position of the edge of the plateau.

Modelling of solar kilns for batch drying of timber

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The Australian timber industry is showing an increasing interest in the use of solar kilns to accelerate the pre-drying stages for hardwoods, followed by the use of conventional kilns for final drying. Research studies around the world have claimed that the advantages of solar kilns are shorter drying time, better product quality and low operating costs compared to open-air drying. The major disadvantages are that the solar kilns depend on weather conditions, thus resulting in less controllability and predictability than conventional kilns. There is also little understanding of optimum designs for different climatic conditions and geographical locations and there are no common standards for comparison between various designs.

The aim of this study is to model the performance of solar kilns to make this behavior more predictable. The model is based on a combined model including stack-wide and stress-strain behavior. This study also aims to set common standards for comparing kiln designs. An existing solar kiln model has been revised. Some preliminary results on mechanical properties of timber for stress-strain modelling have been obtained. Solar radiation, wind speed, ambient temperature and humidity, kiln temperature and humidity and wood moisture content are being recorded on site (Boral Timber's solar kiln at Heron's Creek, NSW) using sensors and an electronic data acquisition and logging system to compare experimental results with the simulated performance. Future research will be carried out to develop and validate a solar kiln model for suggesting an optimum design involving minor modifications of existing designs and a better operating procedure.

Relationship between wood and board properties in *Pinus radiata* logs: application to stand management

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Objective

To determine the relationship between timber strength in sawn boards and wood properties measured in standing trees, grown in different environments and management regimes.

Experimental detail

Increment cores from trees at two sites were obtained prior to log harvest. A total of 48 logs were sampled per site from control and NP fertiliser treatments, thinned and fertilised in mid-rotation. Wood produced before and after treatment was marked prior to sawing, as was the axis of the stem from which the core was taken. Strength properties (modulus of elasticity (MOE) and modulus of rupture (MOR) were obtained for every board close to the post treatment position (Figure 1). Wood properties (density, radial and tangential fibre diameter, wall thickness and coarseness) were extracted from the radius to match the board.

Wood properties were averaged over the 5 post-treatment years and relationships with board strength properties determined. MOE was measured approx. 300 mm above the point where wood properties were determined.

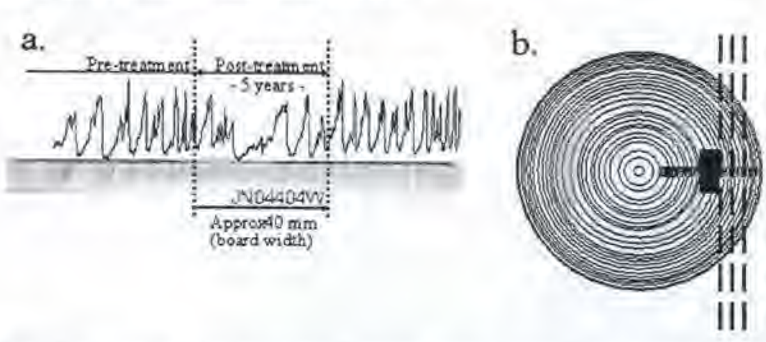

Figure 1: (a) The position of the post-treatment wood property data relative to the whole radius. (b) The approximate board position as affected by sawing. Vertical lines indicate the effect initial saw cut can have on board position and the difficulty obtaining an exact match with wood property data.

Results and Discussion

Research at CSIRO Forestry and Forest Products has focussed on defining relationships between tree growth, wood and end-product properties. The study reported here, examined the relationships between stand management strategies in mid-rotation and their effect on wood and timber properties. The relationship between wood properties and strength properties of boards was examined in a small targeted sawmill trial.

In this study

- Wood density in the 5 post-treatment years explained up to 46% of the variance in MOE at one site (Figure 2).
- The variance explained increased to 60% if ring width and log sweep were also used.
- Both treatments exhibited similar relationships between strength and wood density.

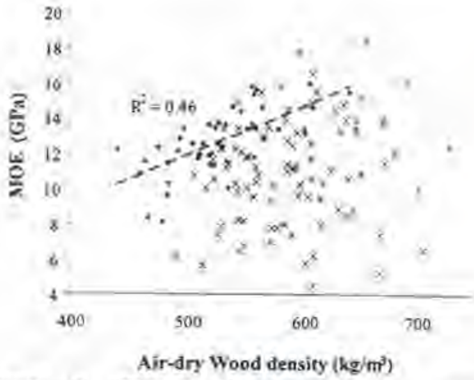

Figure 2. The relationship between wood density and board strength at two contrasting sites.

Figure 3. Motorised corer developed af CSIRO enables a rapid means of sampling plantations.

Fertilisation and thinning had significant effects on log volume, wood density and overall log sweep, which in turn influenced board strengths and recovery during sawing. These effects were not necessarily adverse and results indicated that these silvicultural strategies could improve the value of logs.

CSIRO Forestry and Forest Products is involved in a range of projects defining links between tree growth, wood property development and end-product performance. Sampling strategies have been defined to estimate whole tree properties from increment core samples (Figure 3). Robust relationships will enable growers to use wood property surveys to determine returns within specific markets. Silviculture can then work to change average log properties as well as volume.

The information generated in this study is being used to develop models to examine effects of stand management on whole log properties. Radial patterns of changing ring width and density can be simulated to explore net effects on whole log values. The severity of the effect can be controlled by input parameters to determine when responses might become unproductive. For example changes in ring width and density will vary as a function of site and silviculture. These changes will be largely independent, interactive and influenced by climate over time. Model input parameters could be linked to growth models to explore different management scenarios on growth, wood properties and timber strength.

Acknowledgements

This project was managed by Australian Paper Plantations. Project partners were Australian Paper Plantations, Fletcher Challenge Paper, Hancock Victoria Plantations, Carter Holt Harvey and New South Wales State Forest. CSIRO Forestry and Forest Products was the research provider. Funds were provided by the project partners and the Forestry and Wood Products Research and Development Corporation.

Productivity and utilisation of first rotation, Australian-grown Paulownia

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Paulownia (*Paulownia* spp.) is a relatively new plantation candidate in Australia. Its' fast growth rates in it's native China have seen paulownia trialed and promoted as a short rotation timber crop in several countries, including Australia, South America, Japan, Korea and New Zealand. There is generally a scarcity of reliable information on the wood properties and utilisation potential of young paulownia trees grown in Australia. However, there is considerable anecdotal evidence and speculation, both positive and negative, concerning timber quality and utilisation. Even though there is reasonable evidence to prove that the species can achieve outstanding growth, given the right management on a good site, there is a need to establish the wood properties and potential of the resource.

QFRI assessed three first rotation stands (two at 10 years old, one at seven years old), to provide the data and timber for this study. The project highlighted the advantageous features and identified the wood quality problems which the paulownia industry will need to address in order to ensure the economic viability of growing and processing the species.

A total log volume of 21.5 m^3 was harvested from two sites (both 10 years old), providing average log volumes of $0.32m^3$ and $0.29m^3$. Volume assessments were conducted on standing trees providing average merchantable stem volumes of $0.564m^3$ (10 year old) and $0.488m^3$ (seven year old). The productivity achieved in first rotation paulownia plantations (mean annual increment $15m^3$ Taylor's Arm site, $20m^3$ Bellingen site) was impressive when compared to traditional plantation species, such as hoop ($16m^3$) and Caribbean pine ($23m^3$) and more recent plantings of eucalypts (8 to $11m^3$).

A green-off-saw recovery of 40% was achieved. Dried dressed recoveries were similar to that achieved for other hardwood species. The most significant reasons for reduction in 'saleable' volume were wane, want, pith, distortion and discolouration.

Unusual for fast grown plantation timber, heartwood proportion was determined to account for 75% of the cross-sectional area. Plantation pine of the same age would typically have a heartwood proportion of 25%. The average growth ring width was 20mm and the average number of rings per log was seven.

Accelerated in-ground durability trials indicated that the timber is non-durable (class 4 on a four-class scale). Shrinkage data was calculated to be 3.8% tangential and 1.0% radial (green to 12% moisture content) and unit shrinkage 0.22% tangential and 0.10% radial.

Density, strength and stiffness tests were carried out on small, clear, seasoned specimens to calculate characteristic design properties. This data will be useful for comparisons to other species, and to aid users, for example furniture designers. Average air dry density was $290kg/m^3$, Modulus of Rupture (MOR) averaged 28 MPa and Modulus of Elasticity (MOE) 5.6 GPa.

The ability of paulownia timber to be bonded using adhesive was found to be excellent. Testing was also carried out using bullet head nails and wood screws typical of those used by furniture manufacturers. The timber performed poorly under test conditions, a result that was anticipated due to the species having an average density lower than that required to be assigned a joint group classification under the relevant Australian Standard.

Lyctine activity was recorded in paulownia eight months after inoculation. It can now be assumed that sapwood of this species containing starch is lyctus susceptible.

Positive user feedback was received from surfcraft, venetian blind, toy and hobby manufacturers. Advantages were the ease of working, successful bonding, acceptable colour and weight. Processors involved in joinery and picture frame moulding manufacture provided conflicting feedback. Some were impressed with the dressed finish and aesthetics of the wood, but others were concerned at the furriness of some stock, the incidence of grain tear-out and its' softness. It was suggested that timber from larger (older) trees may provide the quality required for joinery applications. Due to paulownia's coarse texture, it required filling for a satisfactory painted finish, adding to production costs. The ability to remain straight after profiling will prove to be one of the most important factors in achieving market advantage over competitors such as pine. Coffin manufacturers didn't consider paulownia suitable for their product, principally due to its' softness and lack of fastener holding ability. Woodturners were mixed in their opinion regarding paulownia. Some were concerned at the coarseness, softness and chipping-out on certain angles, and others satisfied with the general appearance of the turned product. An ice-cream stick manufacturer deemed it unsuitable for their product due to low strength and bitter taste. A sliced veneer manufacturer was impressed with the manner in which the paulownia sliced and with the smooth, even finish of the veneers produced. However, the manufacturer did comment that in their opinion the softness of the species may cause problems in some furniture applications. Due to its' similar ring-porous structure to Australian red cedar paulownia could be successfully polished for reproduction red cedar furniture. There may be scope for the 'soft' veneers to be glued to medium density fibreboard (MDF) panels and used successfully in cabinets with a hard polyurethane coating lacquer. A separate problem identified by many end-users was that many established species are available in guaranteed continuity of supply, grade quality and at more competitive prices than the currently quoted for paulownia.

It is anticipated that as more timber comes on stream, further research and product development will assist in establishing a reputable, Australian, paulownia industry.

Shrinkage of solid wood during drying and its relationship to tree form in 11-year-old *Eucalyptus globulus* Labill.

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Introduction

In order to understand the factors that contribute to tension wood formation, trial non-destructive screenings have been conducted by CSIRO to assess the occurrence of tension wood in two 10-year-old plantations of *E. globulus*. These trial screenings used shrinkage during drying of 12 mm-diameter increment-cores taken from the outer heartwood and sapwood at breast height at the four cardinal directions of 81, straight, vertical, dominant or co-dominant trees. The plantations studied were from the Mt. Gambier region of South Australia (1) and the East Gippsland region of Victoria (unpublished). The results of these trial screenings suggest that tension wood that gives rise to excessive shrinkage, was commonly encountered at breast height in plantations of this type (15 % of trees at Mt. Gambier and 30 % at East Gippsland affected respectively). However, it is not known how the breast height cores relate to excessive shrinkage (or tension wood occurrence) on a whole tree basis and this can only be done with destructive sampling before conclusions about the occurrence of tension wood can be made. Also in the trial screening at Mt. Gambier no association was found between tension wood occurrence and a number of tree characteristics (1) including the ratio of breast height diameter (overbark[1]): tree height. This parameter was thought to be an indicator of tree slenderness and trees with a slender form would give rise to higher internal bending stress when exposed to wind, and hence would be more susceptible to tension wood formation. Given that destructive sampling is required for whole tree assessment of shrinkage, tree shape can be studied better and the tree form factor determined. This study therefore had two aims; firstly to assess the distribution of excessive shrinkage to validate the trial screenings and; secondly, to assess the relationship between shrinkage and the tree form factor.

Methods

From the Mt. Gambier plantation, one year after the trial screenings, ten trees with varying levels of tension wood based on anatomical examination of the core samples, were selected for destructive sampling. Two of the trees had low percentages of tension wood fibres and three had none. An additional tree was selected from the East Gippsland plantation and was considered to be the tree with the worst shrinkage and highest occurrence of tension wood from either plantation. Ten discs were removed from each tree at the base, 5, 10, 20, 30, 40, 50, 60, 70 and 80% tree height and these in turn cut into a maximum of 16 radial strips. Transverse shrinkage to 12% moisture content after reconditioning was then determined for each radial strip at the point of minimum and maximum shrinkage for three zones based on radial distance from the pith. These being 0-50%, 50-75% and 75-100% of the radial distance from the pith to the cambium. Whole tree shrinkage maps of the differential between the minimum

[1] All diameters discussed later in this paper are underbark

shrinkage recorded for each zone on each disc and the maximum shrinkage recorded on each radial strip in the corresponding zones were then prepared.

The tree form factor was calculated as a ratio of tree volume: the volume of a cylinder with the same basal diameter and height. A Pearson correlation was calculated between a shrinkage index for each tree determined by the number of sections in the outer 75-100% of the radial strips with shrinkage differentials greater than 3.0% and the tree form factor.

Results

The zones of excessive shrinkage were mostly restricted to the lower 30% of the tree height. The excessive shrinkage was usually associated with the 75-100% radius although the zones of excessive shrinkage extended further in towards the pith with declining height. All but one of the trees displayed excessive shrinkage at the base. This result suggests that the trial sampling procedure was moderately successful at detecting trees that had excessive shrinkage. All trees with high percentages of tension wood fibres displayed excessive shrinkage in at least two of the four radial strips located at the cardinal directions in the breast height disc. However the occurrence of zones of excessive shrinkage at the base in the trees that had little or no tension wood at breast height showed that the sampling procedure has limitations and sampling from lower in the tree could be warranted. The high shrinkage found in the basal disc also shows that the percentage of trees affected by tension wood that would ultimately affect product quality and recovery at the Mt. Gambier plantation was greater than the 15% detected in the trial screening.

The Pearson correlation between the shrinkage index and tree form factor was negative with a coefficient of $r = -0.800$ ($p<.01$) for trees from the Mt. Gambier plantation. The reason for differences in form factor was the degree of taper in the lower part of the stem which was shown by the correlation between the shrinkage index and the 10% tree height diameter expressed as a percentage of the basal diameter. The correlation was negative with a coefficient of $r = -.831$ ($p<.01$). These results show that tension wood that gives rise to excessive shrinkage was more common than initially thought and the development of tension wood that extends above the basal region of stems is associated with tree form. However, this association does not appear to extend to trees from other plantations. The correlation coefficient declined when the tree from East Gippsland was included confirming results of the trial screening which suggested that tension wood severity and occurrence was greater at the East Gippsland plantation.

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Rapid estimation of solid wood stiffness using SilviScan

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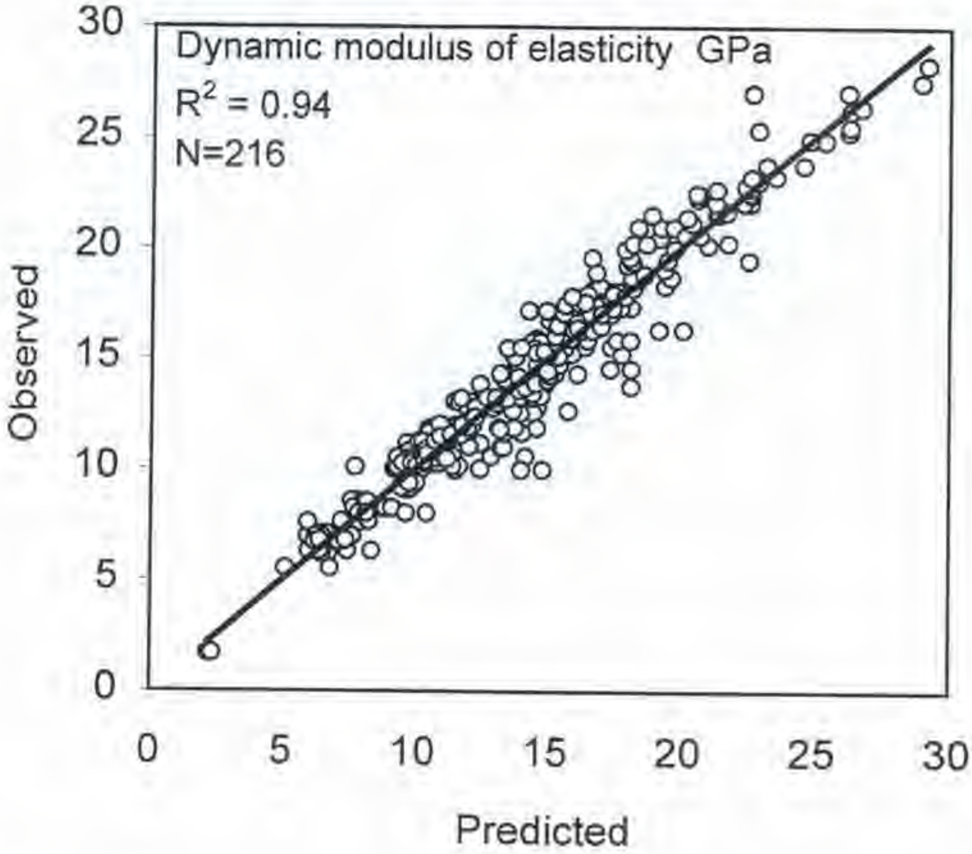
Resource assessment and tree improvement programs require cost-effective methods for the rapid analysis of thousands of samples. Wood stiffness, or longitudinal modulus of elasticity (E_L) is one of the most important wood properties for solid timber applications. SilviScan-2, an automated wood microstructure analyser developed at CSIRO Forestry and Forest Products, was designed for the rapid assessment of wood properties, including density and microfibril angle (1-4). This paper describes a rapid method for predicting E_L using SilviScan data. Very strong relationships were found for 104 samples of *Eucalyptus delegatensis* R. T. Baker, 52 samples of *Pinus radiata* D. Don and 60 samples of mixed species ranging from balsa to red ironbark.

The eucalypt and pine samples used for the measurement of E_L were 20mmx20mm in the tangential and radial directions and 300mm in the longitudinal direction. The mixed species samples were 15mmx15mm in cross section and 200mm long. Dynamic E_L was determined rapidly using impact induced vibrations along the fibre direction, from the first mode of the resonant frequencies using spectral analysis (5, 6).

Small strips cut from the ends of the samples were used for high-speed x-ray scanning diffractometry. A significant advantage of this method (3) is that the average properties of all fibres in the sample cross-section can be estimated in less than 60 seconds. Density was measured gravimetrically.

For the whole set of 216 samples, density accounted for only 65% (R^2) of the variation in E_L. Addition of the diffractometry data increased R^2 to 94% with a standard error of about 1 GPa (roughly equivalent to the difference between stress grades (7)). The relationship between predicted and measured E_L is illustrated below.

The ultimate aim of wood quality assessment is the prediction of end-use properties, and the possibility of selection of trees for the propagation of desired wood properties. There are now opportunities to improve wood quality through selection that have been largely ignored owing to measurement difficulties. The high measurement rate is a significant advantage of this technique, allowing large-scale application in tree improvement and resource assessment programs. With the addition of an appropriate automated sample changer, a service instrument based on SilviScan-2 would be capable of predicting the longitudinal stiffness of wood in several hundred short samples/day and would require only small diameter (5mm) increment cores.



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Estimation of *Eucalyptus delegatensis* wood properties by NIR spectroscopy

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Research conducted at CSIRO Forestry and Forest Products has focussed on the development of rapid, non-destructive methods for the measurement of wood properties and wood chemistry. SilviScan-1, and more recently SilviScan-2, have been developed to measure wood properties, for example basic density, microfibril angle (MFA) and cellular cross-sectional dimensions. Methods have also been developed for the non-destructive evaluation of wood stiffness (longitudinal modulus of elasticity - E_L) based on the sonic resonance properties of the wood. To estimate parameters related to wood chemistry, such as pulp yield and cellulose content, near-infrared (NIR) spectroscopy has been used. NIR spectroscopy is a technique that is widely used to rapidly estimate parameters which traditionally have been time consuming and difficult to measure.

Density and MFA are important determinants of the strength and stiffness of wood. Recently Evans and Ilic (2000) (1), in a study of 104 *Eucalyptus delegatensis* (Alpine Ash) samples, found that density (measured gravimetrically) and MFA (measured by SilviScan-2) accounted for 96% of the variation in E_L (measured by a sonic resonance technique). This study demonstrated that E_L can be rapidly predicted based on measurements of density and MFA. NIR spectroscopy may also provide a rapid, non-destructive option for the estimation of E_L and other wood properties, for example MFA, density and modulus of rupture (MOR). To investigate if NIR spectroscopy could estimate such parameters the *E. delegatensis* samples were analysed by NIR spectroscopy.

NIR spectroscopic analysis involves measuring the NIR spectra of a large number of samples, developing a regression calibration that links the spectra to the parameter of interest, and then using the calibration and the spectrum of a new sample to predict the parameter. The development of calibrations based on NIR spectra is possible as the NIR spectrum contains much chemical and physical information about an individual sample.

The *E. delegatensis* samples were divided into a calibration set (70 samples) and a prediction set (34 samples). Partial least squares (PLS) regression calibrations were developed for a number of parameters using the calibration set. The calibrations developed are given in Table 1. The individual calibrations were then applied to the prediction set (in effect a separate test set) and used to estimate each parameter.

Each calibration was very successful with correlation coefficients in the range 0.88 to 0.96. The standard error of calibration (SEC) and standard error of prediction (SEP) were similar for each parameter. The successful calibrations suggest that NIR spectroscopy may be used for the rapid, non-destructive estimation of solid wood properties.

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Characterization of resin streaks and resin shakes in slash pine stems

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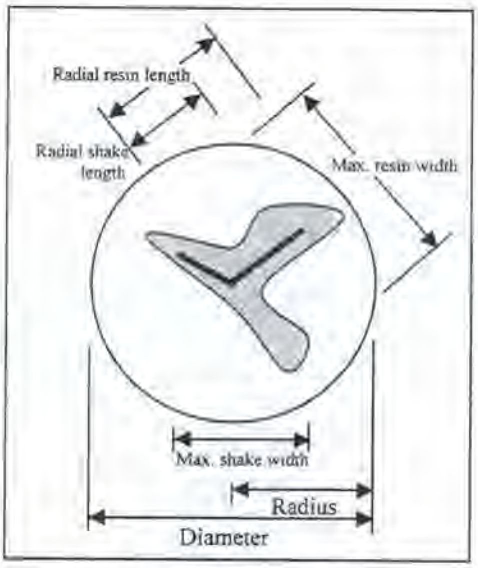
Resin streaks and resin shakes are natural features of plantation grown Slash Pine (*Pinus elliotii*) that cause significant downgrading and rejection of sawn timber during processing. Resin streaks are visible concentrations of resin while resin shakes are longitudinal separations of wood fibres orientated radially within the tree. These separations are sometimes referred to as heart or wind shakes and usually radiate from the centre of the tree. In most cases resin streaks are associated with resin shakes. Resin shake is most commonly found in the butts of logs or stems and can also be associated with knots or external injury. A definitive explanation of the cause of resin shake in Slash Pine has not yet been made despite the issue having been studied for the last 30 years in both Australia and South Africa. It is known that resin occurs in pines in response to injury and/or stress. Research in South Africa has suggested that the cause of resin shake may be related to internal growth stresses, root or wind damage, environmental conditions, silvicultural practices and/or genetic factors. QFRI researchers have previously reported (Greve 1984) that resin streaks and resin shakes in timber products can adversely effect the following processes and wood properties.

1. Sawing – overheating, saw damage
2. Machining – clogging
3. Sanding – reduced belt life
4. Gluing – poor bonding
5. Preservation – impaired penetration
6. Painting – poor paint hold
7. Natural finishes – impaired appearance
8. Structural capacity – reduced strength
9. Nailing – increased splitting
10. Appearance – darkening with age

Hyne and Son's experience has also shown that resin can also be a major problem in the seasoning of Slash Pine, particularly as the cause of kiln fires. QFRI (Smith, Bragg, Palmer and McNaught) has pursued research into the cause and consequences of resin streaks and shakes while Hyne and Son (Stringer) has studied the utilisation and grading aspects of resin shakes. Currently these defects are not included within the breeding program and silvicultural options for reducing the defects have not been determined.

Butt trimming of resin affected stems commenced in 1998. The premise behind butt trimming is that there is a relationship between the occurrence of resin on the butt and the resin affected wood in the butted section. An investigation was designed by Hyne and Son and QFRI to determine the validity of this premise and the general characterization of streaks and shakes along the stems. A total of 53 stems were sampled from 2 rows of felled trees at the southern end of the Tuan-East 85 compartment. The stems were 30 years old and were selected based on the appearance of resin on the sheared butt. The samples were chosen to represent the range of resin features. A number of stems with no resin on the butt were also selected. Docking of 600mm blocks was undertaken based on the occurrence of resin on the butt down to a 150mm top. Where at least three successive cross sections exhibited no sign of resin shake the docking length was increased to either 4.8m or 2.4m depending on the location in the stem. All resin shake lengths and orientations where recorded.



A total of 501 cuts were made on the 53 stems. The occurrence of resin in the stem and on the butt was recorded, as were stems with breeches and stems with multiple shakes. I.e. stems with shakes in three consecutive 600 mm blocks

An analysis of the data suggested,
i) Resin streak and shake have a maximum mean width at the butt of the tree
ii) Streak is wider than shake at the butt, but is closer up the stem from the butt
iii) A secondary maximum mean width occurs in streak and shake 3-4m from the butt

Further analysis was carried out on breech stems and stems with multiple shakes. The torsional nature of the resin in the 10 stems grouped as multiple shake stems as well as their maximum width occurring at 2 – 4 m from the butt suggests the standing tree may be have been subject to some stress. This hypothesis was pursued by surveying broken stem heights in Tuan forest and by undertaking stress analysis on a cantilevered tapered beam. This resulted in the strongest evidence to date that this form of resin in is caused by wind. The strength of individual trees and the wind load applied to individual trees will vary considerably and helps explain variation in shake occurrence. i.e.

Broken stems	High wind loads and/or weak trees
Multiple shake stems	High winds & strong trees, Low winds & weak trees
Stems free of multiple shake	Low winds and/or strong trees

A unique insight into resin in Slash Pine stems is gained through the action of the larvae of the Pine Wichety Grub (Cacodacnus planicollis) which attacks green slash pine logs on the forest floor removing non-resinous wood and sapwood from trees, creating a skeleton that exposes the nature of resin in trees.

In conclusion,

1. Three distinct types of resin occur in Slash Pine stems.
   i) Butt Resin as the major type located within 1200mm of the butt
   ii) Breech Resin extending 5 times the diameter below breeches.
   iii) "Wind" Resin reaching a maximum at 2-4 m from the butt and extending 6 m or more along the stem.
2. Butt resin can be effectively reduced by butt trimming.
3. Trimming of breeched stems at a distance 5 times the diameter below the breech is an effective means of reducing this resin type.
4. Wind forces are the most probable cause of "wind" resin and forest management practices should be investigated to minimize exposure of the plantation to strong winds. Breeding wind resistant trees and non-destructive detection methods of resin should also be pursued.

Compression wood in radiata pine: effect on product stability

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Background
Stability is a critical issue for all types of solid wood products. Plantation species have a reputation for being somewhat less stable than natural old growth forest species (1, 2) and stability in use is one of the major challenges for New Zealand radiata pine lumber. Compression wood is well known as a variable influencing the stability of softwoods, but the effects of severity levels and how they relate to distortion has received limited attention to-date.

Objectives: To quantify the stability of radiata pine studs (juvenile and mature; finger-jointed and solid) containing compression wood.

Methodology, sample selection and preparation
A total of 150, 2.4m samples of 100x40mm dimension were prepared for the study. They comprised three wood types (mature wood with and without visible compression wood, and juvenile wood),and two product classes (solid and finger-jointed) which were made into 5 sample sets (3 from green timber and 2 from dry timber) with10 pieces per set per wood type.

The mature wood, was selected from outside the inner 10 growth ring juvenile wood region. The juvenile wood was selected from within the 10 growth rings from the pith, The level of compression wood was selected as being visually 'severe' compression wood ie.(> 40% of visible compression wood in the cross section and 2/3 or more of the board length effected).

Green samples were prepared soon after selection from the mill with finger jointed samples prepared by Greenweld. The dry finger jointed samples were prepared after all green samples and spare timber had been kiln dried All samples were dressed 4 sides to 70x35mm to ensure a smooth surface for Warpmaster laser scans.

Initial length and shape measurements were recorded on the green samples before kiln drying to 12%mc and re-measuring. All sets of studs were then cycled between high and low humidity (18% & 8% EMC) and reassessed for length and distortion.

Results and Discussion
With the Warpmaster measuring tool it is possible to determine the distortion profile along the length for each sample. The data demonstrated not only the inversion of some of the warp (crook and bow) but also how the maximum point of displacement changed position along the length with changes in moisture content. The inversion of warp produces a larger actual movement than the apparent change in warp based on the absolute values of the warp at any EMC - which is the warp visible to a wood user.

There was no significant difference between the wood or product types for initial shape (crook, bow, or twist).

For the samples prepared from green wood, for each EMC change; crook and bow movement were significantly lower for mature wood than for compression wood and juvenile wood. There was no effect on twist. Length movement was highly significant: normal wood showed least effect and compression wood the most.

A similar trend was found for samples prepared from the kiln dried wood although the movement was generally lower by half or less.

Conclusions

- Finger jointing did not reduce the levels of distortion compared to solid lengths within similar wood types.
- Products prepared from dry wood had lower levels of movement during changes in EMC than those prepared from green wood.
- Juvenile wood and compression wood showed similar levels of distortion.
- Warp inversion for crook and bow occurred in all wood and product types.
- Shrinkage in length from green to 8% MC did not exceed 0.7% in any of the wood types
- From a practical viewpoint this study showed that compression wood is similar to juvenile wood with regard to the warp variables crook and bow, and with greater variability than normal wood
- By being able to visually select samples for the study leads to hope that in the future it will be possible to provide some form of scanning system for such wood, to permit segregation.

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Breeding objectives and selection criteria to maximize the value of sawn southern pine timber

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A description of this Forestry and Wood Products Research and Development Corporation project was presented to this conference in 1996 (1). Representative routine plantations established with first generation improved, 26-year-old, slash pine (*Pinus elliottii* Engelm. var. *elliottii* L. & D.) and 20-year-old Honduran Caribbean pine (*Pinus caribaea* Morelet var. *hondurensis* Barrett & Golfari) were sampled and sawn at QFRI's Salisbury Research Centre sawmill. Additionally, full-sib crosses of 24-year-old Honduran Caribbean pine and 31and 32-year-old F_1 hybrids of slash × Caribbean pine from genetic trials were also sampled and sawn at the research sawmill. These stands provided a sample of plantation southern pine with great variation in stem form, basic density, branch size and other characteristics.

Multi-variate linear models were developed from the research sawmill study results. These have been successfully used to predict sawmill outcomes from relatively simple field-based tree measurements. Attempts to model the full data set of 250 trees covering only the slash pine and Caribbean pine data did not result in high levels of prediction due to the very large variation in the data set. Initially, it was thought that including both species and age differences in the data would be advantageous by extending trait ranges to extremes. However, the complexity of interactions tended to result in such large among tree variation across the total data set that models could not be fitted to the data. Consequently, predictive models have been derived from sets of stems representing the individual taxa and age combinations. Predictive model development involved an iterative process of construction and evaluation (2, 3). Age differences appear to be more significant than inherent differences in wood properties between the taxa as the distribution of stiffness in the recovered volume from these samples contains very large overlaps.

All the models predicting green-off-saw (GOS) recovery are characterised by taper and straightness. Green-mill structural product recovery predictions are a function of DBHOB indicating that stem size determines green-mill structural recovery. Validation results, from independent samples of 50 stems sawn in Hyne and Son's Tuan sawmill, indicate that the green-mill structural models are good predictors. This is not surprising given that the saw patterns used are a function of log size and differences between sawmills using the same sawing patterns should therefore be small. In-grade structural models are a function of stem size (DBHOB, bark thickness) and wood quality (Juvenile to Mature Wood Ratio – defined as the ratio of the basal areas of the inner 10 growth rings to the outer wood at breast height). Where large differences were found, it was observed that the models tend to be very conservative when predicting in-grade recovery from poor quality stands. The models seem to be quite sensitive to stand characteristics and work best in the sort of typical stands used for their development.

Validation studies established that differences in log product handling and docking between the research and commercial sawmills resulted in inconsistent or poor prediction of reject and utility grades and lower structural grade recoveries. However, green-off-saw (GOS) and structural recovery percentages and yield of the higher F8 and F11 structural grades have been modelled very successfully. Production of higher F-grades for premium markets is critical to maximising tree value. High GOS recovery is critical for sawmill efficiency and minimising costs of production. Consequently, being able to model these sawmill outcomes provides a very useful screening tool for classifying the quality of resource intakes. Such a tool was developed as part of the project by incorporating these simple models into a modelling package, Virtual Mill. This package utilises grade recovery prediction models developed in this project to predict sawmill outputs for specified average tree descriptions for a stand. Costs of processing through all stages from harvesting to mill door can be entered. A financial analysis of the outcomes for specific tree types can be obtained for comparison. It also includes a graphing tool to allow the effect of one variable to be plotted against another, with other variables in the model held constant.

This forest growing and processing enterprise has also been modeled to provide a framework for estimating the economic advantage of tree improvement. In this case, the model enterprise consisted of two organizations: DPI Forestry as the grower and Hyne and Son P/L as the processor. Within the model costs are incurred in growing and processing wood and income is derived from log royalties and the sale of sawn products and residues. A "profitability index" for each part of the forest enterprise is calculated as the ratio of profit (as present value income minus present value costs using a specified discount rate) and present value costs. The value of tree improvement is estimated by simulating the effect of trait-change on enterprise wood-flows, costs and incomes. The framework uses either (1) correlations between traits in the selection index and product proportions or, alternatively, (2) predictive models of product yields, to simulate trait-change impacts. Sensitivity analysis has been carried out to indicate the relative importance of all assumptions made to the estimated profitability index. A selection index for ranking trees in breeding programs was constructed using the derived profitability index values and estimates of heritability and genetic correlation. The framework, which can be continuously improved as key genetic parameter estimates and sawing study results become available, provides a tool for the ongoing assessment of research results.

Since this project commenced, a revised breeding objective for QDPI-Forestry's future plantations has been proposed targeting a decreased rotation length of around 20 years. This poses a challenge to complement the work of this project with additional studies that will need to place more emphasis on juvenile wood properties.

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The effect of age and growth rate on the wood quality of eucalypts in Queensland and implications for management

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There is a common perception in forestry that the economic viability of plantations will be maximised if trees grown for solid wood products are grown fast and harvested on short rotations. This avoids the detrimental impact of accumulated interest on growing costs. Other reasons for the emphasis on short rotations are: (a) to reduce the risks (fire, disease, insects, cyclones) associated with long rotations, (b) to meet the projected future shortfall in the supply of hardwood timber, and (c) because short rotations are generally regarded as being more attractive to potential investors in plantations. In order to grow trees on short rotations, intensive management is applied so that growth is accelerated by genetic improvement and/or silvicultural practices such as fertiliser treatment, thinning and/or weed control. The critical question which emerges is: 'Can young, vigorously grown eucalypts supply timber of a quality acceptable to the marketplace'?. Ultimately the economic viability of plantation forestry hinges upon the wood quality and market value of the timber. If it is demonstrated that a longer rotation and slower growth rate produces timber of a substantially enhanced quality and that this in turn produces greater returns for both the grower and processor, this would strongly influence recommended genetic and silvicultural regimes.

Over the last four years QFRI has carried out investigations into the effects of age and growth rate on wood quality in various eucalypts in Queensland and Northern NSW. Wood quality parameters which have been studied include density, longitudinal growth strain, distortion, shrinkage, strength, sapwood proportions, extractives content and grade recovery.

Most of the studies undertaken by QFRI (1-9) indicate that, in general, faster growth rate resulted in no detrimental impact on wood quality. Most studies revealed a positive effect of growth rate in producing timber of higher density, greater heartwood proportion and reduced growth stress. However, positive and negative relationships were found and further studies taking into account other quality attributes such as stability and twist need to be undertaken. Also, as suggested by Downes and Raymond (1997) (1), an explanation for the conflicting results is that the magnitude of the effects due to treatment is relatively small compared to the natural variation and therefore trying to establish trends is difficult.

Even though growth rate per se has been shown to produce limited detrimental impact on wood quality in eucalypts, an indirect effect of fast growth is created via the younger age of harvest, which can alter the proportion of juvenile or corewood to mature wood in the merchantable log. The results from the QFRI studies indicate that density and heartwood proportion tend to increase with age. However, the density in some of these eucalypts is already very high even at very young ages (e.g. at age 11 years, *E.cloeziana* is 77% of its mature wood density). Younger eucalypts featuring slightly lower density and extractives content may be more desirable for some applications such as furniture and composite products due to easier machining, gluing, jointing, workability and handling. Shrinkage in most cases was not greater in the plantation grown eucalypts than the mature values in the species studied.

Even though the studies conducted revealed no severe detrimental impacts of growth rate and age on fundamental wood properties, lower grade recoveries were recorded for the plantation eucalypts studied compared to natural forest grown hardwoods. However, the reasons for downgrade (including knots, kino veins, distortion and splits) may be corrected with genetic, silviculture and processing improvement in the future.

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Wood properties and utilisation of Western Australian goldfields timbers

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About three million hectares of eucalypt woodland and forest have regenerated in the Eastern Goldfields area of Western Australia following the gold discoveries of the 1890s and subsequent harvesting for mining timbers and fuel. Most of the woodland and forest species that can yield timber are eucalypts, which have attractive colour, grain and figure, although the timber has very high density and is difficult to mill and dry.

These species have considerable potential for the production of specialty timbers, but there were few data on their properties. In 1994, the Department of Commerce and Trade, Goldfields Esperance Development Commission (GEDC) and CALM funded the Goldfields Timber Research Project, with considerable 'in kind' contributions from private enterprise, Goldfields Specialty Timber Industry Group (GSTIG) members and CALM. The Project assessed logging, sawmilling, drying, wood properties, general utilisation and processing, and marketing of a wide range of *Eucalyptus* species and other genera. A Research Steering Committee was established to regularly assess research needs, arrange trials, monitor progress and control finances. Membership included GEDC, GSTIG, Kalgoorlie College (now Curtin University of Technology, Kalgoorlie Campus) and CALM.

This paper gives results of the wood properties assessments and discusses utilisation aspects of Goldfields timbers. A general outline of the Project was given at the 1996 Forest Products Research Conference.

Wood properties assessment included detailed measurements of green, basic, and air-dry density of twenty-one species. The eucalypts varied in green density from 1181 kg/m^3 for Goldfields blackbutt (*E. lesouefii*) to 1277 kg/m^3 for giant mallee (*E. oleosa*), with the highest green density being 1321 kg/m3 for black oak (*Casuarina pauper*). The small standard deviations in most sets of data indicated a comparatively uniform resource, e.g. the coefficient of variation for green density of Cleland's blackbutt (*E. clelandii*) was 1.5 per cent while the largest was 7.9 per cent for sandalwood (*Santalum spicatum*).

The green moisture content of the eucalypts was low, as expected with high density timbers, and varied from 25.1 per cent for Cleland's blackbutt to 33.9 per cent for black morrel
(*E. melanoxylon*). In comparison, the acacias varied from 18.6 per cent for Western myall
(*A. papyrocarpa*) to 30.2 per cent for gidgee (*A. pruinocarpa*). Samples from other

species varied in moisture content from 22.0 per cent for sandalwood to 78.9 per cent for native willow (*Pittosporum phylliraeoides*).
Basic density showed similar variation, from 880 kg/m^3 for Goldfields blackbutt to 987 kg/m^3 for giant mallee. Three acacias varied from 1035 kg/m^3 to 1080 kg/m^3. Air-dry density is probably of greatest value in utilisation, and black oak was 1290 kg/m^3 while the eucalypts were mainly in the 1100 to 1200 kg/m^3 range. Other species such as beefwood (*Grevillea striata*) and corkwood (*Hakea suberea*) were found to be more dense than most commercial eucalypts of eastern Australia, with the exception of the ironbarks.

Tangential and radial shrinkage was estimated for the standard 12 per cent MC, and for 6 per cent MC because of the very low equilibrium moisture contents found in Kalgoorlie/Boulder. The shrinkage values for eucalypts were significantly greater than those for the acacias, although wood density was similar. Black morrel had the highest shrinkage with 7.2 per cent tangential and 6.0 per cent radial, compared with Western myall's 1.5 per cent tangential and 1.0 per cent radial. The estimated fibre saturation point (f.s.p.) for each species indicated that some eucalypts had f.s.p. below the 25 to 30 per cent usually quoted in the literature (e.g. black morrel 22.2 per cent and giant mallee 23.0 per cent). The acacias had even lower values, although it is possible that the miniritchie (*A grasbyi*) was below f.s.p. at the first measurement. The other anomaly was the very low estimate of 18.6 per cent for sandalwood.

With general utilisation and processing, potential uses of the Goldfields timbers identified include furniture and flooring, musical instruments (both woodwind and stringed), general craftwork, carving, inlays and veneers, and woodturning. Fine design is required for furniture because of the very high density wood, with the advantage being very high strength properties. Fine design furniture could be promoted as showing the unique colour, grain and figure of these species. The flooring potential is good because hardness (i.e. resistance to indentation) is exceptionally high, and the product would be cost efficient in the long term in areas with heavy traffic.

Musical instrument use has included considerable research into use in flutes by Professor Felix Skowronek of the University of Washington, Seattle, while local boutique guitar makers and woodwind instrument makers have successfully used Goldfields timbers. There is considerable potential to supply timber blanks for woodwind instruments, and veneers for stringed instruments, as availability of traditionally used tropical rain-forest timbers from Africa and Central America continues to decrease. Tests were also done on the suitability of Goldfields timbers for use in manufacture of stringed instrument bows and in other specialised instrument uses. Members of GSTIG have produced a wide range of craft items that demonstrate the unique properties of Goldfields timbers.

Marketing of these Goldfields timbers must be done carefully and efficiently. The product is expensive because the scattered nature of the resource and low yields per hectare make logging expensive, and there are high sawmilling and drying costs because of the generally small logs and very high density timber. The unique features of these timbers should enable a range of small niche markets to be found, and encourage development of a Goldfields timber industry. Publicity and information transfer will be an ongoing process. Two '*LANDSCOPE*' articles on Goldfields timbers have provided information to a large audience and used for public relations purposes. A CALM Bush Book with the title *Common trees of the Goldfields* and the Goldfields Timber Research Report have reached another audience.

Wood and fibre analytical services at CSIRO Forestry & Forest Products

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There is a range of physical and chemical techniques that are used routinely in the pulp and paper industries to characterise wood composition, fibre morphology, adhesive composition and other aspects of the processes used in fibre and paper production. Most of these have not been routinely used to characterise raw materials and processes used to make solid and composite wood products, however many of them are available in CSIRO Forestry and Forest Products and can be considered for solving problems that do not respond to more traditional methods. This presentation reviews the range of analytical services available within CSIRO Forestry and Forest Products and the type of information that they yield that could be used to improve the processing of solid and composite wood products. The tests include:

Chemical Analyses:	Cellulose Content Lignin Content Extractives Content Inorganic Content Gas Chromatography and Mass Spectroscopy
Physical Analyses:	Scanning electron Microscope Moisture Content Basic Density Fibre Morphology Precise Colour Measurement UV-visible spectroscopy Infra-red spectroscopy

Used selectively, these techniques can give precise information about differences in the chemical composition of different raw materials and products, which may assist in understanding why they behave differently during processing.

The future of eucalypts for wood production - outcomes from IUFRO Conference, Launceston, March 2000

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Under the auspices of IUFRO Division 5 Eucalypt Working Party a conference on "The Future of Eucalypts for Wood Products" held in Launceston, Tasmania, Australia from 19th – 24th March 2000.

The conference was attended by 250 delegates representing forest growers, processors, marketers and researchers from 22 countries. The conference focus was on the young eucalypts that make up plantations around the world and second growth production forests in Australia. Presentations and discussions covered the range of actual and potential solid wood products, including reconstituted products, but excluding pulp and paper. It included all phases of markets and production – from seedling to finished furniture, and from genetic manipulation to product specification.

The conference objectives were to:

- Explore future opportunities for eucalypts in quality wood markets;
- Review emerging technologies which are creating these opportunities;
- Define how research can progress these technologies and opportunities.

The conference highlighted the globalisation of eucalypts, but pointed to concerns regarding the fact that much of the resource has been developed for pulp and paper products. However, there is now with an increasing expectation for solid wood products, where there is often little understood regarding the products and their end-use performance requirements, the processing requirements and the impact of resource quality on these above requirements.

Measuring wood microstructure variation in *E. nitens* and *E. globulus* - comparing SilviScan-2 with microscopy image analysis

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Understanding the variability of wood properties will help direct tree breeding programs and silvicultural practices towards meeting product requirements and guide quality control measures in the manufacturing process. The properties generally considered of primary importance or having key indicative value in these respects are basic density of the wood, fibre dimensions, vessel distribution and vessel size.

Fibre morphology, vessel distribution and density vary from pith to bark within annual rings and with height. This study investigates the variation of these wood properties in two eucalypts (*E. nitens* and *E. globulus*). Samples were intensely examined from 4 percentage heights in each tree species. SilviScan-2 data was compared with microscopy image analysis data to establish a relationship between the two methods.

This study found that conventional microscopy image analysis and SilviScan-2 measurements provide similar patterns of variability of wood properties in *E. nitens* and *E. globulus*, consistent with other studies on the variability of vessels, fibres and wood density. These findings will give a better understanding of the variation in fibre & vessel morphology within eucalypts and the relationship with density and ultimately contribute to tree breeding programs to optimise wood quality attributes for the pulp and paper industries.

This study investigates the relationship of fibre length to density. Vessel occurrence and distribution is identified as being highly significant in influencing density estimation and therefore the distribution of vessels in *E. nitens* and *E. globulus* was further investigated. The results of these findings contribute to the selection of clones, development of silvicultural practices and tree breeding programs to optimise wood quality attributes for the pulp and paper industries.

Density has been an important indicator for pulp and paper plantations to determine the quality of wood produce and its intra-annual cell characteristics. Pith to bark 2mm radial blocks were used in Silviscan-2 and then cut up for macerations. Profiles of x-ray densitometry are compared with macerated fibre lengths for two seven-year-old eucalypt trees (*E. nitens* and *E. globulus*) for different percentage heights.

An overview of wood products market in China

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Economic reform in China since the late 1970's has led to dramatic and continuous economic growth in the country. The purchasing power of various groups and individuals has greatly increased in relative terms. China has been recognized as a huge market for numerous products including wood as both raw material and finished products. The country's enthusiasm for economic development, the increasing purchasing power of increasing population, and insufficient domestic production of roundwood and wood-based products have in combination accelerated its demand for wood.

China is comparable in size to Canada and the United States, but its percent forest coverage is much lower, being approximately 13.9%. Being aware of its deficient forest resources, the Chinese government has set up a strategic goal to increase its forest coverage to 17% by early this century. However, despite a significant reforestation effort, China's domestic wood supply will not be able to keep up with its demand. Limited availability of sustainable land and water will also put a strain on the scale of its reforestation. As a result, the gap between the demand and supply will remain over the next few decades. In the last few years, the utilization of wood-based panel products has gained tremendous momentum and the imports of logs and various other wood products have also considerably increased. Having recognized this market potential, a number of overseas companies relatively new to the Chinese market have been busy with promoting their wood and wood products, wood working machinery, etc. taking the risk of operating in an unfamiliar and less stable economical environment.

Domestic circumstances have given China its own wood consumption pattern. The Chinese wood products market is changing all the time. The speed and diversity of the change, and the size of the country have made it difficult to obtain up-to-date information on the exact size and demand of the market. To gain a foothold in the Chinese market, it is important to not only understand what is short of supply, but also the consumer's preference in the products. Consumers' demand comes from various income levels. The majority of consumers are from the low to mid-income levels, whose purchase list would most likely include only wood panel products. However, the number of high-income earners is increasing and this emerging sector is interested in and can readily afford high quality solid hardwood wood products, either domestically produced or imported.

Indoor air pollution by wood and wood-based products

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Introduction

Pollutants emitted from wood and wood-based products have an impact on indoor air quality from two perspectives: exposure of building occupants to air pollutants that affect health and well-being; and degradation of cultural collections due to pollutants emitted from materials used to build display and storage cabinets.

Pollutants and occupant health

The pollutant of greatest concern is formaldehyde emitted from wood-based panels, since it is an eye/nose/throat irritant, it is classified as a probable human carcinogen and it has been linked to the incidence of asthma attacks. However, there are also indoor air concerns about the emissions of volatile organic compounds (VOCs) in general, especially as the total VOC (TVOC) load that has been associated with sensory irritation and effects such as sick building syndrome. In Australia, the NHMRC (1; 2) has recommended indoor air goals for these pollutants, as follows:

- formaldehyde – 130 $\mu g/m^3$ (ceiling limit);
- any VOC – 250 $\mu g/m^3$ (1-hour average); and
- TVOC – 500 $\mu g/m^3$ (1-hour average).

In Europe, the focus on controlling formaldehyde exposure is directed at wood-based panels which are classified as low-emission if they exhibit an emission rate per panel surface area below 130 $\mu g/m^3/h$ (3).

CSIRO measurements of limited samples of Australian particleboard and MDF (4) have found this low emission level is exceeded by a large margin for new panels and that the emissions may not decay to this level for a period of months to years. The emission decay was found to be double exponential such that prolonged formaldehyde emission is expected over the lifetime of the products. VOC emissions were difficult to interpret for MDF, but they occurred by first-order decay for particleboard, becoming largely insignificant after a few months. An emission of hexanal, near odour threshold levels, was the worst likely long-term pollutant released from the panels.

Pollutants and cultural collections

Most cultural items are housed in semi-sealed display cases or stored in cabinets, and it is now recognised that some items are affected by air pollutants emitted from wood materials (raw or reconstituted) used in the cabinets. Of most concern is the damage caused to lead bronzes, calcareous materials (limestone, shells) and glass, sometimes in as little as a few months storage. The pollutants currently known to cause the greatest damage (5) are (in decreasing order) acetic acid, formic acid and formaldehyde. The acids are emitted from some raw timbers such as oak, Douglas fir and birch, even after many decades, but in general our knowledge of organic acid emissions from raw and reconstituted wood is limited, especially for Australian woods. Measurements in cabinets made from wood-based panels, even a zero-formaldehyde product, have found acetic acid and formic acid levels likely to be damaging to collections (6).

Conclusions

Air pollutants are emitted from wood and wood-based panels that may be significant to the health of building occupants or to the stability of stored cultural items. Further research is needed to better understand and control these emissions.

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Recent advances in remote sensing technology for forest measurement and growth prediction

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Forest resource information is increasingly needed at fine spatial scales for operational and strategic applications including monitoring indicators of ecologically sustainable forest management, planning of harvesting operations and implementation of silvicultural prescriptions, and the maintenance of biodiversity and ecological sustainability.

High resolution remotely sensed imagery is one data source that can provide cost effective information for forest management. In this paper we present a number of new methodologies that allow remotely sensed imagery to be modelled to predict forest structure in eucalypt forests.

These methods emphasise the tree crown as the primary indicator of forest structure and utilises algorithms which automatically delineate tree canopies in high spatial resolution data. Another method investigates the spectral variability of the forest in relation to its stand structural diversity (biomass of tree canopy, shrubs, ground cover and litter). In addition, a number of other technology such as LIDAR, offer extra sources of information to forest managers such as height, vertical biomass distributions and branching information.

Examples of these data will be presented and a number of applications in Australian forest environments.

Simultaneous saccharification and co-fermentation (SSCF) of alkaline/peracetic acid pretreated lignocellulosic biomass for ethanol fuel production

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Previous work in our laboratory has demonstrated the effectiveness of peracetic acid, as an alternative process, for improving enzymatic digestibility of lignocellulosic materials at ambient temperature. The use of dilute alkali solutions, as a pre-pretreatment, prior to the lignin oxidation increased carbohydrate hydrolysis yields in a synergistic as opposed to additive manner. Deacetylation of xylan is easily achieved using dilute alkali solutions under mild conditions. In this paper, we evaluate the effectiveness of peracetic acid combined with an alkaline pre-pretreatment through simultaneous saccharification and co-fermentation (SSCF) of pretreated hybrid poplar wood and sugar cane bagasse. Respective ethanol yields of 92.8 and 91.9% of theoretical were achieved using 6% NaOH/15% peracetic acid-pretreated substrates and recombinant *Zymomonas mobilis* CP4/pZB5. Reduction of acetyl groups of those materials is demonstrated following alkaline pre-pretreatments. Such processing may be helpful in reducing peracetic acid requirements. The influence of deacetylation is more significant in combined pretreatments using lower peracetic acid loadings.

Overview of waste wood processing

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Introduction

Wood is one of the most widely used materials in the world. Approximately 900 million tonnes[1] of wood is used each year. More than 50% of wood is used in industrial products (sawn timber, wood-based panels and pulp). In addition, it is the only large-scale industrial material that is renewable and locks up atmospheric CO_2. It is relatively easy to recycle and can ultimately be burnt as a CO_2 neutral fuel.

In Australia we produce about 19million m^3 of wood each year. While a considerable proportion of this wood is exported in the form of pulp chips, roughly 60% of the wood produced is used in paper and in construction products such as sawn timber and wood-based composites (roughly 35% of the total volume produced). At present very little of these construction products is exported (and Australia is a net importer of pulp and paper).

Making some large assumptions about wood product density, this means that we consume around 4 million tonnes of wood a year. On the basis of 'what goes in must come out' (and ignoring losses to biodeterioration) this could be taken as our projected wood waste stream in 25 to 50 years time.

This is both a considerable amount and a considerable potential resource.

Wood waste goes into landfill

At present most wood waste goes into landfill. In the USA MSW (municipal solid waste) is estimated[2] at 147 million tonnesand total US construction and demolition waste is estimated at 57 million tonnes. Solid wood products are assumed to be 11% by weight (roughly 16 million tonnes) of MSW (municipal solid waste)) and all wood products (including paper) are assumed to be 38% by weight of MSW. In the USA 30% of all construction and demolition waste is assumed to be wood.

In landfill (and depending on the control and conditions in the landfill) the wood is assumed to either be stored or will slowly decay[2].

What are the alternatives to landfill?

There is considerable work going on around the world on alternative uses for wood waste other than landfill. There are two main alternatives: cascade recycling (where a lower quality/value alternative is produced with each recycling step); or, direct recycling (where the wood is recycled back to a primary end use). The main purpose of this paper is to highlight some of the activities outside Australia so that we do not re-invent the wheel.

Work on direct recycling is at an early stage. The main advantage of direct recycling is maintaining the value of the product after recycling. There are just starting to be scientific papers published in this area[3].

There has been much more work on cascade recycling with some authors suggesting a maximum of 5 to 6 recycling steps[4]. In reality, 1 or 2 recycling steps are probably more practical with energy production always likely to be the last step.

The intermediate step is most likely to be composite production and this is an area where there has been considerable research and industrial development. For example, the largest particleboard plant in the world (SIT 2000) in Mortara, Italy produces $2000m^3$/day of board from 100% recycled wood[5]. As another example, Canfibre is producing MDF from 100% recycled wood in the USA[6] and is opening two more sites in the USA and one is planed in Europe. There is also considerable interest in less conventional wood composites such as wood plastic composites[7].

The final step in cascade processing waste wood is likely to be the production of energy. It was estimated in 1988 that 25% of Australian households had wood burning appliances[8]. It was also estimated that these appliances consumed 4.4 million tonnes of air dry fuelwood. This is, of course, not usually wood waste.

In other parts of the world, there is a large market for fuel pellets made from both process waste and post-consumer waste wood. In the USA the consumption of fuel pellets is over 600,000 tonnes and pellets sell at around US$140/tonne[9]. In Sweden, the consumption of pellets in 1996 was 500000 tonnes and the pellets sell at around US$190/tonne[10].

There are a range of other uses (including pet products and composting) which will not be covered in detail here but will hopefully addressed elsewhere.

Role of preservatives in recycling

The final point to make in the recycling of wood is the role of preservatives in recycling of waste wood. Preservatives are essential in many markets for a biodegradable material such as wood and when a balanced approach to the whole life-cycle of wood products is taken they can be largely justified against non-preserved wood and alternative materials. It is estimated that about 1.2million m^3 of wood is preserved in Australia each year. This is a mixture of CCA, creosote, boron, LSOP, ACQ and Copper azole treatments.

In general, all recyclers would prefer not to take preserved wood. It may cause problems either during the recycling process or during subsequent recycling steps or final disposal. Possible solutions to recycling preservative treated waste wood may be:

- Direct recycling to other uses where resistance to biodegradation is important (e.g. sleepers → garden use)
- Dilution to legally acceptable levels (though this is usually not acceptable to environmental control bodies)
- Detection and separation (though this has not yet proved to be economically possible[11][12])

The recycling of preservative treated wood waste is probably the largest problem facing wood waste recycling world-wide.

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Development of a wood waste working group in NSW

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In September 1999 the Clean Hunter Centre, in conjunction with the NSW Waste Boards, conducted a "Wood Waste – Exploring the Market Opportunities" Forum, at Parramatta, NSW. The forum brought together speakers from Industry, Research, and Government Organisations to outline the current position and understanding of Wood Waste materials in NSW.

Key aims of the forum were:-

- Determine Opportunities for Wood / Timber Reuse and Recycling
- Identify Issues and Barriers
- Contribute to a Strategy for Successful Outcomes
- Highlight opportunities to provide materials with increased value.

The forum included a series of workshop sessions which focused on identifying the issues and opportunities important to the utilisation of wood waste materials as a resource.

These outcomes provided a platform for the establishment of a Wood Waste Working Group, which have met on a regular basis since November 1999. The group has explored issues such as:-

- Development and progress of a Wood Waste Collection facility
- Australian and International trends in Treated Timbers
- Australian and International trends in Engineered Timbers
- Brief review of research programs being undertaken in Australia and Overseas in the development of applications for Wood Waste materials
- Promote the use of the NSW Waste Boards ARR Network (Waste Exchange)
- Explore the possibility of establishing a CRC for Wood Waste.

Additionally the group has provided a conduit for the establishment of networks and linkages between a range of organisations and associations. A range of projects are currently underway either reporting back to the working group, or being explored between individuals within the group.

The future direction of the Wood Waste Working Group will cover aspects such as:-

- Recommendations for programs to be conducted by the NSW Waste Boards and EPA, relative to data collection, market development, research and development, and infrastructure
- Recommendations on policy to the NSW EPA
- Development of linkages with similar groups throughout Australia
- Accelerate the establishment of market applications for wood waste materials.
- Provide feedback to the broader industry and interest groups at a 2nd Wood Waste Forum in late 2000 or early 2001.

The opportunity to share information and experiences with groups such as those attending this forum will provide extended value to both the programs and relationships which could be established.

Wood waste in New South Wales: analysis, current projects and future directions

M. Warnken

Western Sydney Waste Board

In 1995 the NSW Government legislated the 1995 Waste Minimisation & Management Act. This act set a 60% reduction target for waste disposed. To oversee the reduction in waste to landfill, eight waste management boards were set up to cover the Sydney Metropolitan Area in addition to the Hunter, Central Coast, Macarthur and Illawarra regions. The Waste Board's manage waste in their region through direct control of their member Councils. Each Waste Board recognises that the achievement of waste minimisation will only be met through a partnership approach to waste issues that are cross regional. Wood waste is one such issue.

Based on information from previous projects, in addition to extrapolations from Waste Board data and overseas studies, the amount of wood waste disposed to landfill in the Greater Sydney Region is approximately 350,000 tonnes. This is approximately 10% of the total waste disposed to landfill each year.

For the purposes of the NSW Waste Boards' waste material target definition, wood waste refers to the end-of-life products, failed products, offcuts, shavings and sawdust of all timber products. This excludes forest residues, often referred to as primary wood waste. It also excludes green or garden waste materials such as branches, bushes and tree stumps. Wood waste can be classified into three groups:

1. Untreated Timber
2. Engineered Timber Products
3. Treated timbers

There are four distinctive sources of wood waste in the Greater Sydney Region

1. Commercial and Industrial
2. Construction and Demolition
3. Packaging and Transport
4. Utilities

Wood waste disposed to landfill presents many opportunities, however before these materials can be utilised barriers need to be overcome. Barriers identified include such things as collection infrastructure, stockpile infrastructure, processing infrastructure, physical contamination and chemical contamination to name a few.

To overcome these barriers the Western Sydney Waste Board on behalf of all New South Wales Waste Boards is currently operating a wood waste project in partnership with the Kurnell Land Fill Company. The purpose of this project is to overcome the barriers preventing wood waste utilisation in the Greater Sydney Region. The project is being conducted in accordance with the materials management hierarchy as specified in the NSW Protection of the Environment Act 1997. As a result, wood waste materials are assessed as they are presented at KLF, and by a combination of operational strategies, suitable materials can be recovered for reuse, repair, or reprocessing into defined commodities for subsequent re-manufacture.

Other project activities include wood waste only collection services,(including engineered timber products), wood waste separation and materials handling techniques, processing of problematic wood wastes, marketing of wood waste products and the collation of information into a useable and accessible format. Information gathered as part of the project will be released into the public domain.

The intention of the project is to demonstrate a working model whereby wood waste can be successfully diverted from landfill according to its highest resource value. Once high volume end markets are finalised, it will be possible to create a wood waste infrastructure by replication the project model to form a network of wood waste receival facilities across the Greater Sydney Region. With an infrastructure network established it is then possible to optimise the system to extract maximum economic and environmental return.

Timber recycling in Victoria

H. Lewis

EcoRecycle Victoria

Timber is one of the most wasted materials in Victoria, making up around 12% of all waste going to landfill. Over 500,000 tonnes are thrown away each year, making it the third largest component of the waste stream after clean fill and food wastes.

The main source of this material is manufacturing – furniture, pallets, packaging, wood turning, sawmills, door and window manufacture, and so on. Waste is in the form of offcuts, sawdust, and old packaging materials. The remainder comes from construction, demolition and household sources.

Markets for waste timber are limited, but they include firewood, mulch and compost. High value timber, such as old beams and flooring, is almost always recovered. There are no markets at present for painted and treated timber.

One of the priorities for EcoRecycle Victoria is to support new, higher value markets for timber resources that are currently going to landfill. Projects funded to date include recycling of particleboard back into new particleboard, and use of timber from demolition sources for coloured mulch.

These markets need to be supported through programs with industry to encourage them to reduce waste first, and then to sort and recover any recyclable material. Barriers to greater diversion include the costs of sorting and recycling the wastes relative to disposal charges.

Cat litter from telephone books

J. Clements

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Equinox is a small company concentrating on recycling waste materials. The initial philosophy of Equinox was to gain a high profile in consumer markets for its recycled products by developing a product for sale in supermarkets.

The product chosen was cat litter made from collected telephone books.

This initial product was achieved with assistance from a number sources (including a grant from Telstra and equipment from 'Uncle Toby's').

This talk will concentrate on:

- The initial start-up phase of the company.
- The process developed for cat litter production.
- The problems and opportunities of selling recycled products into consumer markets and against established competition.
- Future directions for Equinox.

The potential for waste wood in particleboard

J. Gardner

D&R Henderson (trading as Monsbent), Particleboard Plant, Yarrawonga Rd., Benalla, Vic 3672, Australia

Monsbent particleboard manufacturing plant at Benalla currently utilises reclaimed softwood material from our onsite sawmill and residues from local suppliers. Plans are underway to expand the manufacturing plant to produce particleboard from recycled "industrial cleans" from our customer base and other reliable sources. Urban and commercial wood waste is seen as a valuable resource at Monsbent with great potential for company growth.

A brief discussion will be made of D&R Henderson particleboard manufacturing followed by an outline of plans for manufacturing particleboard form recycled industrial offcuts and urban waste softwoods.

Production and testing of charcoal briquettes from *Pinus radiata* wood residues

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Production of sawn timber from *Pinus radiata* is an important sector in Australia. These sawmills are typically large with log throughputs of over 300,000 cubic metres per annum. Residues in the form of sawdust, bark and dockings are often used as fuel for timber drying but these are far in surplus to the mill's energy requirements. A project was undertaken to carbonise sawdust residues in a fluid bed carbonisation unit and to produce charcoal briquettes for cooking purposes. The fluid bed system was based on the CSIRO process (1) which burns the volatile by-products of carbonisation from which process heating can be recovered for the kiln drying of wood.

Experimental Results

Charcoal was produced from green *P. radiata* sawdust in a fluidised bed. The charcoal was moulded into lens shaped briquettes. A test cell was designed and built to evaluate and monitor burning properties of briquettes. The tests conducted include ignition times, cooking temperatures and cooking times.

Ignition tests showed that the test briquettes were easier to ignite than commercial briquettes using brown coal based charcoal with ignition 2.7 times faster. The pine char briquettes burnt for 2.3 hours, approximately half the time of the commercial briquettes measured at 4.1 hours. Maximum cooking temperature was 180°C measured 25 mm above the briquette compared with 195°C for the commercial product. Although the combustion time and cooking temperatures for the pine charcoal test briquettes were less than the commercial product, these values were considered adequate for a normal cooking session.

Drop tests and compressive strength tests on the briquettes were also conducted which showed that they could withstand the rugged treatment that normal handling and storage conditions generally require. Drop test onto a steel plate from a height of 1.8 metres showed no breakage after 20 drops for all briquettes. Ultimate compressive strength measurements showed a value of 0.28 MPa for the pine briquettes compared with 0.21 MPa for the commercial briquettes.

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Differentiation of wood waste utilisation options using a multiple criteria decision making system

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Wood waste is a significant contributor to the New South Wales Greater Sydney Region waste stream, accounting for approximately 10% of the total waste disposed to landfill. A large proportion of wood waste is engineered timber product such as particleboard, medium density fibreboard and plywood. Wood waste may be processed into a variety of products that can be grouped under four main processing options, Re-use, Direct Recycling, Indirect Recycling and Energy Generation. There remains, however, the problem of differentiating between options for wood waste utilisation according to techno-economic, environmental and socio-political criteria.

This presentation outlines a process for structuring a multiple criteria decision making framework that identifies critical attributes for measurement. This in turn facilitates a first order decision based on the decision maker's values and objectives according to a variety of scenarios and sensitivities. Such an approach enables the making of a decision at a strategic level by streamlining and ordering the requisite information necessary to inform the decision.

Firstly, the decision problem was clearly defined, the decision makers were identified and the decision objectives were articulated. In this case the problem was defined as "what is the optimum technology option for utilisation of wood waste coming into a regional wood waste receival facility". The decision makers included the owner of the receiving facility as the primary decision maker, the NSW Waste Boards, the Environment Protection Authority and the end user of the wood waste product as other relevant decision makers. Stakeholder views were incorporated through a combination of interviews and forehand knowledge of this problem area.

Motivations driving the decision making process included the minimisation of waste to landfill, avoidance of the section 88 landfill contribution, new business opportunities, resource utilisation at the material's highest resource value, penalty avoidance and availability of cost competitive product.

Decision alternatives for wood waste utilisation included landfill, re-use of materials, feedstock for particleboard, compost/mulch, primary energy feedstock and supplementary energy feedstock. The criteria by which alternatives were measured were the techno-economic, environmental and socio-political issues associated with each alternative.

The system boundary for the decision identified activities that were included in the decision making process. It excluded point of wood waste generation activities and collection and transport, as these were identical across all decision alternatives. Activities at the receiving facility, processing of wood waste, loading and transport and the end user of the wood waste product were included within the system boundary.

The problem was structured by organising an objectives hierarchy that identified all of the relevant attributes of each decision criteria (these being techno-economic, environmental and socio-political). Weights were allocated across criteria (summing to 1) to indicate the importance of each criterion to the decision maker. Similarly, performance at each attribute level within the hierarchy was aggregated for each criterion.

Attributes were scored using a numerical estimation technique on a scale between 0 and 100. The worst outcome amongst the alternatives for any given attribute was arbitrarily set at 0. The best outcome amongst the alternatives for any given attribute was arbitrarily set at 100. The remaining alternatives were spread proportionally. between these two extreme values.

This methodology has the capability of addressing scenario analysis and sensitivity studies within each scenario and can be used to guide the development of new technology options. Furthermore it can be used to support policy development and provides a defensible approach to complex decision making with multiple stakeholders.

Recycling durability: timber preservation with extractives from white cypress

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Introduction

The possibility of recovering potentially useful compounds from sawmill residues of the durable timber species white cypress (*Callitris glaucophylla*) was recognised long ago. Oshima (1923) (1) transferred volatile oils from cypress wood to Japanese pine, protecting it from termite attack. CSIRO researchers (2-4) studied cypress extractive chemistry and identified some of the compounds contributing to the resistance of this timber against decay fungi and termites. From a sustainable annual cut of about 300,000 m^3, the Australian cypress industry produces about 130,000 m^3 of sawn product, which contains about 15% (20,000 m^3) of non-durable sapwood. It also produces about 45,000 m^3 of sawdust and shavings, which contain about 80% (36,000 m^3) of heartwood particles. If the durability-conferring extractives present in the residues could be recovered, and a method could be developed to achieve penetration of the refractory cypress sapwood, there would be more than sufficient of this material to upgrade the durability of all of the sapwood on the entire sawn output to the equivalent of heartwood. Sawn recovery might thus be improved, because the amount of sapwood present on exterior products would no longer need to be restricted. Product quality (longevity in exterior applications) and hence market acceptance and value might also be improved. In 1998, the Australian cypress industry supported the commencement by QFRI of a research project with these aims, funded by the Forest & Wood Products R&D Corp., the Australian Cypress Industry Development Fund and the Queensland Department of Primary Industries, and managed by the New South Wales Forest Products Association. The role of each of these organisations is gratefully acknowledged.

Extraction of residues

Toluene was the most efficient of the solvents tested in removing bioactive compounds from sawdust residues. Methanol was slightly inferior, but also extracted considerable quantities of additional non-active compounds that may be important for other reasons (see later). 100 Kg extraction charges were heated from ambient temperature to boiling point in four hours, and reflux continued for varying periods. Maximum extraction efficiency was obtained when reflux continued for at least 30 minutes, with solvent:sawdust ratios of at least 4:1.

Penetration of cypress sapwood with extract solution

Cypress sapwood had never been successfully pressure-treated before, and most processes evaluated during this work did not achieve consistent penetration. Success was eventually achieved with a process commencing with a long period at high vacuum (-97 KPa) followed by a long period at +1500 KPa, during which the charge was superheated to 120°C. An alternating pressure phase was then applied for two hours during cooling. This 'full cell' process has impregnated all end-sealed specimens evaluated to date, and has been used to prepare full-sized decking material for a long-term field trial. Strength reduction was minimal (MOR down 6%), but stiffness was unaffected. However, process time is undesirably long, and further work is proposed to increase the production rate. Also, because the full cell process entails considerable solvent consumption, recovery systems will be required.

Extractive activity
Laboratory bioassays conducted on fractionated extracts indicated that most activity against fungi and termites resides in volatile, less polar extractives. While many of these compounds have been identified, it is not proposed to routinely isolate them for use alone in preservation. Other less active or inactive extractives may act as synergists, or increase water repellency, or prevent loss of active compounds through evaporation, oxidation or biodeterioration. Our approach has been to use the crude extract, using the greatest quantity and diversity of natural cypress extractives. The translocated crude extractives prevented subterranean termite attack of treated radiata pine (in lunch boxes on termite mounds) at about 50% of their original concentration in cypress heartwood. In an underground 'hutch test' (D, Gardiner, SFNSW), treated cypress sapwood was protected from attack at 30% of the original concentration. Prevention of basidiomycete fungal decay of radiata pine in soil jar tests required an approximately equal concentration to that of cypress heartwood. Required retentions are being more precisely determined in ongoing aboveground field service tests. Questions remain about suitable methods for standardising extract activity between batches, and specifying 'preservative' retentions in the treated product. Analytical methods have been developed for the more bioactive components, but determination of 'total' extractive concentration may also be required for ongoing treatment quality control. A spot test for assessing penetration of cypress heartwood extractives into treated timber has also been developed.

Further information Additional data is available in five papers (5-9) presented at the May 2000 annual meeting of the International Research Group on Wood Preservation, as listed below.

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Wood waste from an electricity production perspective

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The global move toward a reduction of greenhouse gas emissions is likely to fall largely upon electricity generators and large users of energy in the first instance. "Wood waste" has a significant energy potential in the absence of higher value uses, the conversion of biomass to energy can help to reduce the problem of landfill or of otherwise removing the residue, and simultaneously displace the generation of greenhouse gases. The use of biomass in electricity generation benefits from the fact that many of the conversion processes are already well understood by the energy industry. It is probably the most advanced of the non-hydro renewable energy sources, and has the advantage of being of being dispatchable. Co-firing with coal in existing power stations is an attractive option, however dedicated biomass plants using various "wood waste" products can improve flexibility of fuel types and reduce the significant problem of transport costs. There are issues still to be resolved relating to fuel quality, handling, and combustion characteristics.

Commercial bioenergy opportunities for reducing net carbon dioxide emissions in Australia

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Australia has a wide range of policies in place to address greenhouse issues.

Specific Commonwealth government funding for renewable energy amounts to $387 million to be committed in the first half of this decade.

The commercial and technical capacity of biomass to energy (bioenergy) to meet the governments mandated target for the generation of electricity from renewable sources is expected to be in the order of half the total target of 9,500 GWH by 2010.

The ongoing development of technologies and markets to produce renewable transport fuels also provide real opportunities for new bioenergy in the medium and longer term.

It is likely that the long-term realisation of these commercial opportunities will be part of a suite of commercial benefits and a separate suite of environmental benefits associated with both the production and use of biomass based renewable energy sources.

Manufacture of termite resistant MDF from white cypress pine residues

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Introduction

White cypress pine (*Callitris glaucophylla*) is a medium sized coniferous tree found in inland areas of Australia with moderate rainfall (300-650mm p.a.). White cypress pine wood is dense and its heartwood is particularly resistant to termite attack (1). There are large numbers of sawmills processing white cypress pine for use as flooring, cladding and fencing. The demand for white cypress pine wood exceeds supply, but many sawmills do not have profitable outlets for their residues (sawdust and chips). Consequently such materials are often regarded as waste products rather than as valuable by-products of sawmilling, as is the case for radiata pine (*Pinus radiata*) wood chips. Hence there is an obvious need to develop profitable ways of using cypress pine residues thereby reducing the need to dispose of them by uncontrolled burning. In work undertaken previously we showed that it was possible to manufacture a termite resistant, insecticide-free, particleboard from cypress pine heartwood chips (2). This finding led us to examine further the use of cypress pine residues as a means of increasing the termite resistance of wood composites. In the current study medium density fibreboards (MDFs) containing different levels of cypress pine and non-durable wood species were manufactured in a commercial plant and then subjected to a bioassay using the subterranean termite species *Coptotermes lacteus*. The aims were to determine whether MDF containing cypress pine possessed increased resistance to termite attack compared to a control manufactured entirely from non-durable wood species and the relationship between the cypress pine content of boards and their resistance to termite attack.

Materials and Methods

MDFs containing different levels of cypress pine were manufactured in a commercial plant. Bark-free cypress pine wood chips containing both sapwood and heartwood were obtained from commercial sawmills. Chips were screened to remove fines and oversized chips and then washed to remove grit and other impurities. They were then blended with similarly screened and washed slash pine (*Pinus elliottii*) and hoop pine (*Araucaria cunninghamii*) wood chips. The chip furnish consisting of the appropriate levels of the various wood species was fed via a screw conveyor into a digester where it was thermoplasticised at 170°C for 3-5 minutes and defibrated immediately afterwards in a 54-inch Andritz Sprout Bauer refiner. A hydrocarbon wax (<2%) was injected into the refiner housing during the defibration process and, immediately after refining, the fibres were blended with a melamine-urea formaldehyde resin. Fibres were dried to a moisture content of 11-12% in a blowline and stored in a cyclone. Dry fibre mats were vacuum formed, reduced in height using a Siempelkamp pre-compressor and then hot pressed in a Siempelkamp Contiroll (Mark 6) continuous press. Boards were then trimmed and sanded to a final size of 2400 x 1200 x 18mm. Samples measuring 25 x 25 x 18 mm were cut from MDF boards and from solid pieces of cypress pine heartwood and sapwood and slash pine sapwood. Samples were oven dried in a vacuum oven (40°C and –95 kPa) for five days and weighed to obtain their initial mass. They were then bioassayed against *C. lacteus* using laboratory methods modified from Evans *et al.* (1997) (2). At the conclusion of the bioassay (5 weeks), MDF and wood specimens were oven dried as above, reweighed to obtain their final mass and mass losses due to termite feeding determined.

Results and Discussion

MDF specimens containing cypress pine fibre were much more resistant to termite attack than the control, which consisted of non-durable slash (80%) and hoop pine (20%) fibre (Table 1).

Table 1. Mass losses of MDF and wood specimens during the termite bioassay

Specimen	Initial mass (g)	Final mass (g)	Mass loss (g)	% Mass loss
MDF, 80% slash pine: 20% hoop pine	7.38	4.96	2.42	32.8
MDF, 11.4% cypress : 88.6% slash pine	7.54	6.01	1.53	20.3
MDF, 19.2% cypress : 80.8% slash pine	7.52	6.51	1.01	13.4
MDF, 34.2% cypress : 65.8% slash pine	7.39	6.74	0.65	8.80
Cypress pine heartwood	8.25	8.11	0.14	1.70
Cypress pine sapwood	7.81	6.53	1.28	16.4
Slash pine sapwood	5.11	1.09	4.02	78.7

Mass losses of cypress pine heartwood specimens during the bioassay were small (<2%, Table 1), in accord with previous studies that have shown that cypress pine heartwood is resistant to termite attack (3). The slash pine wood blocks were all heavily attacked (Table 1), thus verifying the vigour of the termites used in the bioassay. Cypress pine heartwood contains a variety of extractives that are either toxic or repellent to termites (4). Therefore the increased termite resistance of MDF containing cypress pine compared to the control is most likely to be due to the insecticidal effect of such chemicals on *C. lacteus*. There was clearly an inverse relationship between the cypress pine content of MDF specimens and mass losses during the bioassay (Table 1) and therefore the termite resistance of the MDF could be further enhanced by increasing the proportion of cypress pine fibre in the boards.

Conclusion

MDF specimens made from blends of white cypress pine and non-durable wood species showed greater resistance to termite attack than a control manufactured from non-durable species. Such improvements to the durability of MDF could provide an incentive to manufacturers of MDF to use cypress pine wood chips in their production processes. This would provide a valuable outlet for waste residues produced by cypress pine sawmills and could reduce the need to dispose of them by uncontrolled burning.

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Recycling treated wood waste

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Until recently preservative treated wood waste was generally disposed of by burial in landfill. This practice has however been prohibited in some locations in Australia and more generally efforts are being made to reduce the quantity of waste material, of whatever type, being placed in landfill. In response to these changes in waste disposal practices other options are being sought for recycling treated timber after it has been removed from service. A variety of possibilities have been considered and this paper discusses the current state and future of these options.

Direct or indirect reuse

Given that a significant proportion of treated wood products are removed from service prior to the loss of structural integrity, those products having appropriate dimensions may be suitable for direct reuse. Recycling of this nature may involve a further processing step, *e.g.* resawing, to produce the desired end product. This approach has been used in Italy, where 74% of treated utility poles are reused as garden timbers (1), and whilst it makes efficient use of the original treated commodity, it is however only an interim measure since the reused product will eventually require disposal.

A variety of products have been developed where the treated wood waste has been incorporated into a composite product. Aside from some traditional engineered wood products, *e.g.* particle board (2), wood-cement and wood-plastic composite materials incorporating some proportion of treated wood products may be a viable option (3). The indirect reuse of treated wood in this way does however present some significant problems. For instance, some treated wood is notoriously difficult to glue and where the manufacturing process involves high temperatures, *e.g.* hot pressing of board products, organic preservatives can decompose to volatile products which may present a health risk to manufacturing workers. The use of composite products incorporating treated wood waste may be restricted to applications where the product may actually benefit from the presence of preservative, *e.g.* applications subject to weathering or insect infestation.

Preservative removal - component recycling

An alternative approach to recycling treated wood is to remove and recycle the preservative components, after which the fibre can be reprocessed by conventional means. A considerable amount of the work on preservative extraction has focussed on CCA treated products, where various organic and inorganic acids have been tried with mixed success (4). The use of supercritical carbon dioxide as a solvent for extracting preservatives shows particular promise, although the high capital costs associated with the necessary equipment may inhibit the commercial development of this technology. Patented processes for removing CCA and polyaromatic hydrocarbons (5) from treated wood have been developed. The majority of extraction procedures are designed specifically for certain wood preservatives, such that it would be necessary to have procedures in place for separating wood waste into streams based on preservative type. The problem of sorting treated from non-treated wood waste is also acknowledged as being significant, and various techniques have been evaluated for this purpose (6).

Biodegradation

Some microorganisms that degrade wood are also able to metabolise certain organic preservatives, producing harmless by-products. A pilot study in South Australia has successfully remediated PCP contaminated soil from a wood preservation site by composting (7). Other microorganisms can solubilise inorganic preservatives such as CCA (8). In general however these organisms only function in a controlled environment (pH, temperature, oxygen level) where the concentration of preservative is relatively low. To achieve reasonable rates of biodegradation it may therefore be necessary to reduce the effective concentration of preservative, *e.g.* by blending treated with untreated waste or by first subjecting the treated wood to an extraction procedure designed to reduce the preservative content. One recent study concluded that acid extraction combined with bacterial fermentation should remove over 90% of CCA components from treated timber (9).

Combustion

The combustion of treated wood waste to produce energy and an ash for recycling is an attractive method of disposal, in that it may not be necessary to sort treated from untreated wood. Much of the work in this area has focussed on the combustion of CCA treated products. The conditions required to minimise the volatilisation of heavy metals and arsenic are now reasonably well established, *i.e.* low temperature pyrolysis under a reducing atmosphere. Semi-industrial scale trials in Europe have demonstrated the potential of the technology for commercialisation, whilst meeting the stringent environmental regulations on particle and gaseous emissions (10).

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The effect of "dull" planer knives on adhesive bond performance with radiata pine and eucalypt

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Surface preparation of timber before gluing is critical for effective bonding. Planing is recognised as the optimum method of surface preparation. However, experience in industry has shown that this doesn't always ensure a surface conducive to forming good bonds. This project evaluated key operating variables for planing timber to determine the factors that may compromise bond strength. Parameters investigated for surface preparation of *Pinus radiata* and *Eucalyptus regnans* included; feed speed (knife mark spacing), knife jointing and heel development, knife sharpness and glue type.

Of the parameters investigated, knife sharpness had the greatest impact on glue bond strength. Good glue bonds were achieved using sharp jointed knives, but when the knives were dull, a reduction in shear strength was observed. The dull knives resulted in shallow wood failure, which indicated that damage to the surface had occurred. This was confirmed by microscopic examination of shear block cross-sections, which showed damaged cells and poor adhesive penetration when dull planer knives were used.

A survey of moisture content of timbers in open and sheltered exposures across South East Asia

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Introduction

CSIRO, with partners from Thailand, Vietnam, Indonesia and the Philippines, have undertaken a cooperative tropical research program. One of the project aims is to provide a joint development of regulations governing the durability of components in buildings and infrastructure. As part of this program a survey of moisture content (MC) in timber was undertaken at a number of sites in each country. This paper reports the results of this survey which investigates the variation of moisture content in timber, as this is an important factor in wood degradation.

Experimental

Four species of Australian Timber were exposed at 2 sites in Australia, 4 sites in Thailand, 2 sites in Vietnam, 5 sites in Indonesia and 3 sites in the Philippines. The species were Spotted Gum, Mountain Ash, Douglas Fir and Radiata pine. Three species of Thai timbers were exposed at the Australian and Thai sites. These timbers were *Dipterocarpus alatus*, *Shorea obtusa* and Teak (*Tectona grandis*) (1).

The timber was made up into sticks of approximately 35x20x200mm, with the end grain covered with resin on the top and bottom. The samples were hung vertically by a hook, with three samples of each timber hung in an exposed position and another three of each timber sheltered from direct rain by a small roof. The samples were weighed at regular intervals, mostly every three months, and in some cases every month. The moisture content was calculated based on a dry weight obtained from oven drying the timber at the end of the exposure. Where the timber is still being exposed the moisture content is based on assuming all the samples of each species had the same moisture content initially as the samples that have been oven dried.

Results

Generally the average moisture content of the timbers ranging from High to Low were Radiata Pine > Mountain Ash > Douglas Fir ~ Dipterocarpus Spp. > Spotted Gum ~ Shorea obtusa > Teak. Generally the variability of the MC in each of the species from high variability to low is as follows; Radiata Pine > Mountain Ash > Douglas Fir > Dipterocarpus Spp. >Spotted Gum > Shorea obtusa > Teak. The wood species that had the higher average MC also had the most variability in its MC.

Indonesia
Timber was exposed at 3 locations on the Island of Java and two locations on Bangka Island off of South Sumatra. The MC at the Java locations varied in a similar way with some slight variation due to local climates. After the initial take up of moisture there was a high MC of approximately 16% in May then a low of 12% in August and another high occurring in January. For the samples exposed at the two locations on Bangka, there are two patterns. In the town of Mentok, which is an industrial marine site, after the initial moisture uptake the MC reached a high level of around 16% and the stayed around that level for the monitoring period. In the town of Jebus which is a pure marine site, after the initial moisture uptake the MC only reach a level of around 14% for May to August and then was lower in January on average below 10%.

Vietnam
Wood samples exposed in Hanoi showed an average MC of 16% but the MC between the timber species showed a variation from 12% for Spotted gum to 20% for Radiata Pine. There was no large seasonal variation except for a slightly higher MC in January and August. Ho Chi Minh City also shows a higher MC around September - October.

Far North Queensland (FNQ) Australia
Timber was exposed at two locations in FNQ, Walkamin on the Atherton Tableland and Cowley Beach just south of Innisfail within a couple of metres of the ocean.
Both these sites show the same seasonal pattern in MC with high MC during the wet season around January and low MC in the dry season around September. The only difference is that at Walkamin the MC in the different species is very similar at 13 – 14% in the "Dry", but with more variation between the species in the "Wet". While at Cowley Beach there is more variation in the "Dry", between 14 and 19% and higher and more variable MC during the "Wet".

Thailand
The average MC in Bangkok, Samut Prakan and Rayong tends to be around 7 to 11%. In Bangkok and Samut Prakan there is slightly higher MC in May while Rayong has higher MC between March and November. MC at Phuket tends to be higher (10 and 15%) with its' wettest period between May and September.

Conclusion
Overall we found that the MC contents in South East Asia were lower than we expected and it seems that the highest MC were in Far North Queensland. Further analysis will be carried out to confirm the trends seen here. With the exception of the monsoonal period the openly exposed timber did not have appreciable higher MC than the sheltered.

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Grade recovery from Queensland exotic pine plantations

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Sawing studies conducted as part of the Forestry and Wood Products Research and Development Corporation (FWPRDC) project - Breeding objectives and selection criteria to maximize the value of sawn timber (1) required a standard research protocol. This protocol has been used for other recent sawing studies providing directly comparable results for several studies carried out since 1996.

The processing strategy was designed as part of the FWPRDC project to mimic the industry partner, Hyne and Son Pty Ltd's, Tuan sawmill process. That is, all stems are merchandised to limit log sweep while maximising the recovery of 4.8 to 6.0m log lengths from stems topped at 15cm diameter under bark. Logs are measured prior to sawing to assess: (a) small and large end diameter under bark on two principle axes (longest and shortest), (b) sawlog length to the nearest 10 cm, and (c) log sweep measured as deviation from a string line at 1, 2 or 3 positions as necessary. Logs are then sawn to maximise the recovery of 90 x 35mm and 70 x 35mm dressed framing. Evaluation of finished product includes collating results for: (i) green sawn recovery of both sawn structural (70 x 35mm and 90 x 35mm) and board products (less than 35 mm in thickness), (ii) in grade or out of grade based on visual grading of distortion, knots, incidence of resinosis (particularly resin shakes) and other graded features, and (iii) values for MOE and F-grade from machine stress grading for the in-grade structural recovery.

The FWPRDC sawing studies provided an opportunity to compare the quality of structural grade timber recovered from routine plantings of first generation improved, 26-year-old slash pine (*Pinus elliottii* Engelm. var. *elliottii* L. & D.) (PEE) and 20-year-old Caribbean pine (*Pinus caribaea* Morelet var. *hondurensis* Barrett & Golfari) (PCH), as well as full-sib progenies of 24-year-old PCH and 31-32-year-old F_1 hybrids of slash × Caribbean pine (PEE x PCH) from genetic experiments (2).

Although these taxa samples are not directly comparable due to their age and pedigree differences the grade recovery variation observed between them appears to be more attributable to age than any inherent wood quality characteristics of the taxa. The distribution of structural material recovered by MOE (stiffness) classes, as a proportion of total structural dried dressed material recovered, displays a large degree of overlap. There is a tail of material of higher stiffness in the older hybrid sample and a skewing of the distribution into the lower stiffness classes for the 20-year-old PCH sample. The overlap in the distributions is so large that, for all practical purposes, there is no significant difference in the quality of the taxa for structural sawn timber products

Clonal Experiment 221 GYM was sampled at age 13 years to examine among- and within-clone variation in graded product recovery and relationships with some selection and screening traits. Three ramets from each of 20 clones were assessed. The distribution of structural framing recovered, as a proportion of total structural dried dressed material recovered, was allocated to MOE classes for each clone. To examine which traits contributed to the stiffness of the top 20% and bottom 20% of these clones, they were ranked for each trait. Examining the means of both the trait rankings and the trait values indicates that basic density and stem volume are very important to clone performance at this age. The latter is probably indirectly correlated to wood density reflecting the better recovery of higher density outer wood from larger stems. Stem straightness, spiral grain uniformity (assessed as spiral grain standard deviation) and mean branch diameter also contributed significantly when mean rankings are compared (3). There is also considerable variation among the traits for individual best and worst clones demonstrating how complex the interaction of traits can be.

The same sawing approach is currently being used to obtain sawing study results from a 16-year-old PCH spacing trial. This trial was established by thinning routine plantation stands to 100, 200, 300, 500 and 750 stems per hectare when it was 3-years-old. The results of this study will be added to other silvicultural trial data as part of a decision support system and modelling project.

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Successful acoustic segregation of *Pinus radiata* logs according to stiffness

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Abstract
Wood stiffness varies enormously both within and among trees, so that it is inevitable that low-grade solid wood products are produced from some trees. Accordingly, it would be highly desirable to segregate logs to ensure that only those logs with predominantly high stiffness wood are processed into structural lumber products. This study examined whether sound flight velocity (m/s) could be used as a direct measure of wood stiffness to allow such segregation. Trees of radiata pine were measured before and after harvest with a non-destructive acoustic device (stress wave timer) to see if there was a relationship between sound wave velocity in either standing trees or logs and machine stress-grades of boards derived from those trees and logs. The speed of sound along logs was sufficiently closely correlated with wood stiffness to allow logs to be sorted into classes. A highly significant and positive relationship was found for acoustic measurements made in logs and a weaker, but still significant, relationship existed for acoustic measurements made in standing trees. Such, segregation of logs according to wave velocity measured in the field may save a large sawmill between $1m and $4m each year.

Introduction
Wood stiffness and strength varies greatly among and within stands of *Pinus radiata* and this offers an opportunity to improve the way logs are sorted at harvest time and allocated to processors to optimise the value of lumber recovered. One way of achieving this is to allocate wood with predominantly high stiffness properties to structural markets and wood that does not meet this criteria to reconstituted wood processors (Walker and Nakada 1999). Currently, wood supplies are sorted at harvest only to a limited extent by using surrogate indicators, such as log size, the number and size of knots, straightness, etc that are not closely correlated with wood stiffness or strength.

However, it is possible to use sound wave technologies to more directly assess the mechanical properties of timber (Ross 1999, Ross *et al*. 1997, Kaiserlik and Pellerin 1977). There is a strong relationship between stiffness of logs (measured acoustically) and mean stiffness of boards cut from the logs (measured using transverse vibration techniques) (Ross *et al*., 1997, Ross *et al*. 1991). Although actual correlations are highly species-specific. For example, the correlation was $r = 0.57$ for Balsam fir and $r = 0.91$ for White spruce. Correlations for individual boards were poorer ($r = 0.41$ and $r = 0.71$ respectively) because of the variation between boards cut from the same log.

Nakamura and Arima (1994) reported a good relationship between stiffness and the square of the wave velocity for standing trees across a range of stands. In their study, they calculate MOE from wave velocity from the equation:
$MoE = v^2 * \rho/g$

in which MOE is the Modulus of elasticity, v is the sonic velocity, ρ is the density and g is acceleration due to gravity (=980cm/s). Variation in MOE is due to v and ρ and a good relationship seems inevitable from this equation.

There are numerous reports of a strong relationship between sound velocity and stiffness of logs, but stiffness or strength was usually determined under controlled laboratory conditions for clearwood. Comparatively few studies have examined the relationship between acoustic sound velocity and machine stress grades, which take into account the effect on stiffness of branch knots and defects both of which reduce stiffness and strength. (Ross 1999, Snyder *et al.* 2000). Further, there are few reported studies linking acoustic measurements of standing trees to machine stress grades of boards sawn from them.

Walker and Nakada (1999) showed that acoustic measurements allowed the sorting of *Pinus radiata* logs according to stiffness. However, this still relied on using felled trees. Clearly, it would be desirable to have a method that measured standing trees non-destructively, but there are a few reports that have related standing tree and log acoustic measurements to machine stress grades.

Nevertheless, as this study shows quick and non-destructive acoustic measurements can be used as a direct measure of wood stiffness in either standing trees or logs of radiata pine. Ultimately, this should lead to a more efficient use of the resource by directing the appropriate quality timber to the right market.

Assessment of the pulpwood quality of standing trees using near-infrared spectroscopy

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In Australia, considerable effort has been directed at improving the pulp yield of plantation grown trees through tree breeding programs. However, an improvement in pulp yield relies on the assessment of large numbers of trees. Traditional methods of assessment are expensive, time consuming and destructive inhibiting their use. Cores can be extracted non-destructively from standing trees using TRECOR, a handheld motor driven drill. The cores are milled, their near-infrared spectra obtained and pulp yield estimated using an appropriate calibration model. The height at which the core is taken is very important. It must represent the whole tree and sampling must be easy and practical.

The longitudinal and radial (within-tree) variation of pulp yield for 15 *Eucalyptus nitens* trees was examined using near-infrared spectroscopy (NIRS). The trees were taken from three families (five trees per family) selected for giving high, medium and low pulp yields respectively. Three trees (one from each family) were examined in detail. Maps of within-tree variation of pulp yield were developed. Pulp yield was found to be highly variable within individual trees and between trees of the same family. The yield of samples from 10 % of tree height (approximately 2.2 m) gave the best correlation with whole-tree yield. Samples from 5 % of tree height (approximately 1.1 m) gave a slightly lower correlation but provided a more convenient sampling height.

Ten *E. globulus* and ten *E. nitens* trees growing on five sites in Australia were used to examine the longitudinal variation of pulp yield. Trees from sites in Tasmania, Western Australia and Victoria were sampled. The optimal sampling height for *E. globulus* was 1.1 m. No single sampling height could be recommended for *E. nitens*.