Changes in markets, technology and resources: prospects for wood-based products

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Revised manuscript received 20 December 2002

Summary

Innovation in the design and manufacture of substitute wood products has made inroads into virtually all our traditional timber markets. The difficulty in re-establishing mass markets for many of these products may possibly arise from changes in building culture whereby the use of substitute products has become established as the industry norm and streamlined through architect–builder–contractor relationships. It is argued that future prospects for wood products will depend on:

- forest industry adoption of electronic technology to enhance communication in the value chain;
- incorporation of market intelligence-gathering and processing through electronic communication with end users;
- simplification of products and the number of grades, sizes and durabilities available to the market;
- incorporation of simplified procedures for designing in wood (incorporating design durability principles) into university and TAFE training of architects, engineers and building science students;
- integration of component manufacturing and building procedures.

New technologies are under development that can potentially automate the manufacturing of wood-based components using wood that has been engineered to meet required performance attributes. Traditionally, species and grades were selected to meet specification requirements for the component.

Keywords: forest products industries; wood utilization; wood properties; wood technology; design; engineering; materials; buildings; microwave treatment

Introduction

Markets for solid wood products have traditionally been dominated by the construction (70%), furniture (20%) and packaging sectors (5%). Over the last 15 years, the per-capita consumption of solid wood products has continued to decline. The erosion of traditional markets for solid wood is very evident. Building foundations, for example, are now dominated by concrete slabs, to the extent that many builders do not consider alternative pile or stub foundations and the traditional timber floor. Even when new homebuyers specify timber floors, there is now a tendency to float thin boards (often veneer flooring products) on the concrete slab to simulate the traditional floor. Technology is potentially available for designing solid (‘traditional’) flooring which is durable, dimensionally stable and hardened. However, even with competitively priced products, it is difficult for the timber industry to compete with the now-established building practice.

Preservative-treated wooden piles provide foundations that use mechanised production, are fast and simple to install, and durable. Pile foundations are arguably a better form of construction from an environmental perspective. They are also potentially more durable when considered from the perspective of a homeowner’s tendency to breach moisture barriers by building gardens against the veneer brick walls of the house. It will take promotion and advertising, possibly a generation of retraining of builders, and perhaps some form of alliance between builders and the timber industry, to regain the market for wood-based foundations.

House framing is probably the single most expensive item in house building, representing about $15 000 for an average dwelling (A. deBruin, Auspine, SA, 2002, *pers. comm.*). In Australia, there is pressure to reduce the dimensions of timber used in traditional timber frames. But from an Australian forest industry perspective, consideration should possibly be given to adopting the sizes of North American framing systems (100 mm × 50 mm), so that domestic framing production is linked with potential export markets. The US has a decay and termite problem. New treatment technologies developed in Australia could give export framing an edge on the US market.

Timber framing is under pressure in Australia. Steel is cheap to manufacture and streamlined in terms of size and quality, whereas timber is produced in a multiplicity of sizes and qualities. The building work force is also becoming more skilled in steel fabrication. Conversely, despite advances in pre-fabricating timber frames for delivery to building sites, there appears to be some resistance to such rationalisation. Traditional building

This paper was presented at a conference, ‘Prospects for Australian Forest Plantations 2002’, held on 20–21 August 2002 at Canberra, ACT.

practices of fabricating frames on site appears to be a preferred option. The use of steel purlins in roof construction is gaining in popularity and will potentially lead to further erosion of the traditional timber framing market. Interior joinery has largely been replaced with pre-painted moulded timber look-alike medium density fibre-board (MDF). Plastic is also making an inroad into this market. Even plaster mouldings have achieved a revival.

Timber weatherboards have traditionally been made of softwoods imported from Europe. Radiata pine has not been favoured as a substitute because of its propensity to check in service. New technologies are being developed that can improve the aesthetics and durability of weatherboards and reduce the need for maintenance. Wooden weatherboards, however, have now lost significant market share in preference to brick veneer.

Irrespective of our ability to develop new generations of products, unless we can change building culture, innovation in the use of wood-based products will be difficult to achieve. There is also a paucity of market information relating to the substitution of wood-based products.

Market requirements

The practice of wood science has traditionally defined the performance attributes of different species and matched these against market requirements (Vinden 1992). Components that were traditionally manufactured from wood, for example framing, windows, doors and joinery, were selected from wood species that could provide some consistency in performance. However, innovation in the design and manufacture of substitute products has made inroads into virtually all of our traditional timber markets, such that it has become increasingly difficult to retain mass markets for specific wood products. An example is the wooden window.

Few would argue that for quality and aesthetic appeal, most homebuyers would prefer well-designed and finished timber windows. In the 1960s, timber dominated the window market. However, with the innovation of aluminium windows and durable powder coatings, the mass market has been lost. Wooden windows manufactured in the 1960s were generally of poor design. Coatings needed regular maintenance. Timber tended to move, check and decay. Designs were uninspiring. Fabrication was labour intensive and delivery haphazard. Today, wooden windows are a specialist item. They are expensive because they are fabricated as one-off components. Ordering and delivery are more complex than purchasing standard designs off the Internet with immediate delivery. Today, we have developed innovative treatments for wood that can provide durable coatings and freedom from decay, yet only a small fraction of new buildings use wooden windows. With today's automated production technologies, we have the ability also to compete on price in the mass market for timber windows. The difficulty is that the new generation of builders, specifiers and architects have relatively little training in the use of wood in construction. Without the economies of scale from mass production, the ability of timber windows to compete on price is reduced.

Design

Engineered products

Solid wood products pose problems for architects and engineers because of dimensional instability, surface degradation and checking associated with UV exposure. They also display instability associated with changes in relative humidity, biodegradation due to fungi and insects, and variability in quality (strength, elasticity, hardness and toughness). Traditionally, these characteristics have been countered by selecting particular species for specific end uses, knowing the limitations that may apply in preparing wood for a particular end use and, unfortunately, accepting that the species, grade and quality required might not be available at any particular time. In many instances, the information required by an architect or engineer may not be available. For example, while the relative natural durability of a particular species may be tabulated, it is often difficult to translate the durability class into a life expectancy for a component manufactured from the species.

Design durability

The difficulty of providing suitable information for architects and engineers is approached through design durability. In effect, design durability is the probability that a manufactured component will perform as expected in any defined environment. The engineer is required to define the environment to which the building element will be exposed, and then calculate its probable performance there. The process is understood by engineers. However, whilst Australia has pioneered the concept, there is insufficient information about the process and it is not taught in engineering or architectural schools in Australian universities. More importantly, the calculation of design durability is not translated into standard practices or design solutions that can be adopted by engineers or architects. Not only are standard design solutions required, but confidence that the designs will perform as required is also necessary.

Component manufacture

The technological attributes of a particular species become less important when the timber forms part of a manufactured component (Vinden 1992). For example, the manufactured component may have load-sharing attributes or restraining properties that limit the effect of poor dimensional stability. In this case, the engineer or architect is more interested in the testing and performance of the building component or structure. Moreover, the testing methods might be expected to be independent of the materials used. That is, the same test can be applied irrespective of whether the product is manufactured from steel, concrete, aluminium, plastic or wood. The cost of designing and testing components is high. The resulting information must also be available to architects, engineers and specifiers.

Modular coordination

The design of building systems and building elements provides an unlimited array of sizes, grades and durabilities, and potential confusion to designers. To facilitate interchangeability, modular coordination is used to limit the range of dimensions. Innovative timber frame design in multistorey buildings in the UK has led to a resurgence of interest in the timber frame as a construction material. The method of construction also provides good performance in earthquake-prone areas. Construction time and costs are considerably lower than for equivalent concrete and steel structures. However, despite the introduction of performance standards, there are restrictions on the number of storeys that can use a timber frame in Australia. If we were able to define the performance of wood-based products as needed by a particular building element or market, the whole process of designing and fabricating components would be simplified. However, there has been no systematic analysis of the end-use qualities required of wood or wood-based products to meet these design requirements. Electronic communication makes it possible to process information relating to end-use requirements, define the performance attributes of wood-based components and provide this information, together with availability and price, to architects, engineers and specifiers in a form that is understood and useful.

Design

Interactive design or industrial design to optimise the performance and aesthetic appeal of a wood-based component has not been widely practised in the forest industries, and there is little formal training in wood science for designers. Moreover, component manufacturers have tended to leave any involvement of designers to the last minute before producing and selling a new product line. This is despite the fact that electronic design packages have revolutionised the design processes; these packages can facilitate the simulation of design decisions, and increasingly they can be made to control the machines used in manufacturing.

Wood processing and manufacturing

Solid wood processing has a lower energy requirement than competing materials, but is more labour intensive. Downstream operations, such as drying and wood preservation, tend to be batch processes. This involves queuing, stock holding and storage. The variability of raw material inputs requires grading. Unfortunately, the grading processes applied often do not correlate with the grade output required from an end user's perspective (Vinden and Adams 1997). Automation has had a major impact on sawmilling productivity. The implementation of conveyor belt (just-in-time) processing rather than batch processing can also provide enormous benefits in productivity.

The physical and mechanical manipulation of wood properties

Current wood processing technologies have a number of disadvantages because wood varies in its:

- moisture content and density
- strength
- defects (arising from knots)
- durability
- dimensional instability
- propensity to check and collapse
- sawing characteristics
- drying characteristics
- treatment characteristics
- gluing characteristics.

These properties vary between species, between trees of the same species, and within a tree. Often, the variability within a tree is greater than between species.

Technologies such as microwave wood modification overcome many of these problems by making the wood permeable. Wood permeability is generally overlooked as a wood property. However, most value-adding processing will be influenced by this attribute. For example, in solid wood, permeability influences the rate of drying, the incidence of drying degrade (collapse and checking), preservative treatment and performance in service. Permeability is also important in the case of chemical pulping, because pulping is influenced by the rate at which pulping chemicals come into contact with lignin. The rate is determined by the rate of capillary flow. In the case of impermeable woodchips, the movement of pulping liquid through the chip is limited by the slow diffusion of chemicals.

Microwave processing (Vinden *et al.* 1999) attempts to overcome the problems associated with poor permeability, by creating micro-voids at the intersections of fibres and rays. The voids are orientated in the radial or longitudinal grain direction and can increase the permeability of any wood species several hundred times (Vinden and Torgovnikov 2000). From a processing point of view, this tends to provide a uniform raw material for subsequent processing. If the raw material is expanded to become totally permeable, the wood moisture can be flashed off, and the wood can be impregnated with resins and then compressed back to the original dimensions. Such processing ('Vintorg') can impart new properties depending on the type of resin used. For example, when impregnated with isocyanate resin, some cross-linking of cellulose occurs, potentially providing improved durability and dimensional stability (Vinden and Torgovnikov 2000).

The speed of drying, potentially without degrade, has an impact on the design of dryers. One of the major problems associated with continuous drying arises from warp and twist, particularly in radiata pine. Radiata pine is particularly prone to twist during drying because of the orientation of microfibrils in core wood (the first 12 annual growth rings). Under high-temperature drying, twist is controlled by placing heavy weights on the stacks of drying timber. This solution is difficult to duplicate in a continuous dryer. The core wood of radiata pine is usually heartwood, and therefore of low moisture content (typically 40%). Such material is easy to process with microwaves into Vintorg. However, to date, it is not known whether the properties of Vintorg manufactured from core-wood of radiata pine overcome the influences of spiral grain. Automation and conveyor-belt processing is also possible in the application of wood preservatives. The need for conveyor-belt systems for applying wood resins for Vintorg manufacture has led to the design of 'on-line' pressure impregnation treatment systems suitable for preservative treatment. These treatment systems can be used to improve durability and other properties; for example, engineering properties (density, strength, stiffness, hardness and creep), dimensional stability, machining characteristics (planing, moulding, drilling, routing, turning and sanding), surface finishing characteristics, colour, texture, surface adhesion, scratch resistance, nail holding, etc. In turn, this is leading to the development of new processing systems with the objective of manipulating wood properties to the desired performance, rather than selecting species with the closest performance attributes. This provides an engineering approach to solid wood processing and use.

Resources

Traditional wood science is being replaced on the one hand by molecular biology, and on the other through physical and chemical manipulation of wood properties. The starting point for both disciplines is determining end-user requirements. Unfortunately, information on end-user requirements is not readily available.

The genetic manipulation of wood properties requires a detailed understanding of the biochemical pathways that lead, for example, to changes in basic density, fibre length, cellulose content, etc. The fundamental basis and use of wood science is thus changing. The physical manipulation of wood properties, for example through microwave processing, facilitates on-line processing and potentially does not have to take into account the many species-specific attributes that influence processing of logs as round-wood. New wood-based components can be manufactured whereby the properties required are simply engineered into the product. These attributes include strength, stiffness, durability, hardness, colour, texture, etc. New materials such as Vintorg can potentially be fabricated from any wood species and provide the raw material base for an almost infinite variety of components.

Information and knowledge

In discussing future prospects for wood-based products, one is inevitably drawn into an assessment of economic and political drivers incorporating society, values and culture. Society's attitude towards wood-based products has changed rapidly in the last three decades. Today's societies, whether Australian, North American, European or Asian, have contradictory attitudes towards wood products. On the one hand, society will applaud and value a beautifully designed timber structure or exquisite piece of furniture, and it appreciates a wood fire. Under these circumstances, we are 'using a natural material — it is a physical expression of our intimate connection with the world in which we live'. We are 'using raw materials that are at our disposal with economy and care' (Stungo 1998).

On the other hand, the operations leading to the procurement of the raw material (forestry) is seen less favourably. The harvesting of trees provides the most vivid and controversial demonstration of our disposable society's propensity for 'destroying our environment and the demise of society'. The harvesting of trees is currently not seen as an activity of a cultured society. The contradictions are only too evident and common, for example when environmentalists persuade society to use plastics instead of wood as 'an environmentally sensible and sensitive action'. Environmental contradictions are even prevalent in India, where it has been predicted that the demand for firewood will reduce substantially in favour of electricity. In essence, this is encouraged as a means of reducing human harvest of dead branches from forests for fuel.

Clearly, the future demand for wood products will be linked to the cultural aspirations of society. In our so-called 'Information Age', we are being provided with the tools to correct misinformation that has been prevalent in relation to forestry. In a culture of continuous environmental improvement, we have the tools through electronic processing of information and electronic communication to provide a rational and acceptable means of conveying more scientifically-based assessments of environmental good. The practice of forestry is quantified as a desirable activity, whereas the clearing of forests and woodland for agriculture or urban development is quantified as a less desirable activity.

Developing a forestry and forest industry culture that is relevant to society requires that the linkages with environmental benefits that accrue from this activity be recognised and valued. At the same time, we need to eliminate activities that appear (rightly or wrongly) to be detrimental to the environment. Our culture needs to embrace the concepts of education, training and research; a culture of innovation; a culture of economic good by helping regional development, reducing rural depopulation and expanding exports. We need a market orientation.

Conclusions

The prospects for wood-based products are largely determined by the building and furnishing manufacturing sectors. Innovation in the manufacture and application of new non-wood materials has led to unprecedented substitution of wood-based products in these industries. These new materials, products and techniques have, to a significant extent, become entrenched as industry norms. A reversal of this trend will be possible by adopting an 'engineering design' approach to wood manufacturing and by incorporating this approach into the training of architects, engineers and building scientists in universities, and through vertical integration of the value chain to embrace these end-using industries.

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