USE OF SMALL SECTIONS FOR MODERN TIMBER STRUCTURES

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Abstract

Malaysia is known for its greenery with a green cover of more than 60%; relatively high by any international standards. Traditionally, the country is famous for its tropical forest products export and currently one of the major producing countries in the world. With the increasing awareness on environmental issues particularly, the threat posed by global warming, Malaysia has recently embarked on new policies and guidelines regarding sustainable management of our forests as well as moving towards development of more plantation forests in the country. However, one of the greatest challenges encountered is the long gestation period for the latter investment and low rate of return associated with it. Besides current incentives provided by the government which includes tax relief, another means to mitigate the problem is through the development of more value-added products from small log sections derived from these plantations.

This paper deals with the possible use of small tropical hardwood cross-sections for erecting building elements. Glued-laminated boards will be explored as a means to replace massive timber, concrete and steel beams. Composite concrete-timber floors, as well as trusses and shell structures to cover large roofing areas will also be presented.

In conclusions, sustainable timber constructions are possible provided there is cooperation between wood-related partners, from the forest manager to the building contractor. Maintain the quality of the product throughout its different transformations is essential. A quality assurance scheme shall be endorsed to guarantee the characteristics of the end product will enhance confidence of potential clients.

Keywords : Sustainable forest management, Timber structures, Small sections, Manufacturing, Quality assurance.

1. Introduction

Malaysia has long been known as one of the leading tropical hardwood producers in the world, and more recently, as a nation serious with its sustainable forest management practices. To date, for instance, seven of the states in Peninsular Malaysia have been certified to Malaysian Timber Certification Scheme, a scheme developed based on the indicators outlined by the International Tropical Timber Organization (ITTO). The country is also committed to a high green cover of not less than 60%, a high figure by any international standards. Though noble from the environmental and long-term supply points of view, this commitment has led to the effect of immediate shortage in raw material supply of particularly popular species, resulted in escalating cost in all wood-based materials. In addition, for an economically viable large-scale plantation program across the nation to take place, major challenges lie in the long gestation time and low rate of return. It is strongly believed that apart from the attractive incentives provided by the government, a more practical method is through the development of more economical and technically viable solutions using the small sections derived from our small logs.

2. Forest Industries and wood-based resources

Forestry sector plays an important role in the socio-economy of Malaysia. In the year 2001, the export of timber and timber products amounted to RM 14.33 bil. (USD 3.77 bil.). There were more than 5,000 timber-processing mills, with about 3,200 furniture mills that depended heavily on rubberwood (*Hevea brasiliensis*) plantation timber as raw material. There were 12 particleboard and 14 medium density fiberboard plants, most of which made use of rubberwood as their main source of raw material too.

Besides, there were 176 timber preservation plants and 279 kiln-drying facilities that were involved in the preservation and drying of rubberwood (Singaram et al., 2002).

Timber is derived primarily from the natural forest in Malaysia apart from a small percentage from the plantation forests such as those of *Acacia mangium.* The total forest area of the country is about 20.11 mil. ha., about 62.4% of its total land area. Approximately 20% (3.84 mil. ha.) of the total land area is classified as *protected forest* that is totally protected for environmental and conservation reasons. They are found in the form of wild life sanctuaries, nature reserves and national parks. For the sustainable production of timber, a total of about 10.56 mil. ha of forests have been identified and gazetted as Permanent Forest Estate (PFE) and that harvest is done on a 30-year and 55-year cycle depending on the quality of the tree stock. The balance of 5.71 mil. ha. are allocated for development purposes such as housing, road construction and township establishment etc. Timbers are clear-felled in these development areas. A breakdown of forest area by region is given in Table 1 (Singaram et al., 2002).

Table 1. Estimated forest area (mil. ha) – 2001

Forests / Regions	Permanent Forest		Other forests	Total	Log production ($x10^6$ m^3)
	Protective	**Productive**			
Peninsular Malaysia	1.90	2.90	1.10	5.90	5.13
Sarawak	1.03	4.97	3.79	9.79	12.40
Sabah	0.91	2.69	0.82	4.42	2.48
TOTAL	3.84	10.56	5.71	20.11	20.01

Malaysia started its fast-growing timber plantation in 1970's. Began with Pine (*Pinus caribaea var hondurensis)* which was meant for a proposed pulp and paper mill project that did not materialize hence its planting was terminated. In the 1980's, Compensatory Forest Plantation Project was initiated in Peninsular Malaysia with the planting of *Acacia mangium, Gmenlina arborea* (Yemane), *Eucalyptus spp.* and *Paraserianthes falcataria* (Batai). However, Acacia became the major species planted because of its adaptability to almost all the planting sites and the availability of seeds then. For some technical reasons, the planting of Acacia was discontinued in Peninsula. In East Malaysia, the planting of Acacia is mainly for pulp production (Singaram et al., 2002).

In addition, other "slow" growing species such as Teak (*Tectona grandis*), Sentang (*Azadirachta excelsa*), Mahagony (*Swientenia macrophylla*), Engkabang (*Shorea macrophylla*) and Durian (*Durio zibethinus*) are also being planted by the government and the private sectors. On the other hand, the rubber trees planted earlier for the purpose of latex production became the main source of supply for wood-based industries particularly in West Malaysia owing to its abundant availability and technological breakthrough in its utilisation.

3. Small Wood Sections

The definition of a small wood section varies from countries to countries and mainly depends on the available tree supply. In USA, where abundant supply could be made available resulting from new wildfire protection and overstocked forests management, small-diameter wood is measured as everything below six (6) inches in diameter (15 cm). In Malaysia, there is no widely accepted limit to make the distinction between regular and small round wood diameters. One thing is certain though;

large trees are becoming more difficult to find. Therefore mills have to adjust and process a greater amount of smaller diameter trees in order to cater for current market demands.

There are relatively few Malaysian documents dealing with the use of small log sections for structural uses probably due to the fact that the country has abandoned the construction of large timber structures. Nowadays, most of the Malaysian logs are used in the furniture industry, wood-based processing industry (plywood, fiberboard, particleboard), moulding, and for the production of lumber (graded/ ungraded boards, kiln or air dried). All these applications do not expressly require large log sections, except for some wide boards.

The use of rubberwood (*hevea brasiliensis*) in the furniture industry is the leading example in Malaysia. It was partly due to the depletion of Ramin trees from the forests that led to the use of small rubberwood sections. However, to reduce the tendency to warp and twist of this juvenile timber species during drying, most of the rubberwood furniture is reconstituted from boards of not more than 10 cm wide and 90 cm long. Mastering finger jointing and gluing techniques have resulted in a RM 4 bil. (USD 1 bil.) annual export industry within 20 years (Bumiputra Commerce, 2003).

In short, Malaysia has already embarked on the conversion of relatively small wood sections into certain value-added products. But the emergence of global markets, in which governments have less control over import and export of goods, threatens even the well-established national industries in general, the wood transformation industries in particular. Therefore, it is advisable to look for new market opportunities in order to avoid supply saturation, which inevitably results in price dumping wars and loss of profit margins. The utilization of small wood sections for engineered timber structures is seen as a new alternative in this country.

4. Timber Structures

Timber structures are not widely used for buildings in tropical countries in general, in Malaysia in particular, despite the fact that most of tropical hardwood species have superior characteristics than softwood species grown in temperate climates. Colonialism has undeniably played an influential role in the development of the country and its architecture. Weather conditions are another reason often brought forward to explain this situation. Moreover, termites and fungi attacks have destroyed many wood structures and are still creating problems nowadays with some buildings, in which architects and engineers have not adequately dealt with the specific characteristics of the construction elements made of wood. Besides, the current Building by-laws which restrict the use of combustible materials in urban development also hinder wider use of timber construction in the country.

Fortunately, there are also existing timber structures to show the wood potentialities. Probably the most visible, but nevertheless rapidly disappearing, is the timber Malay house. Are these houses still around because they were built without the supervision of architects or engineers? This is questionable, but one thing is certain; the traditional Malay house created a near-perfect solution to the control of climate, multifunctional use of space, and flexibility in design with a sophisticated prefabricated system. Generations after generations have worked to improve the system, which resulted in cost-effective solutions and adequate construction details.

Construction details are the key to a sustainable structure. Some keep the water away or allow it to dry before getting trapped. Others prevent the attacks by termites or fungi. Wood is a hygroscopic material. It swells and shrinks with a change of moisture content. Particular care shall be given to connection details. Connections shall be able to keep transferring loads even if the wood elements change their sizes over time. This is particularly true in outdoor environments or in structures simply protected from the rain (without being totally enclosed).

Several types of timber structures are adapted for use of small sections. The wood either works in conjunction with other materials or is processed into larger elements like trusses or glued-laminated (glulam) beams.

4.1 Trusses

Round wood or small boards can be used with adequate connections to form trusses of different geometry and free spans. The Olympic information booths in Salt Lake City, USA, are examples of the use of small diameter round wood in spatial trusses (Fig.1). All sections were equal or inferior to six (6) inches in diameter (15 cm). The truss members were assembled with dowel-nut connections.

Fig.1 Round wood trusses (www.fpl.fs.fed.us)

For longer spans, another truss system is presented using only boards, wood panels and screws connections. The "Ariane" truss system developed in Europe by Professor Jean-Luc Sandoz can economically span from 20 to 60 meters (Sandoz, 2004). The truss members are composed of one or several layers of planks depending on the design load. The members are connected together with screws and reinforced with laminated veneer lumber (LVL) panels to guarantee the shear strength of the system. If the truss is kept visible, interesting architectural effects can be obtained by giving different shapes to the LVL plates (Fig.2).

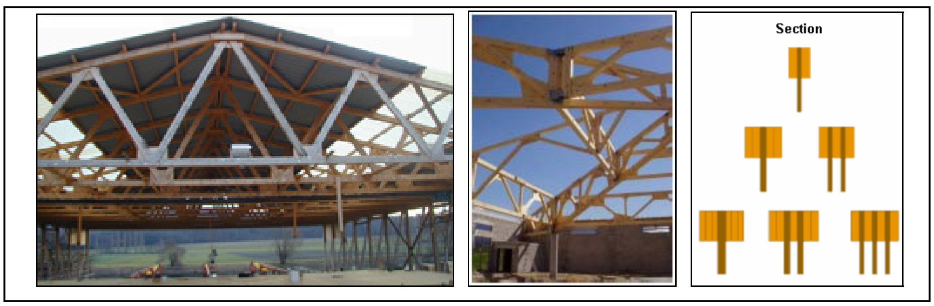

Fig.2 Ariane trusses

4.2 Glued-Laminated Beams

Glued-laminated (glulam) beams are generally large structural elements (Fig.3). They are cost-effective solutions to replace the largest sawn timber sections or even to create bigger and longer elements. They are manufactured by gluing smaller pieces (boards or laminations) together. The thickness of the laminations depends on the shape of the finished beam. Curved glulam beams require thinner laminations, as thin as 18 mm for important curvatures. Thicker laminations, up to 35 mm for hardwoods, may be used for straight beams. If the boards are not as wide as the required width of the structure, they can be bonded together edgewise. Due to the improvement of the finger-jointing technique and the dispersion of defects, like knots, glulam beam strength properties are generally higher than the design properties of the wood composing the beam.

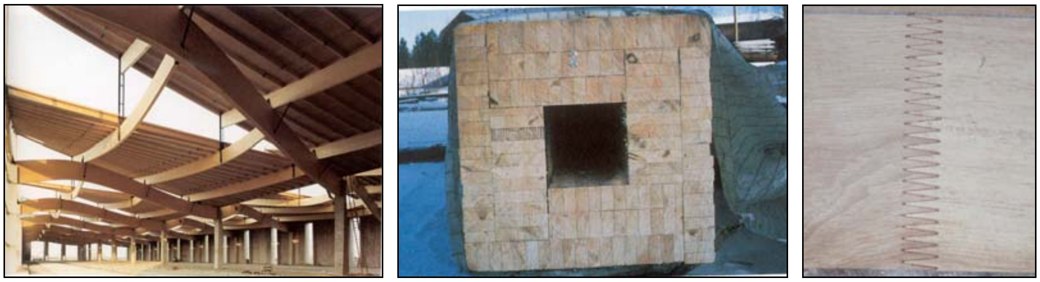

Fig.3 Glulam beams

4.3 Shell Structures

Shell structures are well suited for wood planks of small thickness (Fig.4). The ability of bending the wood without excessive machinery (often using only gravity) and the easy assembly of the elements together with screws or bolts have attracted architects and engineers to work together with some really astounding results. These lightweight structures are challenging the engineers but the final structure can nevertheless be cost-effective due to several factors including reduced foundations, increased column-free area, no false ceiling (the beauty of the wood is put forward rather than hidden away), and reduced erection equipment.

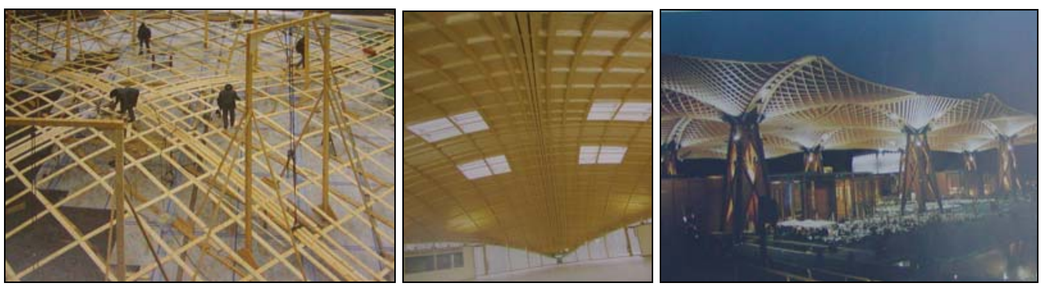

Fig.4 Shell structures

4.4 Composite Floors

Small board sections in association with concrete can be used to create heavy-duty floors or when vibration and impact sound transmitted by regular wooden floors are problematic issues. The composite structure is structurally sound with concrete working in compression and timber in traction. The link between the too material is the key to provide the required strength and stiffness of the floor. Several shear connectors have been proposed over the years with different rigidity. Nails, screws or bolts are generally considered to be the least rigid of all connectors because they tend to split and crush the wood, incurring slip under load. Structural adhesives are considered the most adequate solution for a rigid connection but with the disadvantages of cost and difficulties of on-site application. Between these two extremes, several solutions have been proposed and fully tested to assert the stiffness of the composite structures and their ease of application. Two different systems are illustrated in Fig.5.

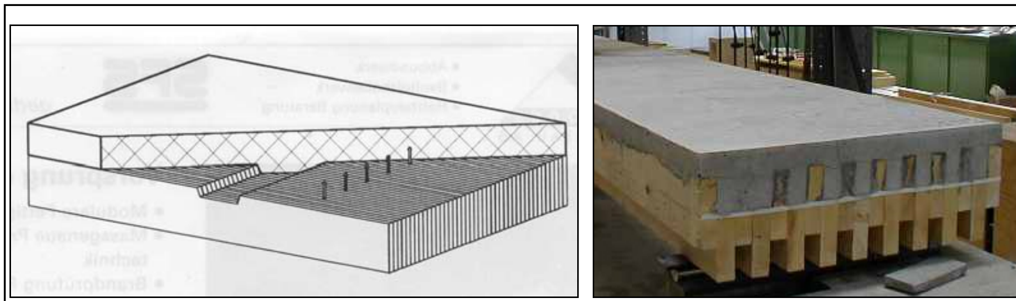

Fig.5 Wood-concrete composite structures

With the concrete distributing the load over several boards, it is possible to create a group effect resulting in higher design loads than if the weakest board properties were used to design the composite floor. This is especially interesting for tropical timber with so many wood species available on the market. This rich diversification has resulted in the classification of the wood into strength classes.

5. Quality Assurance

The quality of a product and more importantly the constant quality of a product is essential to its acceptance by the public. This is no exception with buildings and the elements they are composed of. Structural components are probably the most important elements requiring quality and reliability, as they compose the skeleton, on which all the other parts of the building are attached to.
Quality and reliability depend on the quality of the input materials, the control of their transformation and the respect of their intended final use. This is applicable to timber structures and more so to timber structures made of small sections, as more manufacturing processes are often required to overcome the limitations set by the size of the input material.

5.1 Manufacturing

Quality control of product manufacturing is primordial. As an example, in 2001 the Malaysian public work department (JKR) suspended the use of prefabricated timber roof trusses in its buildings due to a series of collapses. One reason for this suspension was the lack of quality assurance in the manufacture of the product. The timber industry reacted quickly to understand what lead to this drastic measure and how it could be reversed. This was particularly important, as the prefabricated truss was the last major structural application of timber in the country with a turnover of estimated at about RM 500 million (USD 135 million) (Tan et al., 2002).

Based on the work jointly carried out by the system providers, associations and government agencies, two quality documents were amended. The first document relates to the general preparation and construction of prefabricated timber roof truss system. The second document relates to the preservative treatment of timber members to be used in the prefabricated timber truss system. Furthermore, to demonstrate the viability of the new quality assurance scheme, the four Malaysian providers of the system were requested by JKR to build a mock-up roof truss construction in accordance with the requirements of the new quality documents. The suspension was lifted in 2002, once the relevant parties restored JKR confidence in the prefabricated system.

5.2 Erection

Water is affecting the quality of wood. If the wood element is not allowed to dry rapidly, decay and fungal attacks will occur, more rapidly in tropical environment than in any other climates. Therefore, it is important to protect the timber elements when they leave the sawmill or manufacturing plant until they are protected against the rain on the erected structure.
If transportation of the elements is done during the rainy season, the truckloads should be covered. Once on site, the elements should be protected from direct exposure to the weather and maintained in dry condition. Where a dry covered area is not available, a waterproof cover should be used to prevent moisture penetration. A good air circulation should also be maintained between and around the

elements. Elements shall be stored on temporary supports above ground. The spacing of the supports depends on the length and slenderness of the elements.

Wet timber is very slippery. No erection should take place when a risk of falling off a wet structure could result in serious injuries. As with any construction site, adequate safety measures shall be enforced to prevent accidents. Due to the wider use of nails with small wood sections, the danger of walking on nails sticking out of planks should not be overlooked. Besides, adequate site cleanliness shall be maintained to avoid walking on debris.

Working with small timber sections has the advantage of easy on-site adjustment. It is very easy to cut, notch, and drill during erection to facilitate the tight fitting of the elements. Care shall be taken not to reduce the strength and stiffness of structural elements so that it becomes unreliable for its intended use. The role of the on-site engineer is therefore important.

6. Conclusions

It is timely to reexamine the current research direction in the use of small section timbers in the country taking into consideration both technical advancement in timber research and development in many advanced nations and global market trends. With the commitment of Malaysian government towards sustainable forest management, more and more smaller logs are emerging in the market. Although limited success prevails in the use of rubberwood primarily for furniture application, it is essential to explore other possibilities such as the use of such sections for structural applications in order to make the wood-based industries more resilient to globalization, particularly. The examples illustrated here are by no means exhaustive, but perhaps serve as an important step in the correct direction.

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