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Briefing: Stress lamination: utilising low-grade timber in construction

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Stress lamination of timber, as an engineering concept, has a useful future in construction, and should provide many opportunities to utilise UK timber—a readily available lightweight material, excellent in compression yet good in bending. That combination will particularly encourage its use.

Stress lamination of timber is a form of construction designed to utilise the timbers of small and low-quality softwood available from the UK forests. The first use of modern stress lamination took place in Canada and the USA, driven by the need to repair old timber bridges and to replace many others. This was followed by parallel work in Australia and Scandinavia throughout the 1990s. Further developments around the world concentrated on flat-deck construction, using timber in bending. These initiatives were forced by the need to increase spans to something greater than the capability of the largest cross-section of timber, to develop cellular box or 'T' beam composite structures. When such forms of timber construction were explored by the authors, they were found to be unsuitable for use in the UK because entrapped moist air created a rot problem, and so the developments were focused to maximise the performance of stress lamination by utilising the strength properties of timber in an arching action, which contributes significantly to the overall strength and stiffness of the structures.

Mechanical stress lamination of timber is a technique whereby several individual sawn sections of timber are compressed together using high-yield steel (HYS) bars to form a large load-sharing member, or orthotropic plate (Fig. 1). The HYS bars are

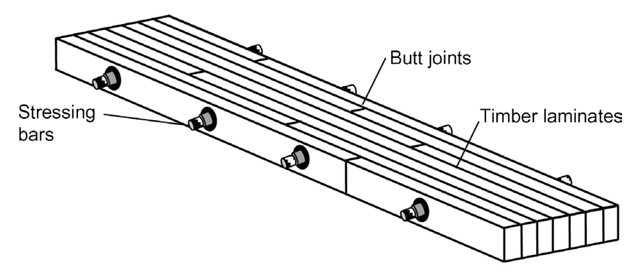

Fig. 1. Stress-laminated timber plate/deck

Fig. 2. Six-metre span test bridge

Fig. 3. Carribber Bridge near Falkirk, 20 m span, November 2005

passed through pre-drilled holes in the wide face of the timbers, which are laid side by side on their narrow faces. The bars are jacked against anchors on the outside timbers, which need to be hardwood in order for them to sustain the very high local bearing stresses. Load is transferred from one laminate to the next by friction forces between them. This converts the whole into a solid load-bearing timber deck with the ability to transfer load laterally and longitudinally.

Examination of the use of stress-laminated timber decks in arched form began at Napier University, Edinburgh, some 3 years ago with a trial arch of 6 m span and 100 mm × 50 mm × 1000 mm timber laminates. It comfortably sustained 50 kN at mid-span and failed with over 30 kN under a quarter point loading (Fig. 2).

The findings of the initial tests led to a research programme involving the construction and testing of a further nine laboratory arches as well as a 15 m and a 20 m span field structures.[1,2] The research has aimed to explore the full potential of stress-laminated arched timber structures with regard to

- factors affecting structural performance and stability, including the effects of prestressing levels in the steel bars, moisture fluctuation and arch profile
- assembly and construction processes; maintenance, durability and life-long reliability and end of life disposal/ recycling issues
- development of comprehensive design guidance and a database of the key design, construction and maintenance issues for the forestry and construction industries.

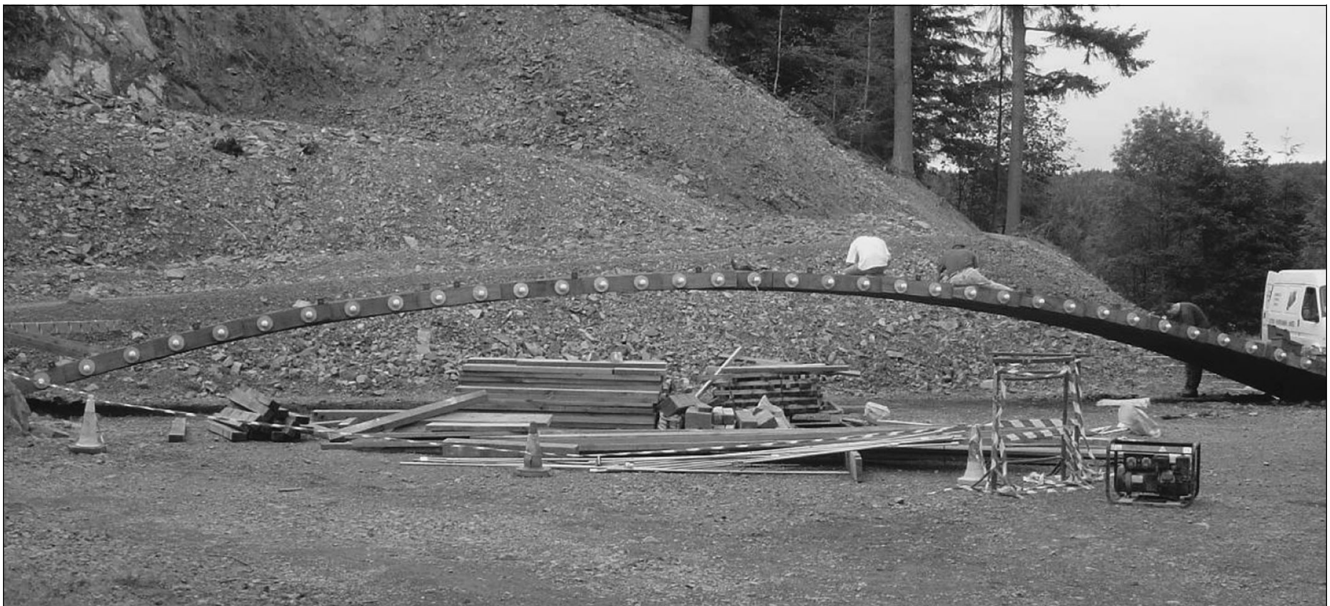

Fig. 4. Twenty-metre span test bridge at Glentress, depth to span ratio of 1 to 100, July 2003[2]

Fig. 5. Timber walkway at Salcey Forest, Northampton, November 2005

Fig. 6. Red Rose, Northwich, Cheshire, 15 m span, 2002

These bridges have also been subjected to a series of extensive static and dynamic loads evaluating their response to crowd and vandal loadings. Design rules and an analysis procedure have been developed and used for the construction of some 20 commercial bridges in rural areas, including four at 20 m span (Fig. 3).

All of the testing has been carried out using C16 (equivalent to general structural grade) timber to demonstrate that large structures can be built without the need to rely on higher-grade imported wood.

These elastic slender structures have many advantages over stone arches as they can effectively sustain relatively high tensile stresses (Fig. 4). This means there is no need to keep the line of thrust within the middle third of the arch ring. The design uses low-quality C16 timber in compression parallel to the grain, which is one of its strongest properties, and it is mobilised without any fear of lateral buckling. The effects of timber defects are reduced because of the intense load-sharing mechanism. This form of construction uses a great deal of timber, but the structure incorporates the deck for pedestrians so the benefits easily outweigh the extra cost.

The cost of the bridges built so far has been approximately £500/m^2 of deck, which is good value. With experience this price could be reduced, as the materials element amounts to less than half of the total cost, leaving scope for saving in labour costs.

These bridges are cost-effective, and much benefit is derived from timber's high strength-to-weight ratio. This means that prefabrication is possible, and whole bridges can be delivered, pre-erected, to site. There is a large market for footbridges in the UK, but the greatest cost savings in the future will be for vehicle bridges. They will probably comprise arches, supporting flat stress-laminated decks. A recent innovative use has been as a roof (Fig. 5). The visual appearance below the deck, or the underside of the roof, is very aesthetically appealing (Fig. 6).

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