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Timber Structures for the School for Woodland Studies in Dorset

Structures en bois pour l'école des sciences forestières à Dorset

Holztragwerke für die forstwissenschaftliche Schule in Dorset

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SUMMARY

This paper describes the use of roundwood thinnings in Norwegian Spruce to construct an arched form workshop and a prototype dwelling house within an historic wood as the Centre for the School for Woodland Industries, Hooke Park, Dorset.

RÉSUMÉ

L'article expose la mise en oeuvre de rondins en sapin de Norvège dans deux constructions à Dorset en Angleterre. Il s'agit d'un bâtiment en forme de plein cintre servant d'atelier et d'un prototype de maison d'habitation, situés dans une forêt historique et destinés au centre scolaire de Woodland Industries, Hooke Park.

ZUSAMMENFASSUNG

Der Betrag beschreibt den Einsatz von Rundholz aus norwegischer Fichte bei zwei Bauten in Dorset, England. Es handelt sich um ein tonnenförmiges Werkstattgebäude und den Prototyp eines Wohnhauses in einem historischen Wald für das Schulzentrum der Woodland Industries, Hooke Park.

Introduction

Britain has a large number of lowland forests of which many were planted from the turn of the century up until the end of the Second World War, largely to produce timber for pit props for coal mining. This need has now gone and these forests, usually planted on land not readily utilised for other purposes, have become neglected due to the low commercial value of the timber.

Now British woodlands are an undervalued resource. Every year Britain imports some 85% of its timber requirements and it was the concept of exploring how to increase the value of small roundwood and of British timber generally which led to the founding of this school.

The School of Woodland studies at Hooke Park in Dorset was founded by the famous furniture design John Makepeace to teach students firstly how to maintain such forests and secondly how to make goods from the annual products from the forests which would enable them to make a living with the overall general ambition to regenerate woodland management and rural industry so the buildings for the school should be representative of imaginative experimentation in the use of forest wood.

In a typical well managed forest, from the total number of saplings originally planted only 10% should be allowed to reach maturity. To give these few trees the best growing conditions the remainder need to be gradually felled as thinnings. Conifers in the U.K. are normally planted with a density of 2500-4000 stems/hectare which will then yield between 200-300/hectare. The high density at planting is necessary due to the uncertainty of how any particular sapling will develop and as the production of straight, knot-free saw-timber is encouraged by keeping the trees crowded when they are young.

The vast majority of 'thinned' stems have trunk diameters between 50 and 200 mm and are too small for sawmilling. They are usually only suitable for low grade uses such as pulp, particle board and fencing. There is little commercial value in this operation and many smaller U.K. plantations are neglected because the cost of removing the thinnings is greater than their value. The effect of this neglect is to suppress the growth of the best trees and therefore to reduce their value.

The School is being built within Hooke Park Forest, a 140 hectare woodland, near Beaminster in Dorset.

Timber Technology:

Three main areas of interest formed the approach to the technology.

One has to be fascinated by the structural efficiency of trees and question whether we now over use sawing of timber. Sawing wastes some 40% of wood by volume, it causes warping fibres, so it make sense to, as much as possible, use timber in the round.

The main structure of a tree consists of cellulose fibres which run in the vertical direction and which account for some 50% of the solid content on the wood. They form cells so that the tree acts like a bundle of drinking straws glued together by a polymeric module called lignin (10-35%) and various other sugar compounds (15-40%). The other important component is water which not only affects the bending but also the possibility of bacterial attack.

The fibres are extremely strong in tension but have only a quarter of that strength in compression. This means that bending in timber is structurally very inefficient. However a small diameter thinning has a great capacity for carrying substantial loads as a tension member as long as efficient end connections to resist the resulting tension force can be produced.

Thicker diameter roundwood members also have greater capacity to resist buckling and to carry compression forces as slender struts due to prestressing of the outer fibres during growth.

The thinning process at Hooke Park yields a large number of Norwegian spruce poles 7m long 50-100mm diameter and a smaller number between 10-15m long with base diameters of 200mm. This is typical of many thousands of woodlands throughout the country.

Therefore, the available timber is well suited for components of building structures where the principle 'direct force' actions will be tension and compression.

The second interest is the protection of the timber from insect and fungal attack. With green timber this is of major importance but commonly available methods were not suitable due to the high moisture content and the resistance of Norwegian spruce to impregnation.

On the advice of Mr David Dickinson of Imperial College the internal timbers were treated on site by dip diffusion. This is a technique developed in Australia and New Zealand, but not popular in this country as it is only effective on freshly felled wood where the moisture content is high. The timber is dipped in a heated supersaturated boron solution (disodium octoborate tetrahydrate) for 15-30 seconds and then stored under polythene for between four to eight weeks. With an initial moisture content of at least 50% the boron solution is able to diffuse into the timber cross section. External timbers require a greater degree of protection and this has been provided by sap displacement using CCA (copper-chrome-arsenate). This has been developed from the Boucherie process, a method popular in France during the last century as a means of successfully displacing a newly felled tree's sap with chemical salts.

The final area of interest is the inefficiency of traditional tension joints. The joint that was developed for this project was based on research in the United States for fixing timber aerogenerator blades to a steel hub. The joint consists of a steel rod embedded in epoxy resin within a stepped drilled hole. The load is transferred into the timber partly by the direct bonding of the resin on to the exposed ends of the longitudinal cellulose fibres and partly by penetration into the capillaries A stepped hole allowed the ends of the capillaries to be exposed and readily available and easily sharpenable drill bits to be used.

Testing of these joints was carried out at Bath University. Initial tests compared the epoxy joint with traditional bolted flitch plate connections and proved the new joints greater efficiency. The first tests used a two part epoxy resin manufactured by Gougeon Bros. and lengths of reinforcement bar. In these tests failure was at about 30kN (11 N/mm^2) with the bar pulling out of the resin cone. Further tests were carried out with the SP110/210 system manufactured by Structural Polymer Systems Ltd. In both cases the epoxy resin had a very low viscosity to achieve penetration into the capillaries and also included cellulose microfibres. This gives gap filling properties to the mixture and also increase the elasticity of an otherwise brittle material. The results of tests on four of these joints are shown in Table A.

Joint	Dia. (mm)	Failure Load (kN)	Failure Stress (N/mm^2)
1	65	62.0	18.0
2	70	24.2	6.3
3	70	47.0	12.2
4	65	43.5	13.1

Table A

The result for joint 2 was attributed to poor workmanship in the construction of the joint as a layer of wood dust was found on the failed epoxy wood interface. The other three samples failed due to the bar pulling out of the resin core. These samples had large radial cracks in the epoxy core and splitting of the adjacent timber . This is probably due to the high shear stresses that develop at the point of entry of the bar into the joint. These shear stresses cause significant cross gain tensile stresses to develop in the timber around the core and the result is a splitting failure of the wood with pull out of the bar.

To prevent this type of failure the joints subsequently constructed for the Prototype House used threaded steel studding and a glass fibre band wrapped around the exterior of the joint. The later also has the effect of preventing splitting of the thinning at the end under eccentric loading.

Tests were also performed on two samples of the tension joints produced by the contractor during the Prototype House construction. The results are shown in Table B.

Joint	Dia. (mm)	Failure Load (kN)	Failure Stress (N/mm^2)	Factor of Safety on max. working load
1	68	42.8	11.8	5.9
2	68	41	11.3	5.7

Table B

The results give an adequate factor of safety and the failure loads compared very closely with those obtained previously. However, failure in both cases was by the epoxy cone pulling out of the timber. This may be due to the higher moisture content of these samples and that they were constructed in a horizontal position, rather than vertically as before, which led to pockets of air being trapped within the epoxy.

The compression joint that was developed is very similar to the tension joint. The steel rod acts as a locator during construction and helps load transfer by reducing the timber bearing stress. Cross grain strength of the timber will also be increased as the epoxy tends to fill the capillaries locally to the joint and strengthen them again crashing. Though these joints are designed principally to withstand compression they also have some tensile strength, which could be useful during frame assembly and in reducing the effective buckling length of compression members due to moment continuity in the joints.

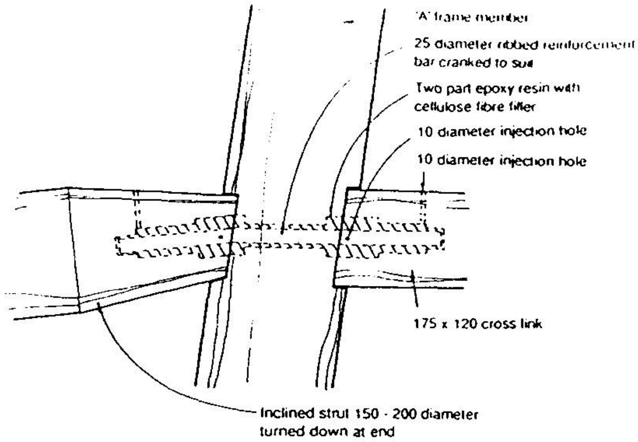

Fig. 1: Jointing technology

Design of a Prototype House

The Prototype House is 11.2m long by 8.5m wide and has six rooms each accessed from a central corridor. All the structural elements were fabricated from Norwegian spruce except for the highly loaded A-frames where corsican pine was used.

The roof structure used thinnings 60-90mm in diameter at 450mm spacing to span a maximum distance of 5.5m. Due to their small diameter the thinnings would be unable to support the expected loads in bending. However, with the thinning formed into a permanent catenary shape and the two ends restrained in direction it acted like a cable resisting the applied load in tension.

This tension is transferred into the building structure at the ridgeline through a tension joint attached to a wire cable hung between the heads of four A-frames. The tension at the eaves is transferred into a cable spanning between inclined side posts.

Work is now restarting on further staff houses and student residences which together with a programme of research work occupying the next two years, will be the subject of a further paper.

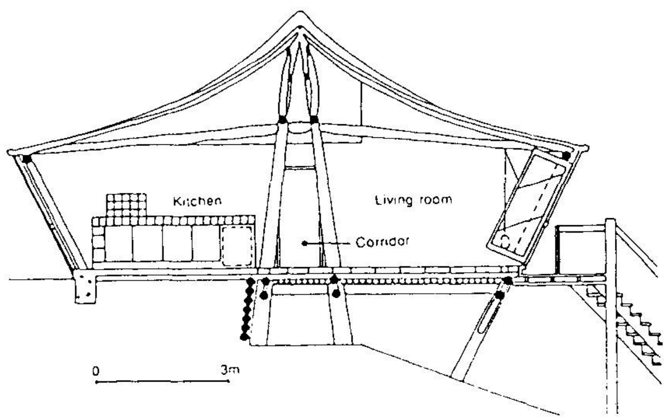

Fig. 2: Section through prototype house

Design of the Workshop Building

The requirements of the workshop building was that it provided a large open space where the machining tools can be situated and a separate area for lecture rooms and tutors offices.

Using an arch shape it is possible to span the 15m width of the building without any intermediate supports and also to obtain sufficient head clearance for a mezzanine floor. By varying the crown level of the arch along the length of the building the elevation. is seen as a series of undulating curves. Also by 'gathering in' the arch bases into groups a space can be created on the surface for window and entrance openings. All the structural timber was Norwegian Spruce.

The building actually constructed is three shells spanning 15m and forming a building 42.5 total length and 7m maximum height. Two of the shells form the workshop area, the third contains the library, seminar rooms, teaching area and offices, all arranged at ground floor an mezzanine levels. Access for visitors is by a bridge which enters the building at mezzanine level between the workshop and teaching areas.

The shells are formed using pairs of thinnings of nominal diameter 155mm at the base to 65mm approximately 9m long joined at the crown by a laminated crown arch member.

Both buildings have now been completed for two years and have preformed well.

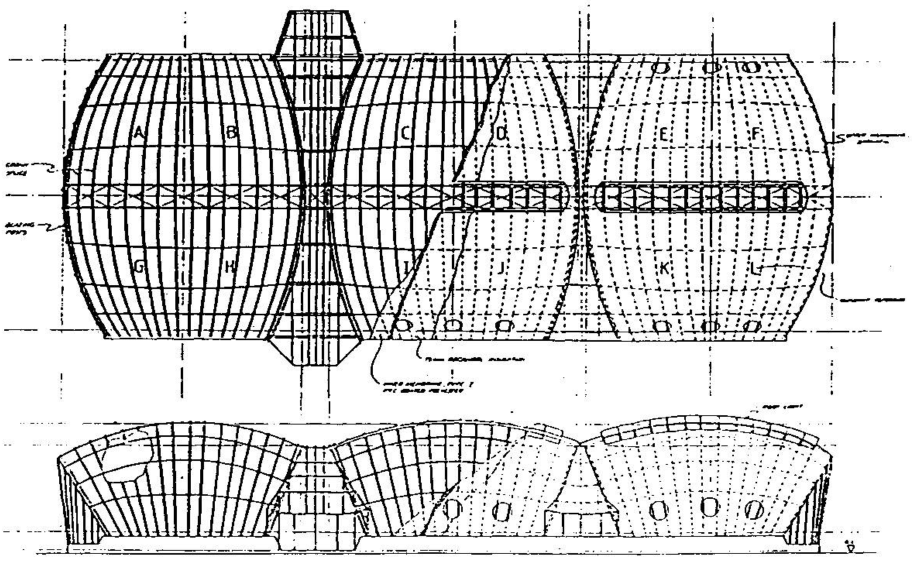

Fig. 3: Plan and elevation of workshop

Acknowledgments

The 'language' of the design of this project was based on the use of the 'wet wood' thinning timber from the site and from the development of a virtually 'full strength' tension joint. This joint was evolved from an introduction by Prof. Jim Gordon of Reading University to Gougeon Bros. of Minnesota and subsequent discussions. The relationship of the stiffness of the epoxy to that of the timber came from discussions with Prof. Bryan Harris of Bath University. The evolution of the building design was carried out with both the architects, Richard Burton of Ahrends, Burton and Koralek and Professor Frei Otto. The joints were then developed by Buro Happold and tested at the University of Bath.