Challenges in Timber

Innovations in composite construction - connecting techniques - outlook

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Summary

Crossing deep and wide valleys, timber is the world's oldest building material. In cases where the dimension or bearing capacity of dried and sorted solid wood is not sufficient, composite materials of timber or of timber and other materials are used today.
When more slender cross-sections or wider spans are required, timber is combined with steel, carbon or synthetic fibres, and textiles. But timber-glass structures, just like high load-bearing constructions with wide spans, require suitable connecting techniques. Various new developments in this field are presented in the following.

Topic: **Construction and Materials of structures (3 S)**
Key words: timber; glulam; new composite materials; CNC-application; construction techniques; design criteria; seismic aspects; human factor;, aesthetics; economics.

1 Introduction

Timber bridges in Mesopotamia (3000 to 2000 B.C.) or in asia illustrate why this wide spread material was used in the construction of big structures using simple tooling and assembly methods. North American forests, for instance, demonstrate that trees used as cantilever girders can span large widths: sequoias standing 80 m tall or redwoods with a height of 120 m have survived for centuries.
The high bending strength of timber compared to its weight is often an advantage. If treated correctly, timber has a long service life, as can be seen in timber bridges and multi-storey framework buildings in Asia or Europe that are over 400 years old.

The principle of separating and re-joining timber has produced a large variety of linear and two-dimensional building elements with defined characteristics, so that adapted solutions are also found for very special requirements. By this approach the limited dimensions of a tree have been overcome [10]. And this development has not yet reached its end.

Fig. 1
Bridge over the Main-Donau-canel near Essing

When more slender cross-sections or wider spans are required, timber is combined with steel, carbon or synthetic fibres, and textiles. These composite high load-bearing constructions, as well as timber-glass structures, require suitable connecting techniques.

Laminated wood of the most diverse systems, such as veneer lumber, and innovative connections form integral part of modern timber construction. Spans of more than 100 metres have been realised (fig. 1). With respect to the technical advancement of composite constructions based on timber, attention should also be paid to innovative techniques, see fig. 2. Quality-related, special high-tech constructions are important design features of modern architecture that improve the image of timber as a competitive option to other building materials.

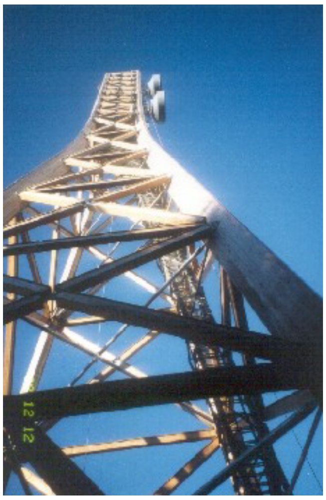

Fig. 2
Mobile tower Rottenbuch

Additionally, in the future, constructions will not be evaluated exclusively on aesthetic and especially economic criteria, but also on ecological compatibility. Aside from its virtually unlimited design possibilities, the possibilities for remodelling and dismantling timber constructions, the disposal and rising energy costs of other materials speak clearly in favour of this natural and reusable material. Timber creates a comfortable and healthy climate, is resistant to numerous chemical agents, does not corrode and is barely brittle – in short, timber is simply innovative.

2 Innovations in Composite Construction

Laminated wood has developed into a high-tech material due to its homogenisation. Nowadays, it can provide slender constructions and, when combined with new materials such as glass or plastic, constructions with very appealing architecture [6]. Precisely in combination with new connecting means, it is possible to use laminated wood in high-stressed, and dynamically loaded structures [4]. Furthermore, constructions of high robustness can be designed as solid structures in timber (keyword **block gluing**, as shown at several bridges [3], [5]) instead of concrete.

The use of currently available materials as a function of the stresses acting on a load-bearing structure, inevitably leads to composite constructions. These highly economic structures have been treated in more detail in [4] and [7].
The most prominent example of a timber-steel mixed construction is the timber girder prestressed by a **steel** cable underneath. New connecting techniques, such as the transversely prestressed floor slabs, the self-drilling bar dowels or the full-threaded steel screws allow new developments and chances.
The timber-concrete composite construction started its triumph more than 15 years ago in Canada and New Zealand. Nowadays road bridges in Switzerland are designed with a superstructure in timber-**concrete** composite design (fig. 3). And there are, in the meantime, also reliable calculation methods to determine the influence of creep and shrinkage (cf. [9]).

Fig. 3 Timber-concrete-composite construction near Innerferrera

Glass combined with timber is frequently used at facades as column-beam-constructions or as structural glazing. There is still a tremendous saving potential in the gluing of glazings on the timber structure.

Plastic: The use of high-grade carbon or glass fibre lamellas, for example in the bending-tension area, can enormously improve the bearing capacity of beam-shaped elements (fig. 4).

Fig. 4
CFK-reinforced timber bridge near Sins over the river Reuss

At last a short reference to the wood recycling product '**paper**'. The Japanese pavilion at the world fair in Hannover in 2000 (fig. 5) impressively demonstrated the future abilities of this product.

Fig. 5
Japanese pavilion at the Expo Hannover 2000

3 Connecting Techniques

The evolution from an originally carpenter construction to new innovative designs can be demonstrated by the example of the so called Zollinger roof (fig. 6): New connecting systems were used for the exposition halls of Friedrichshafen, Rimini, Rostock and Karlsruhe in order to cope with the high connecting forces.

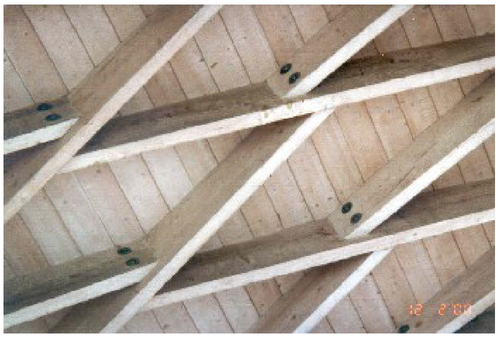

Fig. 6 Zollinger roof in Ostfildern city

4 Outlook

In the public domain and in sports facilities with spans of up to 40 m, plane structures in laminated wood construction are one of the preferred choice in Germany. Spatial structures are often employed in sports arenas with spans of more than 100 m, in exposition pavilions, and in wide-span bridges. Torsion tubes or grid-type girder decks for instance are preferred roofing elements if natural lighting is required. Additionally timber has very good behaviour under dynamic loads e.g. for timber bridge constructions.
Halls in timber design spanning up to 85 m are fully competitive today in Europe. And spans of more than 120 m are also perfectly feasible in timber construction subjected mainly to normal forces.

Further benefits of timber as a structural material are:

Shaping

The laminated woods and panel materials available today permit almost any three-dimensional curvature of beam-shaped and two-dimensional timber elements (fig. 7). In terms of aesthetics and high spans, two-dimensional structures are the future structural elements!

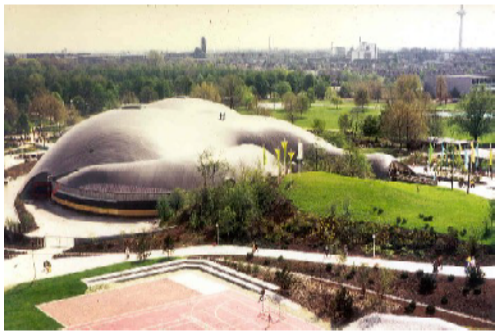

Fig. 7 Multihall Mannheim

Low follow-on costs in the case of remodelling, heightening or demolition.
In this aspect too, timber is nearly unbeatable.

Wide variety of utilization

Building owners increasingly demand constructions that are (almost) column-free in view of the future sale potential of the building or the demands of new users.

High level of prefabrication
improves quality,
reduces construction time and thus offers a corresponding cost benefit.
Low transport cost compared to concrete**,**
higher load-bearing capacity with the same mass
In order to create reinforced-concrete arches spanning 150 m, they are often erected on a wooden arch formwork, in other words "timber supports concrete".
Assembly advantage = cost advantage, short planning and construction times
The contracts for the new pavilion VI on the exposition hall in Sinsheim [8] for example were signed early in February 2002. One month later, in early March, foundation work started and on 24th September 2002 the first trade fair was opened in the pavilion measuring 10.000 m^2. This is a planning and construction period of only 7 months.
Optimised structures for
- wide-span girders subjected to bending,
- arch constructions,
- light cross-sections,
- trusses with few joints,
- exploitation of three-dimensionally bracings,
- composite constructions and
- hybrid systems.

Fireproofing? Often already included.
It is true that wood is an "inflammable building material"; but its behaviour in fire is potentially much better than that of materials, which tend to flow or suddenly have a brittle collapse at high temperatures. Wide-span timber constructions as such have cross-sectional dimensions that allow for a calculated fire resistance of 30, 60 or 90 minutes. Pavilion VI of the fairgrounds in Sinsheim therefore has no full-coverage sprinkler system.
Low costs because "structure = finish"
This keyword is self-explaining.
Benefits in terms of building physics, dimensional stability in case of glued materials
The use of chemical wood preservatives can be largely avoided when the planning is carried out meticulously.
Aggressive media – no problem
This keyword too requires no further explanation.

5 Conclusion

Timber is a durable building material of high architectural appeal. It offers virtually unlimited possibilities– in short: a challenging building material!
It is regenerative, easy to use and has thus a positive ecological balance.
Its resistance is comparable to steel or concrete;
timber is admittedly inflammable but its failure behaviour is fully calculable.

More effort, however, is required to expand the use of timber construction; the order of the day is cooperation instead of competition.

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