Des ponts-sculptures à l'aide de bois massifs collés

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1. Introduction

The history of bridge construction has always been connected to the technical state of the art. It started with applications of natural material as stones and wood. During the industrialization construction materials changed to steel and afterwards to concrete and high developed wood constructions got displaced by concrete or steel structures. Due to a mind change to ecological matters there is a rediscovery of wooden structures in the last decade. And the characteristics of wood – light but strong, easy to process – push this natural material into focus of architectural interests.
Glulam is a structural timber product consisting of number of layers glued together to a certain cross section. Further it is possible to block laminate a number of glulam beams together to achieve bigger cross sections. Block lamination generates massive timber cross section to achieve loadbearing structures for large spans with a thin side view.
In the year 1989 the first modern, block laminated timber bridge was built in Germany. Since then many various bridges have been designed with these structures – with tendency to rise. And a new architectural approach will increase the idea of solid timber building.

2. Ponts Sculptures

2.1. Glulam structures

Timber constructions have their own industrialization, but with some retardation. In 1906 a German Otto Hetzer patented the gluing of wooden beams. The modern glue-lamination was born. Glulam is a structural timber product consisting of number of layers glued together to a certain cross section. Additionally, it is possible to block laminate a number of glulam beams together to achieve bigger cross sections.
This invention provides the possibility to produce wooden beams with huge dimension in a constant quality: length of 50m and more, width and heights of 3m and more. The gluing process even offers the possibility to produce curved elements or even twisted elements. This allows thinking and constructing in free forms.
Since 40 – 50 years glulam is used in halls – not just for the roof but also for the posts – and reaches a respectable market share by now. Wooden bridges are on the rise since almost 15 – 20 years.
There is a diversity of reasons for using of timber in bridges. For example, prefabricated large-sized parts are easy to handle and assemble because of their lower weight – a well-known advantage for economical constructions.
The durability of the construction often is discussed seriously because latest planning often does not consider historic knowledge as constructive wooden protection.
The development of gluing technology including block lamination is a type of the retarded timber industrialization.

Figure 1: process of block lamination

2.2. Block laminated structures

Block lamination generates massive timber cross section to achieve loadbearing structures for large spans with a thin side view. Block lamination comprises three main steps: limitless gluing of lamellas through finger jointing, gluing layers of lamellas to a glulam beam and finally gluing numbers of beams to a massive block.

A certain form like a curve is created in step 2 "lamination of layers". The curve is always vertical to the narrow side because flexibility of the boards relates to the thickness. Therefore smaller radiuses require thinner lamellas.
According to the required form a block laminated beam may have a curvature in top view or in side view. The difference in production is

a) Horizontal block lamination (curvature in side view)

Figure 2: horizontal block lamination (examples)

Figure 3: block lamination of twisted beams

or b) vertical block lamination (curvature in top view).

Figure 2: vertical block lamination

Even twisted forms are possible. Twisted beams are curved in two axes. The first curvature is generated in step 2 "lamination of layers" as usual. Afterward a horizontal band saw cuts the curved beams into thin layers. These thin layers are sufficient flexible to be curved again in a second direction during block lamination.

A part from curved gluing, through block lamination stepped beams are feasible both in cross section and in longitudinal section. There for glulam beams with different height or length are block-laminated to one block beam.

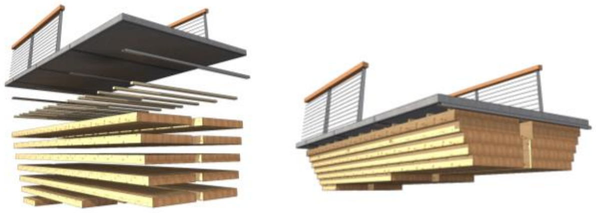


Figure 3: cross section bridge beam

Figure 6: exploded view curved beam bridge

Figure 7: Passerelle Neckartenzlingen (DE)

2.3. Timber-concrete-composite bridges

The increasing role of ecology and sustainability of building materials more and more influences construction industry and leads to a rethink on site of the builders. The symbiosis between wood and concrete has the best conditions to meet all resulting claims. Constructions of massive wood beams statically connected to a concrete slab on the upper side ensuring optimum utilization of the material specifications of both materials. In this case the wooden cross-section is considered to take tensile forces and the concrete slab takes the pressure forces. Special connectors ensure the interaction of timber beams and concrete slab to get a more effective loading capacity and serviceability.
Advantages in comparison to conventional timber bridges:

- higher load capacity with lower height of construction
- good structural wood protection through cantilevered concrete slab on the top side
- optimal load spreading of point loads by the concrete slab
- better cross bracing
- use of proven details in connections to the concrete

Figure 8: stepped block-laminated timber

Advantages in comparison to conventional concrete bridges:
- lower weight of the superstructure and thus more efficient structure
- fast and efficient installation with high degree of prefabrication without extensive formwork
- cost savings in foundation and the abutment
- improved energy balance and eco-balance, sustainability through CO² reduction

Figure 9: shear connection by HBV-shear connector

2.3.1 HBV-shear connector

The HBV-shear connector by TiComTec (Haibach - GER) is an expanded metal part that is glued perpendicularly into the wooden structure. The dimension and number of connectors is determined to the static needs. The concrete slab usually has a thickness of at least 20 cm and has several functions: road decking, carrier
plate for the dispersal of transverse loads and constructional wood protection.

2.3.2 Head bolts

As known from steel-concrete bond structure in this alternative the connecting parts between wood and concrete are steel bars with welded head bolts. The bars fit exactly into milled kerfs and are fixed with screws. To achieve an efficient utilization, the axial distances of the dowel bars correspond to the traffic load and transverse force caused by the traffic load.

Figure 10: shear connection by head bolts

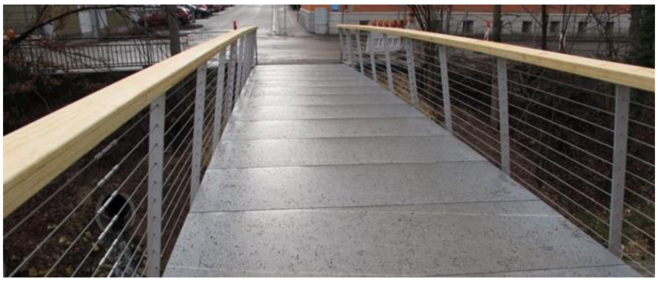
2.3.3 Kerfs and Glued in reinforcement bars

The shear connection in this type of timber concrete composite is implemented by a combination of kerfs and glued-in steel bars. The kerfs are milled in transverse direction and transfer shear forces (from longitudinal direction) into compressive forces to the vertical sides of the kerfs. To avoid a lifting of the concrete additional fasteners or connectors are considered (e.g. glued in reinforcement bars).

3. TIMBER – GRANITE-HYBRIDE

A hybrid structure refers to techniques where the advantages of two technologies or materials are combined optimally together.

Figure 11: shear connection by kerfs



So, the combination of a carrying timber structure with granite as a bridge flooring material brings interesting prospects:

Two natural materials with different properties: timber has a high tension (and good pressure) capacity, but needs protection against weathering. And granite with its high compression capacity is a waterproof material. So, it's attractive to combine both materials for bridges.
Research projects engage in the idea of combining it also statically with shear connectors.

4. Inspection and monitoring

Bridge structures are part of the traffic infrastructure and therefor part of administrative structures. Owner of the structures are mostly government institutions such as municipalities, counties or the federal government. Regular inspections are standardized in Germany by DIN 1076. Within the planning phase accessibility for inspection as well as possible renovation or replacement of components of a bridge structure need to be considered. Typical damages in timber constructions are caused by a high level of moisture that allows growth of wood-destroying organisms.

The German national Appendix to the European Standard EN 1995-2 differs between protected and unprotected timber bridges. Protected timber bridges require a constructional protection of all structural timber elements against weathering e.g. by lateral claddings and a covering of the top sides.

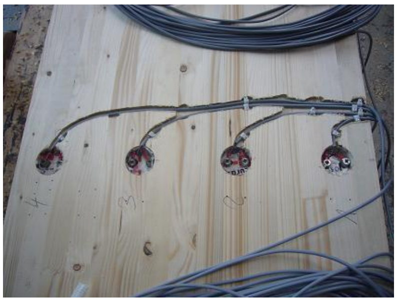


Figure 12: permanent control of wood moisture

In this way, protected bridges have a significantly longer lifetime and require significantly less maintenance than unprotected structures. Nevertheless, a leakage in the sealing may lead to a higher moister level that may cause decay. Such leakages must be detected quickly to avoid moisture getting into the timber parts. Appropriate monitoring systems can help to detect leakage or moisture sources at an early stage and thereby reduce possible damages and restoration costs.

4.1. Permanent moisture control

One type of monitoring system is the perma-nent control of wood moisture. Sensors that measure the level of wood moisture are placed inside a wooden element.
The data is collected in a logbook and can be send online to the client or is read out in a certain period.

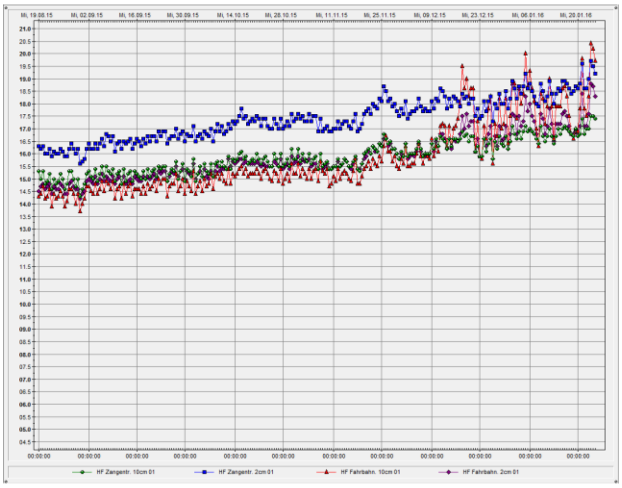


Figure 4: data output of a wood moisture recorder

4.2. Automatic location of leakage

Another type of monitoring is the permanent control functional test of a sealing. Therefore, a fibrous web or membrane is placed between the timber structure and the sealing. The membrane is connected to a minimum electric potential. Once the sealing gets permeable and moisture gets in contact to the membrane an electronic signal is generated. The membrane is connected to a digital system that raises alarm by sending an email to the client, once the electronic signal occurs.

5. Conclusions

A changed awareness on ecological matters is the proper basis for timber bridges. Timber is the one and only material that saves and stores CO2 permanently. And the technical possibilities are still growing. For example, researches on modern glues and gluing methods show in near future glues will be more efficient (temperature-resistant and the level of bonding pressure during the gluing process will be halved from 0,4 N/mm2 to 0,2 N/mm^2). Against this background the combination of block lamination and timber-concrete-composite is the beginning of the latest development: The comeback of timber bridges as adequate road bridges.

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