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A new pedestrian bridge made of regional beech wood in Adliswil

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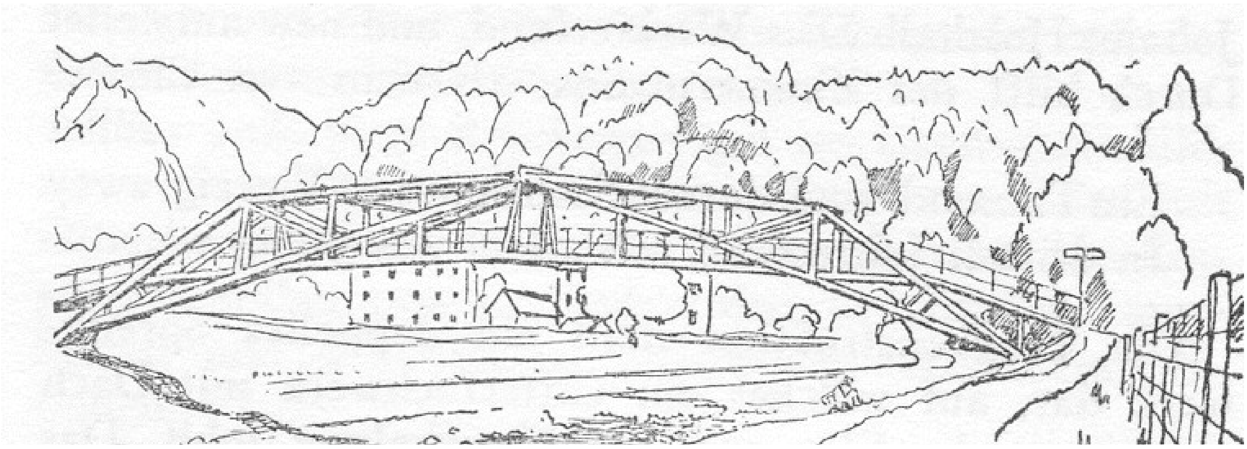
1 Introduction

The Tüfisteg is a pedestrian bridge over the Sihl in Adliswil. This 45 m long overpass was first built in 1932 as a trussbridge. truss bridges were originally built by the military They are characterised by the fact that they are built of easily accessible, often local material, i.e. wood. This classification for such bridges has been used up to the present day, even though they have long since been built by others than just the military.

The first version of the Tüfisteg was an unroofed truss construction with a suspended roadway. The building material used at the time was tar oil impregnated larch wood.



In 1985, the initial bridge had to be replaced. Following the military tradition, the new bridge was rebuilt as an unroofed truss construction made of solid wood. The side truss constructions formed a flat truss structure with the roadway resting on the lower chords. This bridge was built from CFRP pressure-impregnated spruce and fir wood.

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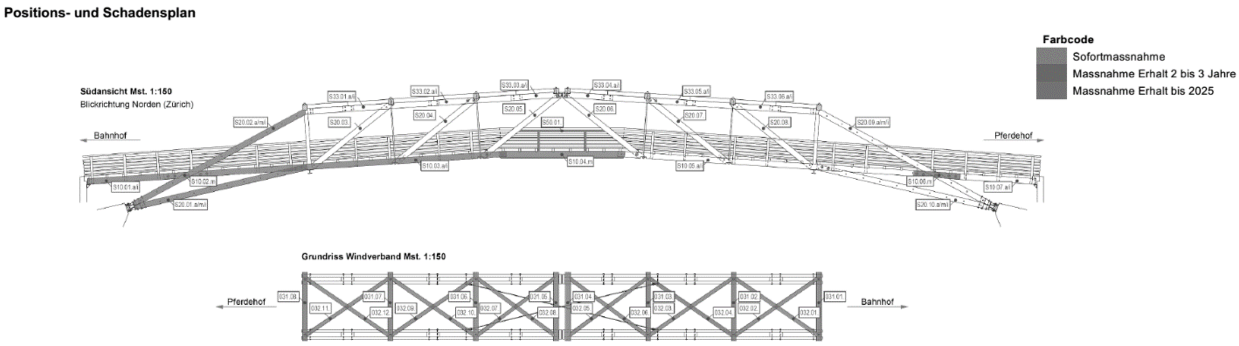
In 2006, the damage to the structure had progressed so much that the bridge had to be thoroughly renovated. Unfortunately, in the course of this renovation, it was decided to seal the cracks in the solid wood beams with epoxy resin.

A condition analysis from 2017 shows that the bridge is in such a bad state again that it is in need of major rehabilitation. The components rehabilitated with epoxy would all have had to be replaced. However, due to the construction, the primary components could hardly be replaced without dismantling the entire bridge.



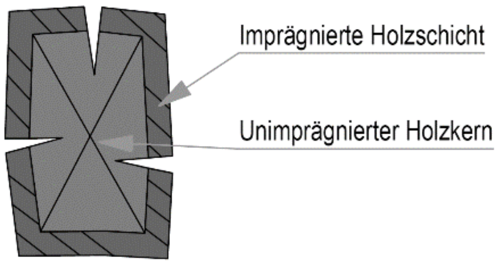
Accordingly, it was decided to replace the bridge altogether. The new bridge should be an unroofed truss bridge that reuses the existing abutments. As with the first bridge from 1932, a technical durability of at least 40 years should be reached.

1.1 Insights from damage analysis

As a basis for the new bridge design, a thorough damage analysis was first carried out.

The following factors turned out to be critical for durability:

- Large cross-sections lead to severe cracking
- Large, cracked cross-sections absorb more moisture and dry out more slowly.
- With large cross-sections, the cross-section core can hardly be impregnated, which remains susceptible to rot in the event of moisture penetration.

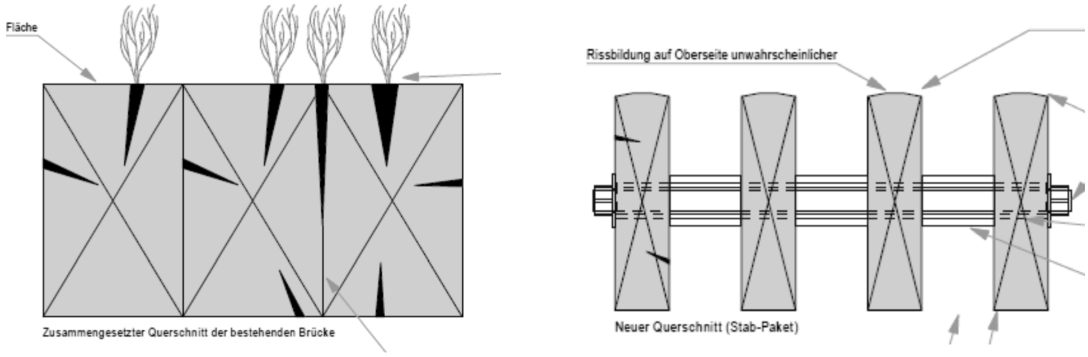


1.2 Solution approach

The new bridge should have similar appearance (truss bridge) and reuse the existing abutments.

Built of solid wood, this again means large and compound cross-sections for coniferous wood. In the case of an unroofed truss bridge, the only structural wood protection that is contemplable are cover and sacrificial boards on the top of the structural components. These can protect the individual beams between the connections. Yet these board covers are of little use in the truss nodes. Here, water can still get into the connection points and lead to moisture penetration.

One solution to this problem is the use of hardwood. Thanks to the higher density compared to coniferous wood, the individual timber cross-sections can be smaller. Formerly large composite cross-sections can be dissolved into air-flushed bar groups with similar load-bearing capacity.



Board-type bar assemblies have a much higher surface-to-volume ratio, which means they dry more quickly and are much less susceptible to cracking.

Now the challenge arises to choose the "appropriate" type of wood. One possibility is to use wood species such as oak, robinia or chestnut. These types of wood have good natural durability, but are relatively very pricey and/or not constantly available in the desired profile dimensions.

Even with the best structural wood protection, localised moisture penetration at contact points can occur in an open, uncovered truss bridge. Even with a construction in oak, damage can occur after only 10 years.

Pressure impregnation can prevent this. Since the critical contact points are usually well protected from direct weathering, chemical wood preservation remains effective in these areas for a very long time. However, this requires wood species that can be impregnated easily and are available as construction timber.

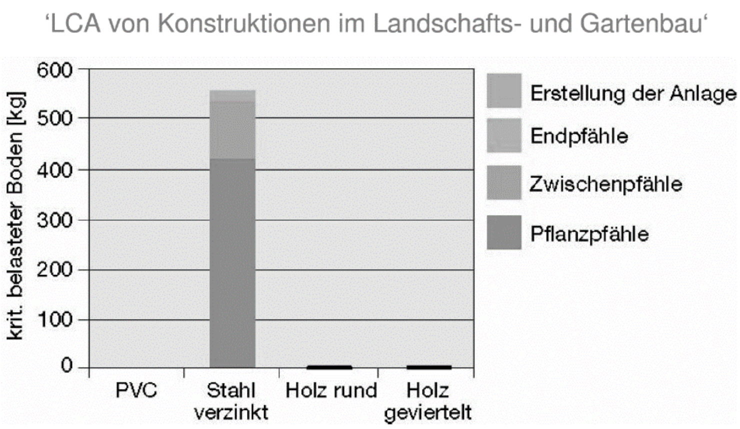
A wood species with high mechanical properties that is available in large quantities is beech. It can easily be impregnated, provided there is no red heart. However, unimpregnated beech has very low natural durability. Accordingly, with beech it is essential that the individual cross-sections can be completely impregnated with wood preservative.

1.3 Pressure impregnation - is this still "state of the art"?

Chemical wood preservation is frowned upon. "If you construct properly, you don't need to poison the wood" or "Pressure-impregnated wood poisons the environment and can only be disposed of later as hazardous waste" are the most frequent reactions when pressure impregnation is mentioned.

But are these statements still true? What used to be true for tar-oil impregnated wood is no longer true for today's salt-based impregnation options.

A study conducted by Empa in 2001 entitled "Life cycle assessment of constructions in gardening and landscaping" compared, among other things, the life cycle assessment of vineyard stakes used in vineyards. The impact of the stakes on the soil was also investigated. Stakes made of plastic, galvanised steel and pressure-impregnated wood were compared. The result was that compared to galvanised steel, the soil load of wooden stakes is negligible.



Applied to a bridge, this means that the leaching of preservatives from the wood is not relevant compared to the zinc from the steel parts.

regarding subsequent recycling, salt-based pressure-impregnated wood is equivalent to painted window frames, door leaves, parquet flooring or resin-covered chipboard for furniture.

If the alternative is only steel and concrete, pressure-treated wood is still considerably better in terms of environmental impact.

1.4 Beech wood in outdoor use - is that possible?

Everyone who deals with wood seems to know: Beech wood is a difficult material and certainly not suitable to be placed where it is exposed to the weather.

Is this statement generally valid, or is there a way of handling beech that makes its use possible? Everyone is looking for utilisations for beech wood. But beech wood sales will hardly be increased only with the now established high-performance components for interior use. There is also a need for low-threshold applications for beech wood on a larger scale.

1.4.1 Balconies Saumacker

In 2014, as part of a pilot project, we planned the use of beech wood outdoors on a balcony on Saumackerstrasse in Zurich. We were looking for planning approaches that would do justice to the specific properties of beech wood.

High residual stresses, deformations: Lamella construction in which each board can deform without great constraints

Low weather resistance: Complete impregnation with wood preservative (CKB).

High mechanical strength: design that takes advantage of this.

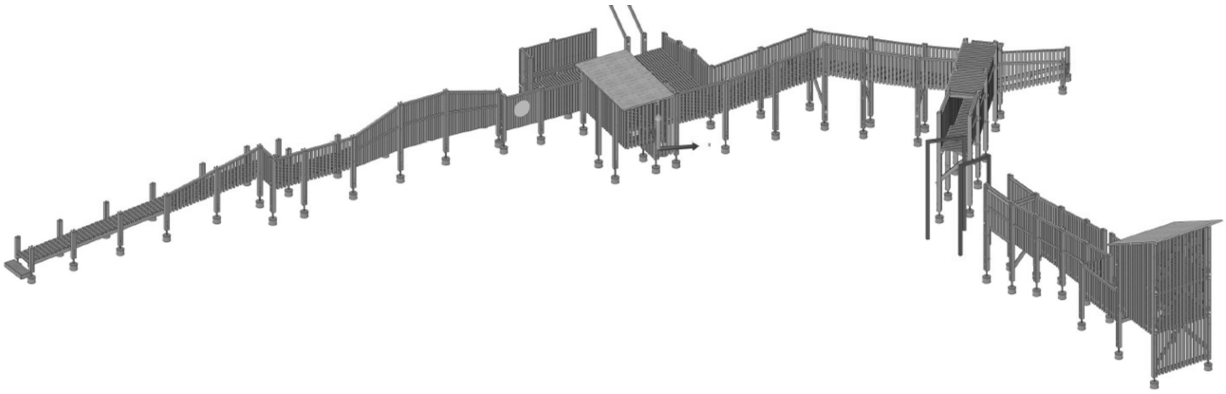
In the first few years, the ageing behaviour of the balconies was observed with annual monitoring. It was detected that the construction behaves much better and more benignly than assumed.

Around 40 m3 of local Zurich beech wood was used for the balconies at Saumacker. The balconies were also awarded the Swiss Wood label.

1.4.2 Playground Buchholz

A second opportunity to use beech wood outdoors arose with the renovation of the "Buchholz" playground in Zurich Witikon.

The original playground dates to the 1970s and was built as a "telephone pole construction" at the edge of the forest in an old quarry pit that has since become completely vegetated again. Due to safety deficiencies, the structure was replaced in 2003 by a similar structure made of natural oak and larch wood. After only 10 years, this showed considerable damage (fungal infestation with the oak spore, among others), which by 2015 had become so severe that the facility had to be replaced again.



In an evaluation phase, we concluded that a durability of considerably more than 10 years cannot be guaranteed for a structure constructed with domestic timber under the prevailing climatic conditions without chemical wood protection.

But if chemical wood preservation is necessary, then we will at least live up to the name and build the playground called Buchholz in local beech wood.. Based on Our previously gained knowledge from the beech balconies, we have planned the playground with colourless BKD-5 impregnated beech planks. All existing foundations were reused. The playground was completed in 2017 and has since been monitored annually for its condition and ageing behaviour in this climatically difficult environment.

Here, too, the beech wood playground has so far behaved pleasantly and as expected.

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1.5 Previous insights for an open bridge made of beech wood.

When building with beech wood constantly exposed to weather, the type of construction and the treatment of the material must be adapted in favor of the properties of beech wood. In the case of a bridge, the static strains are many times higher than in previous applications. Based on the experience with the two previous projects, we decided on the following framework parameters:

Timber harvest: If possible, only beech wood felled in late autumn. The sap and glucose content must be as low as possible.

Wood quality: No red-core wood, as it is inconvenient to be impregnated.

Cross-sections: Maximum cross-section width 60 mm. Such a plank can build up less residual pressure so that minimal restraint cracks occur.

Construction: All cross-sections are air-flushed on all sides with minimal contact surfaces. All components must be individually replaceable without having to dismantle the bridge.

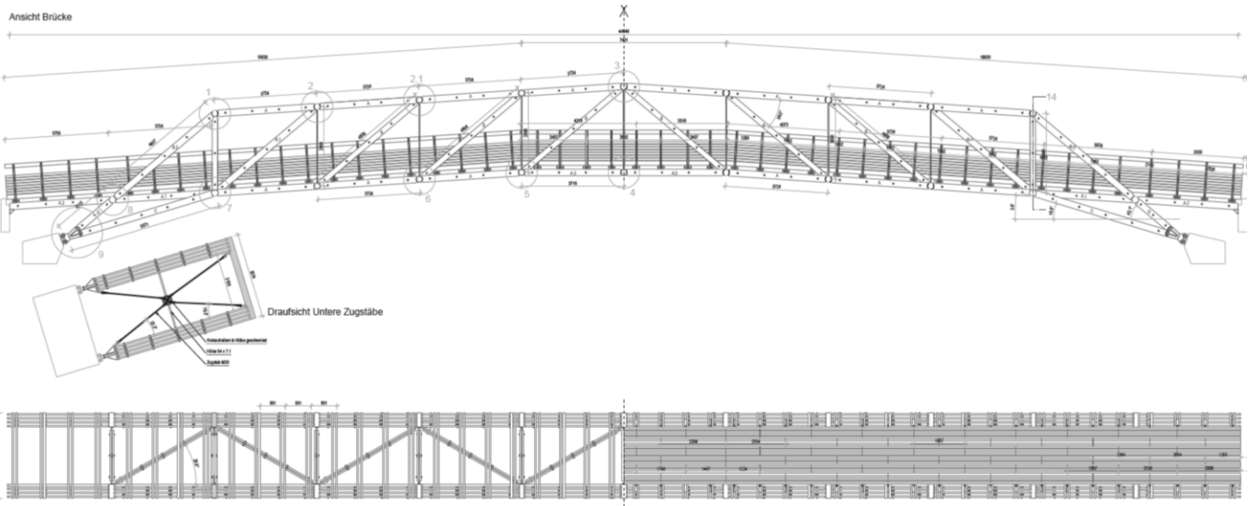
Pressure impregnation: Only executed by an impregnation plant that has experience with beech wood. All components are impregnated twice: Once before and once after joinery. This procedure guarantees thorough impregnation. In addition, strongly throwing or twisting components show up and can be sorted out.

Load-bearing behaviour: The load-bearing behaviour (buckling) of beam groups must be examined/researched in more detail. For this purpose, corresponding tests were carried out as part of a thesis at the BFH.

2 Construction principles of new Tüfisteg made of solid beech wood

2.1 Truss conception

The new bridge conforms with the previous bridge, so that the previous abutments could be reused 1:1. Since the length of the structure in hardwood is limited, the truss struts in the abutments were designed steeper in order to shorten the component lengths. In the same profile, the new bridge now has 8 instead of 6 truss struts.



2.2 Rod groups

In the beech version, the truss chords are arranged in open rod groups by geometrically breaking up the previous assembled beams. These are threaded at regular intervals onto steel tubes with spacer rings and braced with a continuous screw to form a fixed package.

Between the gaps, water can flow off unhindered at any time. Due to the much larger surface, these cross-sections also dry out much quicker after a rainy period. This arrangement also allows for later replacement of individual bars with relatively little effort.

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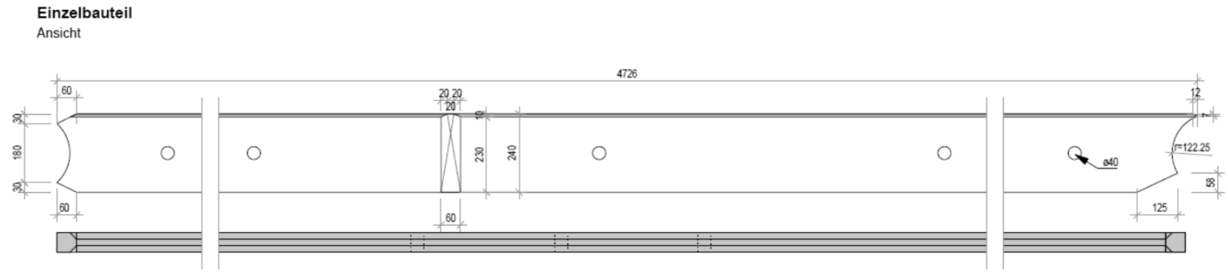
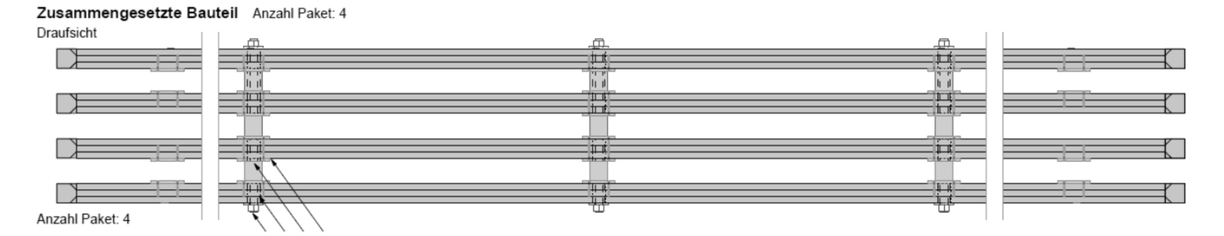
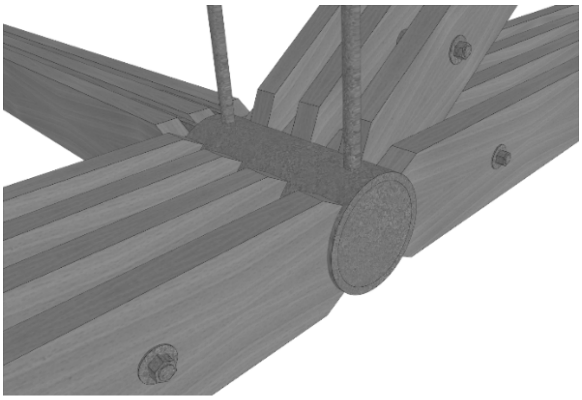


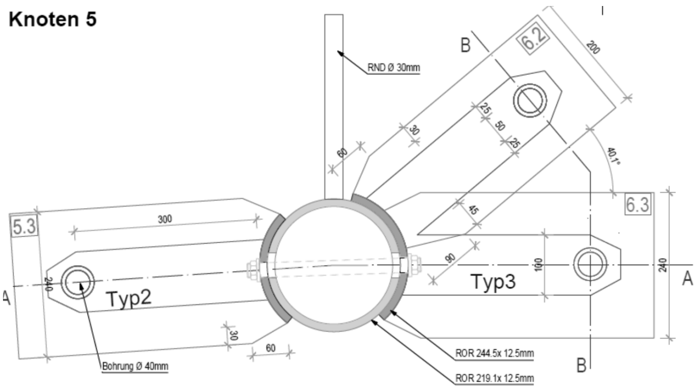


2.3 Node

The connection of the beech rods in the nodes is carried out as a pure compression connection onto a round steel profile. All components subject to tensile stress are again realised with steel tension rods, as in the existing bridge.

The design principle in the nodes is to minimise capillary joints so that water always drains away.





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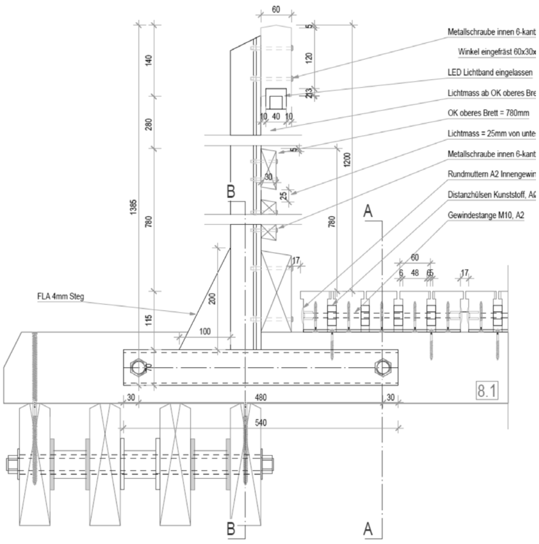
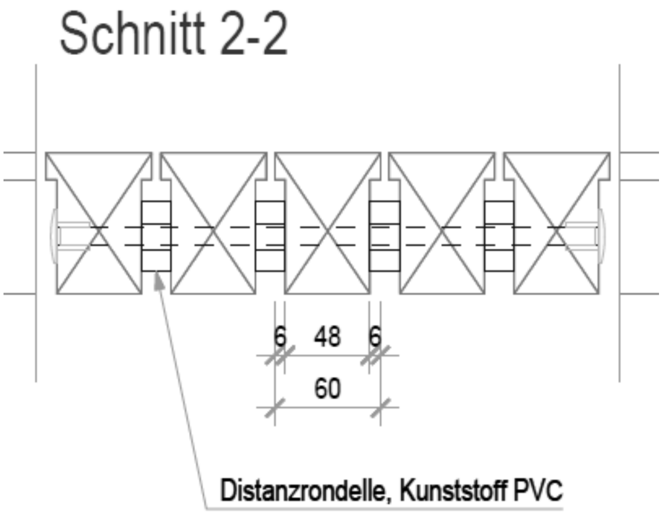
2.4 Roadway

The roadway was also made of beech. T-shaped profiles were assembled into groups of bars. Beech cross-sections were used, which do not meet the strength requirements of the main structure, but can be processed as roadway slats without any problems. As with the existing bridge, the roadway slats were provided with an anti-slip coating made of sanded epoxy.



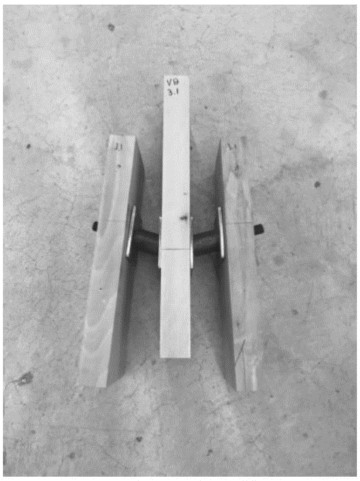


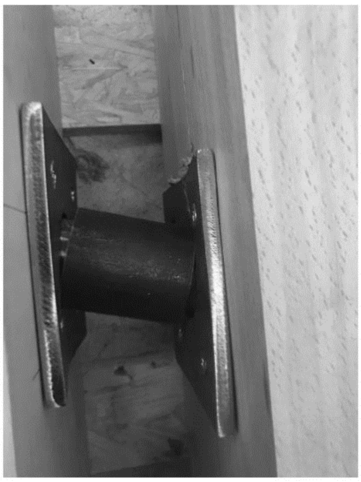
3 Buckling research at Berne University of Applied Science

Since the fasteners are very specific and the composite compression members are generally described very sparsely in the national and international standards, a complex structural analysis model was developed by the Timbatec company for evaluating the stability of the components in the direction of the connection axis. With the help of the model, the effective moment of inertia of the components is calculated via the bending deformation and, in a second step, the stability verifications are carried out on a replacement profile.

Two different test series were carried out as part of a bachelor thesis. With the first test series, the structural analysis model is checked globally. For this purpose, the effective moment of inertia of the components is determined via the bending deformation in the same way as in the model. The second series of tests is used to assess the stiffness of the fasteners and thus to check the model locally regarding the parameters introduced for representing the fasteners as displacement and torsion springs.

These tests served as the basis for the design of the rod packages used for the Tüfisteg.





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4 Assembly and first insights

The bridge was mostly pre-assembled in two parts at the factory (Burch Sarnen) and pre-assembled on site. The bridge, which weighed around 30 tonnes, was then lifted into place on the supports using a large pneumatic crane.

During the one-year inspection, it was noted that the beechwood bridge has been behaving very well so far, as expected.