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History and development stages in timber bridge construction in Switzerland

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1 Introduction - Topography of Switzerland

Switzerland is a relatively small country in the heart of Europe (Figure 1). Its territory stretches 220 km from north to south and 348 km from east to west and covers an area of approximately 41,000 square kilometers. Switzerland is roughly divided into three geographic regions, the Jura mountains in the north-west, the Alps in the south and between these two mountains there is a relatively flat band that runs from north-east to south-west and forms the so-called Central Plateau. The Alps make up almost 60% of the total area and thus form the largest part of the total area. Due to its topography and the high rainfall of approx. 1430 mm/a [1], Switzerland has a widely dispersed network of streams and rivers with a total length of around 65,000 kilometers. There are also around 80 larger and more than 6,500 smaller lakes. No Swiss person lives further than 16 km from a lake and the distance to the next watercourse is likely to be even much shorter in most cases. The four largest Swiss rivers - Rhine, Aare, Rhone and Reuss - have their sources just a few kilometers apart in the Gotthard region. The Swiss rivers empty into the North Sea (Rhine), the western Mediterranean (Rhône), the eastern Mediterranean (Ticino via the Po) and the Black Sea (Inn via the Danube). For this reason, Switzerland is also known as Europe's Water Tower.

The mentioned geographical conditions had and still have a major influence on mobility in Switzerland. Mountains, rivers and lakes are massive obstacles to the unhindered transport of people and goods. Overcoming the mountains required the construction of passes and/or tunnels, while water had to be crossed by (mobile) ferries or – of course – mainly by (fixed) bridges.

The building materials available for early bridge construction also resulted from the topographical conditions in these days. Stones were available in endless numbers and sizes from boulders and debris in rivers and lakes, or they could be hewn directly from the rock. The building material wood was (and is) available almost endlessly, since the forest area in Switzerland (today) accounts for 32 percent of the total area. Below the tree line, wood was and is available locally as a building material practically throughout Switzerland and therefore does not have to be transported over long distances. Figure 2 shows the three dominating materials for the construction of historic Swiss bridges united in one picture.

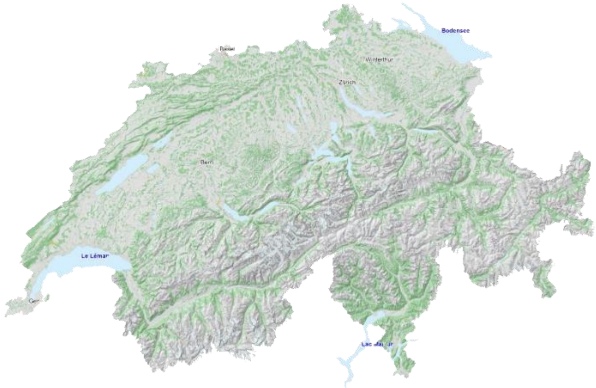

Figure 1: Map of Switzerland highlighting the presence of mountainous areas, water (river valleys and lakes) as well as wood (forests, highlighted in green). Picture: geo.admin.ch

Figure 2: Timber, iron and stones (masonry). Kubelbridge (1776) with a span of 30 m in the first plane and Sitterviadukt (1910) with a length of 365 m and a maximum span of 120 m. With 99 m this is the highest railway bridge in Switzerland. Picture: R. Widmann

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2 Early days timber bridges

As Werner Stadelmann [3] explained, it is therefore not surprising that our ancestors preferred wood for their constructions for centuries. The rounded trunks of the early bridges were laid close to each other, and branches filled their gaps. This technique is still used today for temporary bridges, e.g. in the area of forest roads (Figure 3). Later the road was covered with gravel, earth and clay. However, the bridges required constant supervision by "bridge-keepers" and goalkeepers. Covered with earthen material, the bridges were soft and difficult to walk on in rainy weather, and therefor, from the 15th century, the decks were covered with sawn timber. For better bases, the craftsmen processed the round trunks into rectangular squared timber with an axe. Planks were laid over them, some of the covering laid at an angle or loosely, held down at the edges with battens.

Since the reliable span of a wooden beam was limited to six to ten meters, intermediate supports made of stone or wood had to be installed for wider rivers/spans. Probably the oldest yoke bridge in Europe is the famous Kapellbrücke in Lucerne with spans of approx. 7.65 m (Figure 4).

In the event of war, such structures could be quickly removed and later, after the danger had passed, being reinstalled. Floods and ice drifts repeatedly destroyed intermediate pillars and caused bridges to collapse. Parts of the bridge that were washed away endangered other bridges downstream. In this regard, Stadelmann [3] also quotes the Swiss novelist Jeremias Gotthelf with his story "Water Distress in the Emmental", how the flood of August 13, 1837 destroyed all wooden bridges over the Emme, with the exception of the Horben Bridge, the only one without an intermediate pillar. The connection between the two sides of the valley was limited to this single transition for years.

Figure 3: Modern interpretation of early log bridge by Prof Gehri. Untere Hürlisegg Bridge – Eggiwil BE – constructed in 2009. This comes close to the historic "Schlagen einer Brücke", which refers to "Schlagen eines Baumes", in English cutting a tree/trunk with an axe. The wood was locally cut and processed on-site in order to arrange it as a bridge (deck) for forest-traffic. Pictures: E. Gehri

Figure 4: Renowned Kapellbridge in Lucerne, central Switzerland with a total length of 205 m. This is the oldest existing bridge in Switzerland (1365). It almost completely burnt down in 1993 and was rebuilt in 1994. Pictures: R. Widmann and sgkgs

3 Larger span timber bridges

3.1 Strut- and post- framed trusses

In an effort to achieve larger spans, supporting structures were developed from the 15th century by joining beams to form triangles und thus trusses. There were/are three basic construction types:

- In German "Sprengwerk". These are trusses made from struts that are positioned below the deck. This results in all members (except the deck itself) being loaded axially in compression. Joining the single members is relatively easy, e.g. via direct contact. Regarding the position of the truss relative to the deck, such constructions could also be referred to as "deck trusses".
- In German: "Hängewerk". These are trusses made from posts and struts which are positioned above the deck. They resemble king- or queen-post structures used in roofing constructions. The deck is suspended ("hanging") and the vertically running posts are loaded in tension. The connections have to transfer tension and thus are more difficult to realize. Regarding the position of the truss relative to the deck, such constructions could also be referred to as "through trusses". An advantage of this construction is that there are no structural members below the deck and thus the flow section is not reduced.
- A combination of the two above mentioned trusses, could be referred to as "composite truss frame or "Swiss trussed bridge" (Figure *5*). Regarding the position of the truss relative to the deck, such constructions could also be referred to as "pony trusses". This kind of trusses, in particular when they were made as polygonal strutted frames, allowed for the biggest spans of timber bridges before arches were introduced and realized.

Stadelmann [3] and Blaser [4] mention that one of the first suspension bridges spanned the Martinstobel near St.Gallen in 1468 with a length of 30 meters. Two other examples with widths of up to approx. 20 meters are the Neubrügg built in 1535 over the Aare near Bern and the Saane overpass near Gümmenen built in 1555. For the bridge construction, the craftsmen used straight wood with as little knots as possible, such as fir, spruce and larch, and also oak for special purposes. Because of its density and resin content, larch wood was the most suitable.

The best material, careful design and execution have always influenced the service life. Covered wooden bridges reach an age of more than two hundred years. Even if they had to be renovated and strengthened several times in order to reach this age, this is a great achievement. Especially if you compare the envisaged lifetime of 80 to 100 years for modern steel and concrete bridges. In practically all areas of Switzerland, most timber bridges were given a roof and side panels to protect them from the weather. These roofs, often elaborately executed, also served to reinforce the supporting structure. These bridges are still referred to as "Hüslibrücken" ("little house-bridges") to this day.

Figure 5: Letzibrücke from 1853 crossing the river Necker in Canton Thurgau. This is an example for a composite truss frame. Since 1969 a pre-tensioned concrete bridge close to the timber bridge takes the road traffic. The picture on the right shows how historic timber bridges can be used in Switzerland nowadays. Like many others they can be, e.g. rented for events like weddings or birthdays. This possibility of use contributes to the fact that the local population often has a strong emotional bond with "their" wooden bridge and thus also takes care of the structure. Pictures: R. Widmann

In the 18th century, the manual construction of wooden bridges with its variety of load-bearing systems reached a peak that was hardly surpassed later. Successful master carpenters like Hans Ulrich Grubenmann (1709-1783) from Teufen in Canton Appenzell Innerrhoden, Eastern Switzerland, Josef Ritter (1745-1809) from Lucerne, central Switzerland and Blasius Baldischwiler (1752-1832) from Laufenberg, southern Germany and other talented professionals created important buildings, some of which were well known in large parts of Europe [3].

3.2 The impact of the Grubenmann Bridges

The internationally best-known bridge structures of this time came from the Grubenmann brothers, and here in particular from Hans Ulrich Grubenmann [5]. In addition to numerous large roof structures for churches, the Grubenmann brothers designed and built more than 10 large wooden bridges, some of which are listed in Table 1. Their bridges show how it was possible to build bridges with large spans of over 50 m using wood. The transition from dissolved multiple trusses and hanging structures to arch structures can already be seen here. The two best-known and most important Grubenmann bridges are those of Schaffhausen (completed 1758) and Wettingen (completed 1766). With spans of 63 m (longer of the two spans in Schaffhausen) and 61 m (Wettingen), they were definitely among the widest-span wooden bridges in the world in that era.

Table 1: Examples of bridges of the brothers Hans-Ulrich and Johannes Grubenmann. Unfortunately, only 3 of the Grubenmann bridges are still existing.

Bridge	Year	Span [m]	Destroyed
Ziegelbrücke	1743	38	1799
Schaffhausen	1755-1758	56 + 63	1799
Reichenau (2)	1757	ca. 35 (1) and ca. 70 (2)	1799
Wettingen	1764-1766	61	1799
Schindeleggi	1765	31	1946
Netstal	1766	ca. 30m-35m (?)	1799
Ennenda	1765	ca. 48m (?)	1799
Schwanden	1765	?	1799
Oberglatt	1767	28	
Hundwil	1778	29	
Kubel	1780	30	

However, there are indications in the literature that one of the two bridges of the same age, at the confluence of the Vorder- and Hinterrhein in Reichenau, clearly exceeded the above-mentioned bridges with their approx. 70 m span. Unfortunately, unlike the first two bridges mentioned, no technical documentation or models of the Reichenau Bridges (and especially the longer of the two) remain. Contemporary witnesses report in the literature that this bridge was superior to the Schaffhausen and Wettingen bridges, in addition to or despite the larger span, with its obviously lower susceptibility to vibration.

With regard to the span of the Schaffhausen Bridge, there is probably not a single relevant treatise in which the topic is not discussed whether it was a single-span 119 m long bridge or a two-span bridge with spans of 63 m and 56 m (Figure 6).It is undisputed that Grubenmann at least initially wanted and proposed to build a single-span bridge. He proved the suitability of his construction with a corresponding single-span model, which he loaded with his full body weight in front of the responsible Schaffhausen officials. It is also clear that the Schaffhausen councilors rejected this and forced Grubenmann to place his bridge on an existing central midspan pillar.

It is clearly visible that the executed bridge contains features for both, one-span and two-span structures, to a certain extent as a kind of hybrid. There are records that allegedly prove that it worked at least temporarily as a single span bridge, but also those that refer this to the realm of fables. However, the analysis of the floor plan clearly shows that a single-span bridge is difficult to imagine. The reason for this is the bend above the central support, which in this case would greatly encourage the pressure members to deviate to the side. When discussing the two bridges, it seems to be much more important to the authors that the change or further development and transformation from the dissolved polygonal strutted frame (Schaffhausen) to the arch (Wettingen, Figure 7) is clearly visible. This transformation is also well described an documented in detail by Blaser [4] and Steurer [6]. Arched timber structures were probably already in use beforehand and other Swiss master timber builders also adopted this construction method at the same or subsequent time.

Other examples are the Emme bridges in Hasle Rüegsau (Figure 8) and Schüpbach (Figure 9), both from 1839. These arches have in common that the individual lamellae were clamped/bolted against each other and interlocking tooth-shaped recesses ensured the transmission of shear forces in the arch. In the period that followed, both types of construction existed side by side.

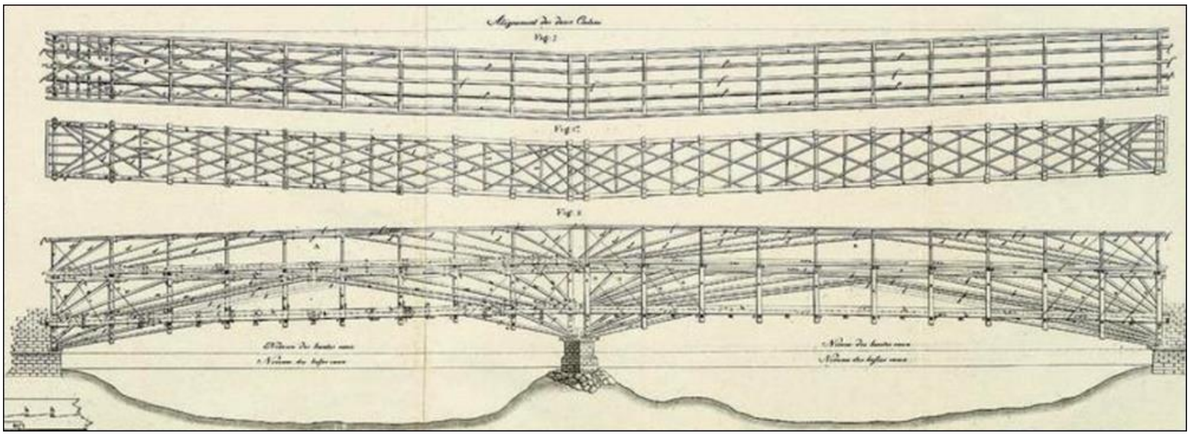

Figure 6: One of the two most important and renowned bridges of Hans Ulrich Grubenmann. is the Schaffhausen bridge crossing the river Rhine as shown here in a drawing from Christian von Mechel. The bridge was opened for traffic in 1758. The side view of the construction reveals that there are distributed arch-like polygonal struts that form a two-span structure as well as such that form only a one-span structure. From the plan view it can easily be recognized, that there is a bend at the middle support. Picture: B. Nebel

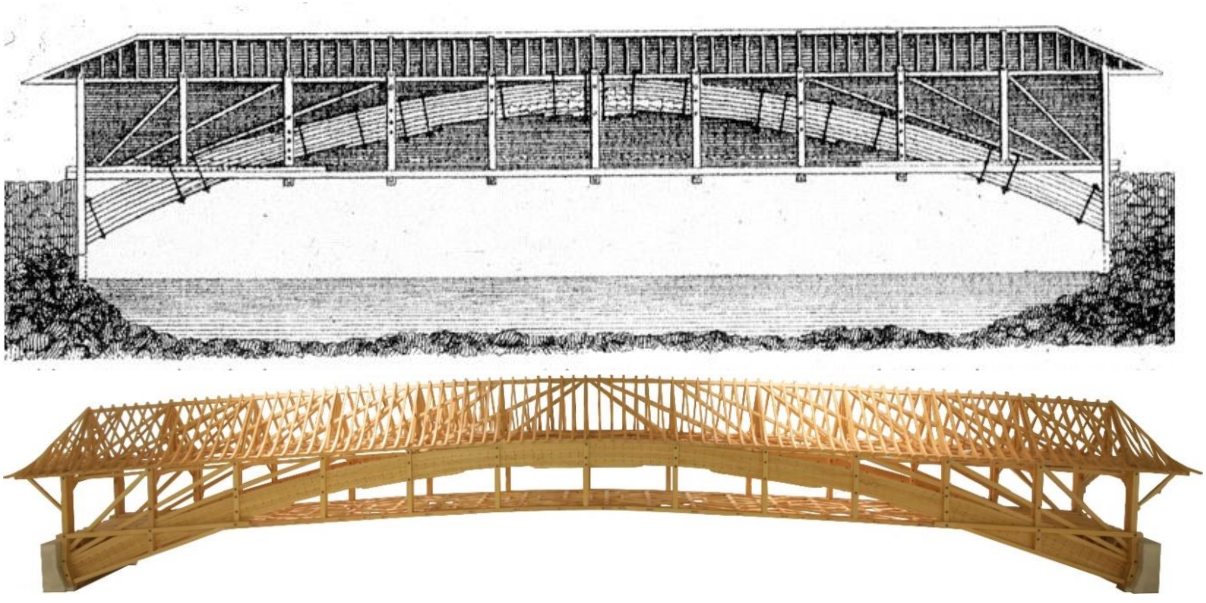

Figure 7: The other very important and renowned bridge of Hans Ulrich Grubenmann is the Wettingen bridge crossing the river Limmat with a span of 61 m. The bridge was opened for traffic in 1766. At this stage, the transition from combined polygonal struts and post constructions as used in Schaffhausen to an arched structure was performed. For the transfer of shear forces the single lamellae had to be spanned together. It is not clear, how it was realized. In the shown model (Zeughaus Teufen), as well in the original (?) model in Aarau, it has been realized by bolts whereas the drawing shows the use of braces. Pictures: B. Nebel, R. Widmann

Figure 8: Bridge at Hasle-Rüegsau BE crossing the river Emme. Built in 1839, it has a span of 58 m and thus is very similar to the Grubenmann Bridge in Wettingen, Picture: R. Widmann

Figure 9: Another Emme bridge (in Schüpbach) with an impressive 49 m span and similar construction as Hasle-Rüeggsau and Wettingen bridges. The picture shows nicely the technics used to create an arch with interlocking tooth-shaped recesses in the lamellae and/or hardwood dowels for the transfer of shear forces within the arch. Picture: E. Honegger (A. Steurer) [6]

3.3 US – Truss technology adopted for Swiss Timber bridges

They were supplemented by the lattice trusses developed in the USA at the beginning of the 19th century based on the designs of Ithiel Town ("lattice truss") and William Howe. Numerous bridges in Switzerland were built using this method, of which some impressive bridges still exist today, e.g. between Vaduz and Sevelen (Howe truss) over the Rhine and over the Necker (Town lattice truss) in the Canton of Sankt-Gallen.

Figure 10: Necker Bridge Anzenwil SG from 1863 with it's main structural elements being Town lattice trusses. The bridge spans 46 meters (with the addition of an intermediate support) and was under road traffic load until the year 2000, when a modern concrete-steel hybrid bridge was set next to it. The new bridge carries the main traffic load and leaves the slow traffic to the old timber bridge, Pictures: R. Widmann

Figure 11: Howe truss bridge crossing the river Rhine between Sevelen (CH) and Vaduz (LI). Built (opened) in 1871/1901 it was one of a series of more than 10 Howe truss bridges along the river Rhine, including one for railway. It is the only one that still exists. This bridge was under road-traffic load (6t) until in 1975 a new pre-stressed concrete bridge (from which the picture at the bottom was taken) was built next to it. www.swiss-timber-bridges.ch/ lists a total of 34 Howe truss bridges that exist(ed) in Switzerland. Pictures: Documentation: Die alte Rheinbrücke Vaduz–Sevelen

3.4 New (old) role for timber in bridge constructions

With the beginning of industrialization and the associated construction of railways and efficient roads, however, more and more bridges were built first of iron, then steel and concrete. Thus, the construction of (large) wooden bridges was strongly pushed back. In addition, numerous existing wooden bridges were destroyed and replaced by supposedly more efficient bridges made from modern building materials. After all, wood was still used in bridge construction for installations and scaffolding and formwork (Figure 12).

Figure 12: Renowned Salginatobelbrücke in Schiers, Graubünden, Eastern Switzerland by Robert Maillard (concrete structure) and Richard Coray (timber scaffolding) 1929-1930. These pictures highlight the transition of the role of timber in bridge constructions from being the dominant permanent solution in the past to serving as a temporary auxiliary construction. Pictures: L. Gianadda, R. Widmann

However, since the middle of the 1950s, a rethink has started. Numerous "Hüslibrücken" have been thoroughly renovated and placed under monument protection in order to preserve them for posterity. A few were left next to new concrete bridges as unused "siblings" (Figure 13).

Figure 13: Examples for timber bridges in Switzerland that lost their initial primary purpose as the main traffic bridge to their modern siblings. Left hand side shows the Lüthisburg bridge with length of 58m and its replacement can be seen in the background. Right hand side is the bridge from Figure 10 with its younger sibling just sitting next to it. Both timber bridges are well preserved and still serve for pedestrians and bycicles and in the Lüthisburg bridge can also be rented for event. Pictures: L. Gianadda, R. Widmann

4 Renaissance of timber road bridges in Switzerland

In the 1980s, timber road bridges experienced a renaissance in Switzerland. In 1985, the Dörfli Bridge was put into operation. The Bubenei Bridge followed in 1988. It is thanks to the canton of Berne that multi-lane road bridges in wood have once again been built in Switzerland, especially in the Emmental. There is probably no other region in Switzerland with such a high density of wooden bridges than the Emmental.

From the very beginning, attention was paid to excellent structural wood protection. Even then, only protected bridges were built. This was important to regain lost trust and has proven its worth to this day. The protection concept was initially based on a roof. The roadway deck was additionally protected with sealant and asphalt. Arches were predominantly used for the main structure. This supporting structure is excellently suited and efficient for bridges.

Figure 14: Dörfli-Bridge, Eggiwil, Canton Bern, built 1985, Span 30.6 m, Live load 28 Tons, Type Covered arch bridge, Design: H. Vogel and Prof. Gehri, ETH Zürich, Pictures: Archiv K. Schwaner.

Figure 15: Bubenei-Bridge, Canton Bern, built 1988, Length/Span: 50.0/43,4 m, Live load 28 Tons, Type Covered arch bridge, Design: H. Vogel, Bern, Moor Hauser & Partner AG, Bern, Pictures: Kolb

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4.1 Adoption and further development of stress laminated timber deck plates in Switzerland

The QS plate certainly helped to achieve a breakthrough of the highly stressed road bridges in wood.

Around 1985, the system of transverse prestressing was adopted and further developed in Switzerland. The adaptation to the European requirements has led to the so-called "QS panels", which are frequently used in timber bridge construction and partly also in building construction reports Andreas Bernasconi in [10]. He explained that massive, slab-like roadway elements connected with nail plates were already used decades ago in Canada. Due to the vibrations caused by the traffic the nail connection has been detached. In order to improve the interaction of the elements as a slab-shaped load-bearing element, these roadway elements were pressed together in the transverse direction with the help of steel rods. This closed the open joints and the load-bearing effect was restored. From this rehabilitation measure the Stress Laminated Timber Deck Plates emerged. The QS panels were often formed by impregnated boards for simple forest bridges.

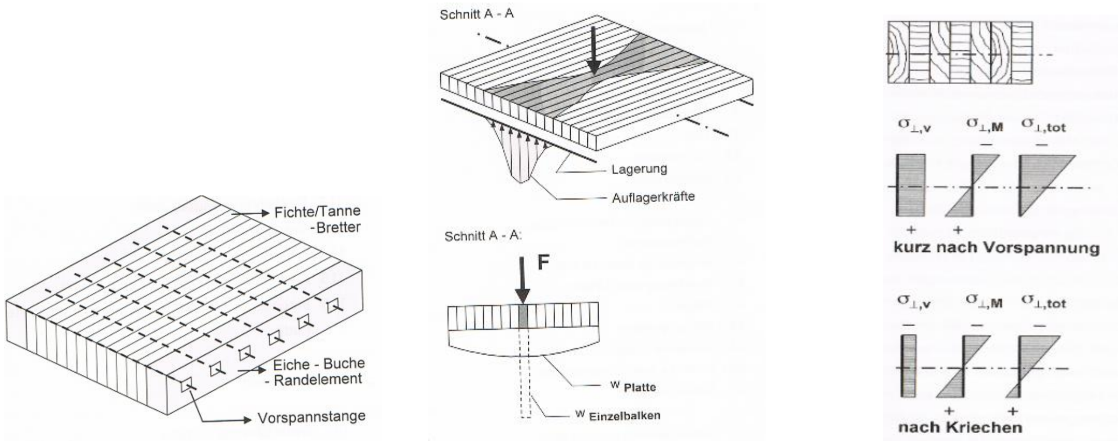

Figure 16: Stress Laminated Timber Deck Plates in: Schwaner K., Horsch B. (1999) Brücken aus Holz – Konstruieren, Berechnen, Ausführen, Tagungsband INFORMATIONSDIENST HOLZ [10], Pictures: Archiv K. Schwaner.

Figure 17: Forestry-Bridge-Typ with Stress Laminated Timber Deck Plates, Design: Prof. E. Gehri, Pictures: Archiv K. Schwaner.

4.2 Protection concept using lamella formwork

In addition to the road bridges, numerous footpath and cycle path bridges continue to be built in wood. An impressive example is the bridge over the Simme near Wimmis, Canton Bern. Julius Natterer used open lamella formwork instead of closed formwork. This type of cladding is widely accepted for the protection of wooden bridges. It is open and transparent and offers views for people of different sizes. Technically, it ensures excellent drying capacity for the protected components.

Figure 18: Cycle Path Bridge over Simme near Reutingen/Wimmis, Canton Bern, built 1989, Length 108 m, /Span 27/54/27 m, Type Covered truss bridge, Design: J. Natterer, Pictures: Kolb. Schwaner.

4.3 Protected bridges without roof

In the 1990s, the roof was dismissed for the first time. Confidence in the waterproofing systems has grown. The main reason, however, was to increase the economic efficiency. A covered bridge causes higher costs. As a result of the moisture input from the traffic, the deck must be carefully protected anyway. Between 2000 and 2010, 75% of the bridges have already been built without a roof [8].

High-performance materials also found their way into wooden bridge construction. In particular, components subjected to stress perpendicular to the grain were made with reinforcements of plywood and laminated veneer lumber (LVL).

Figure 19: Bridge San Nicla, Canton Graubünden, built 1993, Length/Span: 47,8/39 m, Live load 28 Tons, Type Arch Bridge, Design: A. Mayer, Sent, A. Deplazes, Chur, Prof. E. Gehri, Pictures: BFH

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4.4 Timber-concrete composite bridges

In the same time period, timber-concrete composite bridges were built for the first time. The advantages were seen in the fact that the reinforced concrete carriageway slab perfectly protects the timber components underneath and at the same time ensures a significant part of the load-bearing capacity.

In particular, they ensure load distribution. The load distribution of the high individual loads of the load models does not cause a problem. The use of detail solutions from solid construction, which have been used and proven thousands of times, was seen as a major advantage. The most important of these are the connections of the scraper curbs, the roadway transitions and the anchoring of the crash barriers.

As is customary in Switzerland, different shear connections were developed and just used and tested on the current object.

Figure 20: Glenner-bridge, Graubünden, built 2002, Length 34,6 m, / Span 24,6 m, Live load 4x75 Tons, Design: Conzett, Bronzini, Gartmann AG, Chur, Pictures: Graubündenholz, Landquart/LIGNUM

Figure 21: Planchy, Bulle, built 2005, Span 25,9 m, 40 tons, Vial SA, Le Mouret, Pictures: BFH

Figure 22: Ronatobelbrücke in Furna, Graubünden, Timber-Concrete-Composite, built 1991; Span 12-12-13,75-12,25 m; 28 tons, Engineers Buchli + Joh. Fromm, Picture: Andrea Bernasconi HES-SO Yverdon/LIGNUM

Figure 23: Crestawaldbrücke in Sufers, Graubünden, Timber-Concrete-Composite, built 1996; Span 31 m; 28 tons, Engineers W. Zöllig, Arbon, M. Krattiger, Happerswil, Pictures: Archiv K. Schwaner

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4.5 Competition for a new generation of timber bridges

In a competition for the renewal of four wooden bridges in the upper Emmental [12] a distinction was already made between timber bridges without roofs and timber bridges with roofs. The result of this competition was convincing. In the first stage (ideas competition) 45 designs were submitted. in the second stage 8 feasible bridge designs were developed. With this competition, the broad spectrum of timber bridge construction could be shown. This was important to convince even skeptical decision-makers of the quality of timber bridges.

Figure 24: Obermattbrücke, Canton Bern, built 2007, Through Bridge, vertically adjustable (70 cm) bridge when high water, span: 32 m live load 40 tons, Design: Paul Grunder AG, Täufen, *Pictures: BFH*

Heavy rainfalls often lead to the destruction of infrastructure structures/building. In this case rapid replacement is required. Every large-scale weather event was therefore also an opportunity for timber bridge construction. Innovative solutions for lifting, excavating and moving out of the danger zone were developed as important prevention measures. Due to their low dead weight, wooden bridges have an advantage here.

4.6 Timber bridge construction today

Today timber bridges are often made with block glued beams sometimes in combination with multilayer LVL or CLT deck plates as composite construction. Nevertheless, covered truss bridges are still being built today. These are very economical option for large spanned single-lane bridges. Some of these are designed for 66 tonnes.

Figure 25: Horenbrücke, Canton Aargau, built 2008, lenght: 30.87 m, span: 6,25 – 17,32 – 7,30 m, 40 tons, block glued girder bridge, Design: Makiol + Wiederkehr, Beinwil, Wilhelm+Wahlen, Aarau, Zimmermann Architekten, Aarau, Pictures: A. Müller BFH

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Figure 26: Luthernbrücke, Canton Luzern built 2010, Lenght: 13,55 Span: 13.05 m, 40 tons, block glued girder bridge, Design: E. Winkler & Partner, Luzern, Makiol + Wiederkehr, Beinwil, Picture: Makiol + Wiederkehr

Figure 27: Kirchenbrücke Muotathal, Canton Schwyz built 2009, Lenght: 34,00 m Span: 33,40 m, 40 tons, arch bridge, Design: Pirmin Jung, Rain, BPP Ingenieure, Schwyz, E. Imhof, Luzern, Picture: BFH

Figure 28: Enningerbrücke, Malters, Canton Luzern, built 2010, Lenght: 46,0 m Span: 42,0 m, 28 tons, truss bridge, Design: Pirmin Jung, Rain, Emch + Berger WSB AG, Luzern, Pictures: Kolb, Pirmin Jung Ingenieure

4.7 Timber- ultra-high performance fibre composite (UHPC) composit structures

In the meantime, ultra-high performance fibre composite (UHPC) has found its way into timber bridge construction. The combination of wood and UHPC is promising. The material combination of timber with decks made of UHPC has already been used several times, especially in shear composite (wood-UHPC composite construction) in the new construction of wooden bridges (2018 Gletschersand bridge in Grindelwald, 2020 Fruttli bridge near Rigi Fruttli) [13].

Figure 29: Fruttlibrücke in Arth, Canton Schwyz built 2020, Span: 10,45 m, 40 Tons, Timber- UHPC composite structure, Design: Edgar Kälin, Einsiedeln, Neue Holzbau AG, Lungern, Prof. E. Brühwiler EPFL Lausanne [15], Pictures: E. Kälin

In contrast to the mastic asphalt structure, the UHPC layer serves to increase the load-bearing capacity of the roadway slab. With a roadway slab made of UHPC, 3 layers (waterproofing, protective layer, surface layer) can be replaced. According to [14] Brühwiler 2017), a UHPC layer thickness of 30 mm is "liquid-tight" up to an expansion of 1.2 ‰.

In expert circles, this type of construction in timber bridge building is considered to have good market chances, as the described advantages can significantly improve not only the increased performance but also the durability by protecting the underlying timber construction and thus also the economic efficiency of timber bridges.

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