INTRODUCTION

Germany’s historic wooden covered bridges are not well known. The latest edition of the World Guide to Covered Bridges (World Guide 2005) lists 43 existing historic (older than 50 years) bridges in Germany including two that cross into Switzerland, 16 further existing bridges whose age is not determined and 63 existing new bridges (younger than 50 years). Recent research has revealed a great many more structures and it has been able to date most of the previously undated bridges, although in some cases these dates have yet to be confirmed, bringing the current total of existing historic wooden bridges up to 64. Further historic German covered bridges are held in memory in archives, photographs, descriptions and occasionally as a professional documentation, but just how much and where this information lies has still to be determined. Just how many of these bridges have never been documented and are therefore permanently lost we will never know.

THE Earliest Examples

The earliest evidence of wooden covered bridges in Germany dates back to the middle ages. Apart from numerous simple written references to wooden bridges, that contain no constructional information at all, it is the so called Trockensteg over the river Pegnitz in Nürnberg, Bavaria that can be considered Germany’s oldest known covered bridge. It was taken down in 1814 (Horn 1980) and was over three hundred years old at the time as it was drawn by the famous artist Albrecht Dürer (1471-1528) sometime around 1496. The bridge had two spans, each consisting of two parallel trusses – one upstream, one downstream. Dürer’s drawing shows that the trusses were a mixture of struts, a king-post and auxiliary braces. They are drawn in such a way that one can imagine a polygon-reinforced frame. Who the carpenter or designer was is unknown as is where the design originated.

Sixteenth and seventeenth century engravings of German towns show several wooden covered bridges but generally contain no constructional information. It is only in the second half of the seventeenth century, after 150 years of no relevant information, that the first real clear representation of the construction of these bridges in Germany simultaneously appears in the from of drawn and actual examples. Following the Thirty Years War Johann Wilhelm published one of the earliest known books in German on carpentry (Wilhelm 1668) containing detailed drawings of roof- and other trusses, wooden

ABSTRACT: For the past five years Germany’s historic wooden covered bridges have been the subject of a rudimentary documentation undertaken by Neubrandenburg University of Applied Sciences, Germany which has culminated in a complete inventory of the known bridges still remaining. For the engineer and construction historian it is not just their age, heritage value and romantic settings that make them interesting, but the construction problem given and the technical solution employed. The problem is to free-span distances that exceed the intrinsic physical capabilities or economic viability of the building material, in this case wood. The solution was the clever use of assembling small components into a larger load-bearing frame or truss. The paper will summarise the current state of the inventory and present examples of the different truss-solutions found.

Historic Wooden Covered Bridge Trusses in Germany

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Figure 1: Germany’s historic covered bridges – truss types and relative free spans; (delineated: Caston)
scaffolding, cranes, stairs, various machines, deck- and trussed bridges. The two illustrated covered bridges (Wilhelm 1668, plates 20 and 21) consist of two parallel trusses as found in the Trockensteg and are constructed as double extended queen-post trusses. Plate 20 shows the queen-posts carrying transversal floor beams. These beams, which span between the two trusses, are attached to the queen-posts using metal straps wrapped around each beam and nailed to the lower end of the queen-post and lower chord. The upper chord is also strapped to the queen-posts. The floor-deck follows the line of the lower chords which form a slight polygonal arch.

The second bridge, shown in plate 21, has a horizontal deck supported on longitudinal floor-beams, which in turn are supported on four transversal floor-beams. These transversals span between a pair of split queen-posts and are encompassed by the bottom ends of the posts and straps. The ends of the metal straps wrap around the ends of the queen-posts and appear to be bolted together through the posts. Split posts, metal straps and bolts are state of the art jointing solutions and can be found in other heavy German carpentry such as in roof trusses. Plate 21 also features two simple cross-sections, which show how the roof bracing is incorporated (or not) into the queen-posts. The left cross-section shows how the angle-braces between the queen-posts and ceiling-beam are taken up into a statical inherently rigid triangular roof truss, which opposes any tendency for the rectangular sectioned bridge to move into a parallelogram shape. The right cross-section shows angle-braces independent of the main roof cross-brace.

Of the three known existing built examples of German covered bridges from the seventeenth century, only one has a similar queen-post construction. This is the Kleine Wallbrücke spanning between the ramparts and the inner defensive ring on the west side of the Fortress Rosenberg in Kronach, Bavaria (N50°14.676’ E011°19.614’) and is just 15 m long. Although the date of the bridge has yet to be confirmed, its position in the relative chronology of the fortress and the workmanship found suggest the bridge was built before 1700.

NON-TRUSS COVERED BRIDGES

The other two seventeenth century examples have extremely small spans, which do not require a major truss construction. The Siebenbrücke in Staden, Hesse (Fig. 2, N50°19.949’ E008°54.715’) proudly carries a plaque stating that it was built in 1684, making this structure the oldest remaining covered bridge in Germany. To my knowledge this date has not been confirmed and the small circa 5 m span might lead some to debate as to whether it is a bridge at all or just part of a building on stilts. The half-timber framing in the non-truss is identical to the wall construction as found in houses and barns in the region.

The same can be said for the other non-truss covered bridge, again spanning between the ramparts and the inner defensive ring of the Fortress Rosenberg in Kronach, but this time on the eastern side (N50°14.690’ E011°19.730’). The Grosse Wallbrücke has a total length of approximately 16.5 m over three spans. The stone piers have the date 1686 carved into them providing the same, but unconfirmed date for the wooden bridge itself. The half-timber framing in each span is divided into two bays. Each bay has two diagonal struts morticed into the bottom plate or cill and purlin and also partly into the dividing-post. At first glance the mid-span dividing-post appears as a king-post, but the joints between the diagonal struts and the post have not been designed specifically for the purpose of hanging the post.

COVERED BRIDGES WITH TRUSSES IN THE EIGHTEENTH AND EARLY NINETEENTH CENTURIES

It isn’t until the first half of the eighteenth century that we find another example of an existing wooden covered bridge in Germany. The Hammerbrücke in Schwarzengraben, Saxony (N50°33.455’ E012°45.849’), built in 1733 and rebuilt in 1908 and 1992 has a 14.6 m clear span. The up- and downstream sides of the bridge are built as king-post trusses, with an additional polygon-reinforced frame set in the same plane as the struts and jointed at the intermediate posts. The struts are doubled up and due to the bridge height-span ratio, are set very shallow. The further use at that time of multiple arch and strut systems overlaid in a single plane can also be found in several of the recorded bridges found in Jacob Leopold’s Theatrum Pontificiale published in Leipzig in 1726. Leopolds drawing of the covered bridge over the river Mulda in Grimma (plate XVI) shows a large span with a multiple queen-post truss including counterbracing and large splitt and notched queen-posts. The bridge over the river Elbe in Meißen (plate XVI) is even more elaborate. A ten bay braced truss is overlaid with king-post and an overlapping queen-post construction. The ends of the bridge sit on struts at the abutments which also form part of a polygonal arch. Both these bridges no longer exist but show how far German carpentry had progressed in terms of the use of complex structural systems and the practical capability of being able to erect such structures.

Exactly how this high standard of design and competence developed can no longer be ascertained. Too few bridges survive to tell this story. Looking at the few remaining sixteenth and seventeenth century bridge examples in neighbouring Switzerland doesn’t present a complete story either. The four major sixteenth century bridges at Neubrück bei Bern, Canton Bern (not earlier than 1535, N46°58.428’ E007°25.687’), at Wangen a. d. Aare, Canton Bern (1549-59, N47°14.242’ E007°39.313’), at Gümmenen, Canton Bern (1555, N46°56.649’ E007°14.593’) and the Speuerbrücke in Lucerne, Canton Lucerne (1568, N47°03.104’ E008°18.096’) use simple king- or queen-post trusses. Later seventeenth and early eighteenth century bridges such as the Pont Du Berne in Fribourg, Canton Fribourg (1653, N46°48.257’ E007°10.140’) or the Alte Steinhausener Brücke near
Steinhausen, Canton Zug (1712, N47°10.837’ E008°29.008’) are relatively simple multiple queen-post trusses and don’t reveal a significant development. It isn’t until the later half of the eighteenth century that we find an increase in the number of remaining covered bridges. The designs, some of them quite complex, are nearly all based on the king-, queen-post solutions, the polygonal arch or a mixture of these. These trusses form the design solution until the middle of the nineteenth century, when new foreign influences bring additional designs to the bridge builder’s repertoire. They reveal the continued use of the basic design as conceived over three centuries previously and the established ingenuity in practically combining several structural systems in one truss. The Schiffsbrücke over the river Vils in Amberg, Bavaria (1761, N49°26.630’ E011°51.444’) is another small German covered bridge, just over 16 m long the actual free span is around 14 m. The trusses use a simple double queen-post. Being a pedestrian foot bridge and thus carrying only light loads, this simple design solution uses struts with a cross-section (24 x 24 cm) that did not involve massive timbers or joining them with notches. The same basic queen-post design was also employed some 15 years later in the covered bridge over the river Weisse Elster in Wünschendorf, Thuringia (1786, N50°47.686’ E012°05.418’). The bridge is one of Germany’s longest (approximately 72 m) and consists of three spans. The shortest truss is 17 m long, the two longest approximately 26 and 27 m. The bridge is over 4.5 m wide and was intended for heavy road traffic such as large horse-drawn carts. The members are dimensioned accordingly with timber cross-sections in the region of 40 x 40 cm, requiring massive tree trunks to be felled. The two longer span trusses are simple double overlapped queen-posts. The struts in the lower queen-post frame are similarly doubled. The bridge is striking due to its constructional simplicity, paid for at the expense of large heavy timbers. Despite being restored in 1998, it is still in its original condition and open to modern motor traffic (not exceeding 3 metric tonnes and 2.1 m in height). The use of a simple queen-post design at a large scale can also be found in two other covered bridges in the vicinity. The 43 m long covered bridge over the river Ilm in Buchfahrt (1816-18, N50°55.274’ E011°19.949’) has two equally long spans. The struts are doubled but the queen-poses are single trunks. The dimensions are generally smaller; the struts and straining beams have a cross-section around 24 x 24 cm, but the transversal floor-beams measure 41 x 39 cm. The bridge is rated for vehicles not exceeding 9 metric tonnes due to the fact that the floor has been replaced with modern self-supporting steel RSJs. The second similar bridge spans the river Flöha in Hohenlichte, Saxony (1837, N50°49.252’ E013°08.350’). It is over 54 m long with equal spans of approximately 21 m length. The simple queen-post trusses contain doubled struts and straining beams. The posts themselves are constructed as a pair of single trunks that are joined by keys (or shearblocks) 58 cm wide at the top and reduced to 37 cm underneath the Struts. This detailing and the way the struts are wedged into the queen-poses sets this bridge apart from the other two. All three bridges differ from each other in other details such as how the transversal floor-beams are supported or how the ceiling is braced suggesting no formal common designer. Further south in Germany in the vicinity of Lake Constance and along the river Rhine bordering Switzerland there are a number of exceptional late seventeenth and early eighteenth century covered bridges still in existence. The most famous of these is the Rheinbrücke at Bad Säckingen, Baden-Württemberg (Fig. 3) linking the town of Stein in Canton Aargau, Switzerland. The bridge, in seven spans, is 204 m long, a few centimetres longer than its Swiss rival, the Kapellbrücke in Lucerne, Canton Lucerne (1333? – 1993, N47°03.105’ E008°18.456’). It is currently the longest existing wooden covered bridge in Europe and was probably the longest historical wooden covered bridge in the world until the completion of the over 390 m long covered bridge in Hartland, New Brunswick, Canada in 1921 (N46°17.800’ W67°31.820’). The Rheinbrücke has a long and chequered history. A wooden bridge on the same spot was washed away in 1434. The replacement had 12 spans, 11 of which were washed away on the 24th July 1480. The bridge was rebuilt again and damaged several times in the sixteenth century. A new bridge was started after 1570 which had seven stone piers, the last being completed in 1630. The wooden spans must have been finished shortly afterwards as the whole bridge was razed to the ground in 1633 during the Thirty Years War. New spans were begun in 1653 and this bridge was also destroyed in 1678. The current bridge with its seven spans can trace its origins to a rebuild in the years 1699-1700. The name Hannes Maier, a Bad Säckinger citizen, is engraved with the year 1700 in the straining beam of the upstream truss in span 7, the most easterly span and which is on the Swiss side (N47° 33.082’ E007°57.154’). This span was rebuilt in 1843 by Fridolin Albüz and again by Wilibald Ebner in 1888. The true age and design of the various parts of the trusses are currently not clear. Span 1, the most westerly span and on the German side (N47°33.091’ E007°57.017’), was rebuilt in 1926-27 with no record of the design of the previous span. Span 2 (N47°33.089’ E007°57.041’) is similar to Span 7 with a similarly unclear age and heritage. The middle four spans can be clearly divided into two groups. Spans 3 (N47°33.086’ E007°57.057’) and 4 (N47°33.085’ E007°57.088’), both approximately 21 m long, are attributed to German born Blasius Baldischwiler (1752 – 1832, Jehle 1956), who restored the trusses in 1785. Possibly he also restored spans 5 (N47°33.085’ E007°57.111’) and 6 (N47°33.084’ E007°57.131’) as well, but these were destroyed in 1799. Their replacements, completed in 1810 – again possibly by Baldischwiler, are similar in design but shorter with wider bays requiring not so many queen posts.
Figure 2: Seufzerbrücke in Staden, Hesse. The oldest remaining covered bridge in Germany; (Photo: Caston)

Figure 3: Rheinbrücke at Bad Säckingen, Baden-Württemberg; (Photo: Caston)
All four spans display classic Baldischwiler design traits. The trusses are simple queen-post design with multiple overlapping layers forming polygon reinforced frames. A simpler polygonal reinforcement is included in the angled bracing planes in the roof construction as is common in the other five surviving bridges in Switzerland attributed to him. These details require more investigation as do their general usage.

This collection of historical wooden trusses is unique and impressive, but none of the spans approach the longest known free spanning German truss of that era – Etzel’s Pont couvert over the river Neckar in Plochingen, Baden-Württemberg (1776, James 1997). Sadly this bridge was demolished in 1905 (Jurecka 1979) but it was recorded and the design published 1805 in J. Ch. Krafft’s famous Plans, Coupes et Élévations ... (Plate Nr. 29 - described as being in Ceslingen, Krafft 1805). The bridge spanned approximately 62 m between buttresses and consisted of four parallel simple rectangular bay trusses, each reinforced by eight overlapped polygonal frames. The bottom chords consisted of composite beams made by joining two horizontal beams together with saw-tooth notches. The direction of the notches reveals how the bottom chord was expected to sag. As the lower chord is supported approximately every 6 m and the predicted sag is set at 12 m distance, the prediction can not respond to the behaviour of the chord in its final built state, but to some other span. This can only be during the erection sequence, which tells us two things. Firstly, the truss was built up vertically over the river and not horizontally in an adjacent workplace and dragged over the river and tipped up. Secondly, that there were supporting structures in the river. The remains of these supports, should they exist in the river bed, may one day reveal the exact location of the bridge.

The longest known remaining free spanning German historic wooden covered bridge of that era is the Hiltensweilerbrücke spanning the river Obere Argen near Hiltensweiler, Baden-Württemberg north of Lake Constance (Fig. 4, 1790, N47°39.103´ E009°46.585´). The free span is only half as long as the Plochinger bridge and has only two parallel trusses. The framing consists of multiple queen-posts supporting a saw-tooth notched bottom chord. The overall truss frame shape is not a rectangle but cambered. The deformations make it difficult to tell whether it was originally arched or cambered as a polygon, in either case the direction of the bottom chord notches reveals that the predicted sag was mid-span. The notches are cut so that the two pressured faces don’t actually touch each other. A squared hole is left at each join which is filled by a wedge and counter-wedge pair. The wedges ensure at the very least that each pair of opposing teeth are perfectly joined together. By jamming the wedges together and pressurising the joint the chord can not only be strengthened but also curved, in this case upward, helping to counteract the tendency to sag. The bridge was conceived and administered by Abbot Breda from the monastery in St. Gallen in Switzerland as part of the consolidation of the infrastructure incorporating both German and Swiss highways. The monastery also provided the builder (Falk 1987), whose knowledge of Swiss bridges is evident when one compares this bridge with contemporary Swiss examples. In order to properly understand the design and the spread and exchange of carpentry and building methods it is therefore necessary to study Swiss and Austrian bridges in addition to the German examples, which exceeds the scope of this article.

COVERED BRIDGES BETWEEN THE MIDDLE OF THE NINETEENTH AND TWENTIETH CENTURIES

It is well known that German-speaking engineers travelled to Great Britain and the United States of America around the middle of the nineteenth century to study advances in bridge design. The Austrian engineer Carl von Ghega (1802 – 1860) spent almost the whole of 1842 in America and published his findings, especially his statical computations of the Howe truss, in 1845. Similarly German engineer Karl Culmann (1821 - 1881) undertook a study of North American bridges in 1849/50 and published his results in the renowned periodical Allgemeine Bauingenieur in 1851. As German railways expanded with their heavier loads replacing the previously lighter carriage loads, new stronger bridges with much higher load carrying capacities were suddenly required. It is not surprising then that the railway engineer Friedrich August von Pauli (1802 – 1883) cashed in on this new published technical information in the design of his three large bridges for the Ludwig-South-North-Railway line. All three bridges were constructed as American lattices.

The Laiblachbrücke near Mariahann and the bridge over the Elhofer Tobel were replaced by iron bridges, but the third bridge over the River Iller in Kempten - St. Mang (1847/51, N47°42.934´ E010°19.313´) is still in its original position, although supported by auxiliary steelwork and rerated as a footbridge. Pauli stated quite clearly that his design is based on Ghega’s recording of the Connecticut river bridge near Springfield, USA (Hilz 2002). Two other American railway bridges, one over the river Elbe, near Wittenberg, Saxony-Anhalt built in 1849 (Howe truss) – the other over the river Danube in Straubing, Bavaria built in 1855/56 (Town truss) are documented but sadly destroyed leaving just two nineteenth and early twentieth century American road bridges still standing and in use in Germany.
The Rotbrücke over the river Rot near Neuhaus-Mittich, Bavaria (1853, N48°26.874´ E013°24.868´) is ca. 64 m long with two 28 m spans. In contrast to this structure is the little known Wildhofbrücke over the Kammer Canal / river Havel near Ahrensberg, Mecklenburg-Vorpommerania (Fig. 5, 1928, N48°26.874´ E013°24.868´). This 16 m long bridge is possibly an engineering school study.

The remaining thirty or so covered bridges of this era represent a diversity of constructional ideas. These range from the traditional German queen-post / polygon arch truss to engineered solutions. Several covered bridges are replicas or improved replicas of historical originals. A good example of this is the covered bridge over the Murg river in Forbach, Baden-Württemberg (1955, N48°40.666´ E008°21.679´). Very often these replicas are misrepresented as rebuilt originals. Whilst the Design is based on the eighteenth century predecessor, the materials are contemporary as are many of the details. The Forbach bridge can however be considered historic because it is (just) inside the boundary of the definition. The definition of historic as being over 50 years old may seem arbitrary and may well be so in future years, but it currently ends wooden covered bridge design at a point in history where radical new materials such as glue laminated beams completely change the appearance and design details of these bridges. This is a good point for future historians to pick up the development of the wooden bridge.
CONCLUSIONS

The development of historic German wooden covered bridge trusses as based on the known examples can be divided into three basic groups. The earliest known truss design is the Trockensteg in Nürnberg, Bavaria which is older than 1496 and uses a king-post, polygonal arch solution. This design type and the similar queen-post truss plus combinations and variations thereof can be found in bridge truss designs up to the 1950s. This is the largest group and its design origins are linked with Swiss and other Central European bridge designs.

Another design solution is the use of traditional half-timbered framing which is a non-truss solution. The three known examples are all in areas known for their traditional half-timbered framing. The third group consists of engineering trusses, that is to say trusses based on calculation and industrial production. The first bridges of this type are linked to the import of truss designs from North America in the middle of the nineteenth century; later bridges include truss designs of as yet unknown origin. In addition several bridges are replica attempts of lost originals, but none copy exactly the original construction.

Too little information about the origins of the German and other Central European wooden covered bridge trusses is available to attempt a serious understanding of their early development. The basic elements date back to the late medieval period, possibly earlier. During the seventeenth century, increasingly complex combinations of frames appear in the trusses and this is enough to satisfy bridge building needs until the heavier railways demanded changes in design. Other materials such as iron that became increasingly affordable during the nineteenth century and later concrete eventually led bridge truss designers into new field and new carrying capacities. Wooden trusses were relegated for use as vernacular or historical solutions.

With the recent rekindled interest in wood as a building material and the increase of new wooden covered bridges in Germany, maybe there are important lessons to be learned from the historic precedents. Let us hope that the research can continue in this field.

REFERENCES


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World Guide 2005: The World Guide to Covered Bridges is available as a digital databank from The National Society for the Preservation of Covered Bridges (www.coveredbridgesociety.org/default.html). It was last published in 1989 and has since been updated. The latest version is due to be published in the near future.

All coordinates are geodetic and are based on the map datum: WGS 84, as used in the Global Positioning System (GPS). They may vary slightly from true astronomical coordinates.