BÜTZOW’S WROUGHT IRON LATTICE TRUSS BRIDGE ACROSS THE NEBEL RIVER, 1848: DESIGN, HISTORY, AND RECONSTRUCTION

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Abstract
This paper explores the history of a lattice truss bridge built near Bützow in Mecklenburg, Germany in 1848 and partially reconstructed in 2013-2014. It was the first German lattice truss bridge to graduate from its experimental phase to the railway network. August Borsig, its designer, ran tests by spanning the Havel River near Potsdam, Germany, in September 1846. The historic assessment of the bridge is compared with results derived from recent material testing. This paper concludes with a discussion of the dismantling of the bridge and the incorporation of its latticework as a non-supporting element in a new bridge.

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INTRODUCTION

“Come the end of the world, I shall move to Mecklenburg because everything happens 50 years later there.” (Otto von Bismarck)

Until recently, Germany’s oldest surviving lattice truss bridge was standing almost untouched in the small northern town of Bützow in Mecklenburg. The bridge was constructed in 1848 for the Bützow-Güstrow line of the Mecklenburg Railway Company. Two spans each with a clearance of 40 Prussian feet (12.55m) bridged the Nebel River. On May 13, 1850, the Mecklenburg Railway opened a regular service along this line.

The surviving bridge once had a structurally identical sister bridge along the Nebel River that served the Bützow-Rostock line. Today, only a drawing from 1897 (MLHA 1897a) and an inspection report from February 25, 1896 remain (MLHA 1896).
In 1884, the Bützow-Güstrow line was rerouted and the railway bridge modified and converted for use as a road bridge (Falow 2009). Not until 2004 was its closure recommended, following a bridge inspection that resulted in a rating of 4 (Saase 2004). The demolition of the bridge went ahead on July 4, 2013. The inauguration of the substitute bridge followed on November 6, 2014.

**BRIDGE TYPE**

In 1845, Ludwig B. Henz built Prussia’s first wrought iron lattice truss bridge, utilizing old rail tracks as girders (Henz 1845 and Ržiha 1878). Borsig, the famous Prussian locomotive designer, manufacturer and foundry owner, meanwhile developed a lattice truss design that the Prussian Railway installed from 1846 onward. This early “standard type” corresponds to the two bridges spanning the Nebel near Bützow.

In September 1946, Borsig installed the first of his bridges in Potsdam. “For this structure (the first on the continent) iron lattice girders have been used” (DTMB Borsig-Archives 1847).

Theodor Weishaupt’s 1853 report on the Prussian Railways’ lattice truss bridges (Die Gitterbrücken der Preußischen Eisenbahnen) covers a variety of early Prussian bridges and construction types. He mentioned the Potsdam structure: “a slanting bridge spanning the Havel River with a length of 40 feet (Prussian).” He wrote that the “interconnecting transversal beams . . . were originally made of cast iron,” which, he stated, provides “less stability than wrought iron. Additionally it disproportionately multiplies the weight of the bridge itself without significantly reducing the costs…” (Weishaupt 1853)

By the 1850s, the construction of Britannia Bridge across the Menai Straits and the Conwy Railway Bridge to Conwy Castle not only advanced construction technology, but fueled an almost ideological debate about the advantages and disadvantages of lattice versus tubular bridges (Dreicer 2010).

The apparent success of the tubular bridges inspired the Kingdom of Hanover to apply the concept to their South and West Railway. Prüsmann carried out a test series using 3:1 models designed to compare the tubular bridge with the wrought iron lattice bridge. Consequently the Hanoverians opted for the former. The Prussians stayed with the latter, but they did, however, compensate for shear force weak points with added wrought iron plates (Prüsmann 1851 and Mehrten 1900).
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BORSIG’S BRIDGE WITHOUT BORSIG

From 1845 onward, plans for the Mecklenburg Railway were designed hand in hand with the construction of the Prussian rail network (MLHA 1845 and MLHA 1847a). As the majority of Mecklenburg’s locomotives were provided by Borsig, it seemed only natural to also take over Borsig’s bridge design. Baurat Neuhaus, head of the Berlin-Hamburg Railway and primary advisor to the Mecklenburg Railway, and Baurat Arndt, head of the Mecklenburg Railway (and formerly associated with the Stargardt Railway), were most likely responsible for this decision.

Ultimately the structure was not built in Borsig’s workshop but was delivered by foundry owner J.C.C. Meyn in Hamburg (MLHA 1847b).

Figure 4: The Prussian railways lattice truss bridges (Weishaupt 1853, Bl.67). Weishaupt introduced a succession of structural improvements: first in line is the Neiße Bridge near Guben 1845 (32 Prussian feet, girder made from rails, plaited latticework, interconnecting cast iron panels), then the type used for the Havel bridge in Potsdam 1846 (40 Prussian feet, cast iron interconnections, iron plate-boxes for wooden sleepers) and finally the Ruhr Bridge near Altstaden (100 Prussian feet, wrought iron interconnections, sheet metal panels in the corners.)
THE STRUCTURE – QUALITIES AND DEFICITS

Why did Borsig’s 1846 bridge design become obsolete so soon? In Britain, the collapse of Robert Stephenson’s bridge over the River Dee (in Chester, Cheshire) on May 24, 1847 caused a great sensation (Malberg 1849). The Dee Bridge disaster confirmed suspicions held by many engineers, including I.K. Brunel, regarding the combination of cast and wrought iron. Borsig, who developed his bridge before the Dee Bridge disaster, had knowingly added a structural safeguard against the problematic combination of cast and wrought iron.

To understand this, one must take a closer look at the function of the central beam that has its own bearings on each pier. Due to this middle “air pillar,” the tension rods below don’t place direct stress on the u-shaped, cast-iron crossbeams but instead support the wooden sleepers. Thus Borsig’s construction avoided the problem faced by many cast iron structures of the day, namely direct shocks and bending stress.

LOAD TESTS AND CALCULATIONS

In 1847, the Berlin Architekten- und Ingenieur-Verein (Society of Architects and Engineers) mentioned Neville’s bridge system in a memo, comparing it to Borsig’s iron lattice truss bridges. Bridge tests run in Berlin proved Borsig’s construction to have a high stiffness: the deflection in relation to the span stood at 1:2000. Neville’s structure deflection rate, tested in 1846 in Mecheln (Belgium), swayed between 1:600 and 1:800. Borsig’s structure, however, was considerately more expensive (Hoffmann 1847).

We can assume that Borsig’s construction tests were carried out under the supervision of Adolf Brix. Brix had gathered experience in 1846, performing load tests on rails that served as chords for the Berlin Mühlendamm Bridge and support girders for the Mühlendamm building.

Interestingly in 1853 Brix developed an approach to calculate Borsig’s bridge over the river Ruhr near Altstaden at the Verein für Eisenbahnkunde (Rail Society) (Verein 1853). As is still customary today, Brix determined the maximal stress of the upper and lower chord by analyzing a section in the center of the beam. Afterwards, Brix regarded the changing lengths of the diagonal members caused by deflection of the lattice. From this, he was able to deduce the stress S. The equation of the “elastic curve” led Brix to the deflection ($\delta_1$) in the center of the beam ($a/2$), whereby a distributed load ($Q$) and a central single load ($P$) are assumed:
\[ \delta_1 = \frac{a^2 (8P + 5Q)}{384E} \]

He determined the “elasticity” (today \( E \)) through experimentation; the structure was represented by a simply-supported beam. Beam deflection is calculated with the “elastic curve equation.” Deflection differences among adjacent points reveal the various deformations (elongation or compression) of the diagonal lattice members, along with their stress rates. These culminate at the abutment points.

\[
\Delta = \frac{P + 5Q}{256E} \frac{a^2}{12} \quad \Delta_o = \frac{P + 5Q}{256E} \frac{a^2}{12} \quad \Delta = \frac{P + 5Q}{256E} \frac{a^2}{12}
\]

Figure 7: Brix’ derivation of stress in diagonal members of a lattice as used for recalculation of the Ruhr Bridge near Altstaden

The modulus of elasticity is based on a rate of 25,000,000 pounds per square inch (Prussian) = 182.75 kN/mm² (construction steel today measures 210 kN/mm²). Borsig noted, with regard to the bridge over the Ruhr, that calculations should be made with greater loads (Verein 1853). To date, calculations pertaining to Borsig or Bützower bridges have not been found. Presumably, only the upper and lower chords were calculated using figures deduced from experiments.

**DAMAGE TO THE BÜTZOW BRIDGES**

The challenge of increasing loads and the stimulus for structural innovation becomes evident from a report on the Bützow-Rostock line (MLHA 1862) and a Prussian bridge test report circulating in 1861 at the Mecklenburg Railway (MLHA 1861). Both emphasize the ongoing transition to a completely riveted structure. According to the latter report, Prussian bridges evaluated up until 1861 were never subjected to loads that caused stress greater than 10000 pounds per square inch (Prussian). Data concerning lattice stress were not given: at the time there was no clear method to determine it. The structural quality of a bridge has been derived from the proportionality of load and deformation. Non-proportionality indicated weakness of joint members; the inclination of structural elements pointed to faulty construction.

Design developments until 1890 led to the substitution of the first generation of bridges, mostly by statically determinate and fully riveted structures. Structures with cast iron members were replaced. Thus, the Warnow-Bridge at Rostock, built by Harkort, stood for best practice in 1885 at the Mecklenburg Railway (Mehrtens 1900).
After 1884, Bützow’s two identical Nebel River bridges were subject to different conditions. The road bridge was not subjected to growing loads. Its sister bridge, however, still in use on the Bützow-Rostock line, gave engineers cause for concern. Official correspondence and a sketch dating back to 1896 confirm that the railway’s growing traffic required structural changes; the lattice had “cast iron components and other structural deficiencies … Deficiencies are evident in the main beam, but more so in the complete absence of bracing, as well in the insecure bearing and low strength of the intermediate structures where a bolt-hole tear was found - but showed no signs of growth (1881). Furthermore, one of the cross connections had a broken tie rod that needed replacing (1886). Other material faults are not known. The bearings needed adjusting”. Also, the “low stiffness of the bridge structure… causes significant vibration when trains pass.” The decision to build a new bridge over the Nebel River on the Bützow-Rostock line seems to have been made on the June 21, 1897 (MLHA 1897b)

DEMOLITIONS AND RECONSTRUCTION - CONCLUSIONS

An historic fortuity left the converted lattice truss road bridge across the Nebel River untouched until 2013. Considering its longevity, it showed surprisingly little corrosion damage. Those involved in the reconstruction work weren’t aware of the bridge’s significance as the last remaining example – a living fossil – of this early type of lattice bridge in Germany, but they did know one thing: the old bridge was salvageable. Appropriate structural modifications could have restored the bridge making it accessible for pedestrians and cyclists forming part of the tourist cycling-and-hiking path from Berlin to Copenhagen.

![Image](image.png)

Figure 8: Reversal of the support mechanism: the deck bears the lattice.

Figure 9: Stress-and-strain diagram of three samples of tension bars. Measurements taken at the FH Potsdam 26.01.2015. The proportionality limit is approx. 200 N/mm², or 13682 pounds per inch. To date measurements have not been concluded.

What led to the decision to build a new structure with a 40t load capacity, rather than to restore and conserve the original bridge? The answer is simple: it was a question of money. As funding programs designed for the development of “rural areas” could be accessed to finance a new replacement bridge, restoration plans were ill-fated from the start.
In accord with German Heritage Management, significant sections of the original structure – predominantly the lattice – were salvaged. Technically the new design was a reversal of the original with the road itself forming the beam structure. The old lattice walls were then attached to the side. The cast iron interconnections were cropped and installed as transitional elements between beam and latticework.

A more preferable solution would have been to preserve the structure of the old bridge and in addition build a new, modern bridge.

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