Bridge-building and Industrial Revolution

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The bridge at Coalbrookdale, the Halle au Blé or the Magdalen Market, Pont Ivry or the Carousell Bridge in Paris, the Hammersmith suspension bridge or Crystal Palace in London: we could cite numerous examples of engineering feats that were topics of lively discussion at the time of their construction. Some of these structures have remained noteworthy, although they are no longer standing. Others make a grand first impression, but are soon lost in the forgetfulness of time.

Success and failure are bound up with values that are part of an elaborate communication process. Yet we may ask whether there are reasons for the abiding interest in some types of construction and the fading interest in others. What has remained significant up to today, and what might yet be rediscovered? The answer to these questions is relevant not only for the history of engineering and the preservation of historical monuments, but also for new construction projects.

MINISTERIAL ARCHETYPES

In Prussia regulations concerning construction projects were officially published in a series from 1830 to 1848 under the title «Bauausführungen des Preußischen Staats» (Building Descriptions for the Prussian State), to which we shall make frequent reference in this discussion. The instructions were directed by the Ministry for Finance and Commerce to Prussian building authorities. Their intent was formulated as follows:

It is advantageous that architects engaged in construction projects gain knowledge of building practices concerning unconventional constructions that have been approved by the highest authorities. This knowledge not only contributes to his training, but also aids him in planning and completing his project in accordance with standard approved methods . . .

Something like a Prussian tradition in civic engineering, emphasizing the construction of useful and economical buildings, had already been developed by this time. The first such civic structures go back to the exemplary constructions of housing settlements in the vicinity of the Oder and Warthe rivers in the 18th century. Especially David Gilly (1748–1806) earned a reputation about 1800 for his technical «archetypes», which he managed to realised in spite of the oversight of the chief building administrations, the so-called «Oberbaudepartement» or later «Oberbaudeputation» (General Building Administration).

Archetypes were being sought at this time on account of the development of new materials (especially cast iron and wrought iron) and new construction methods, especially for bridge construction. The discussion of technical solutions could only take place by means of actual on-site experience, or else by means of detailed descriptions and technical drawings of the construction elements.
Because there were only a small number of exemplary buildings and because of travel difficulties (there being no railways), the availability of descriptions and construction details was of central importance. As yet there were only very few technical periodicals and engineering schools. How then did the communication take place, which led to the formation of archetypes or paragons?

We will address this question by looking at three examples illustrating the development of bridge-building systems in the 1820’s.

The publication of the «Bauausführungen» began in January of 1830. The third assignment included, among others, the cast iron «Long Bridge» or «Lange Brücke» in Potsdam (built 1822–1825, plates 11–13), the Pipe Bridge or Röhrenbrücke over the Hammerstrom (built 1828/29, plate 27) and a suspension bridge in Malapan in Silesia (built 1825, plates 25–28) (Bauausführungen 1842). However, Förster’s «Allgemeine Bauzeitung» (General Building Newspaper) of 1837 does not report on the suspension bridge (Förster 1837). The same is true of later assessments and reports concerning this bridge, showing that it did not fulfill the expectations of the Prussian General Building administration, which was oriented toward «archetypal constructions» (Malberg 1857–1859; Heinzerling 1870; Mehrten 1900) (1984). Let us first of all address the history of early cast iron bridges in Prussia.

CAST IRON BRIDGES

The beginnings of the Silesian iron industry at the end of the 18th century can be traced back to English influences. The director of the Silesian mining industry, the earl von Reden, directed his energies toward introducing new English technologies into the mining centres, especially the use of sand-molds and coke blast furnaces.

The very first German-language periodical addressed to construction and architecture, the «Sammlung nützlicher Aufsätze und Nachrichten, die Baukunst betreffend» (Collection of useful essays addressing architecture), was established in 1797 as part of the preparations for establishing the Berlin «Bauakademie». In its first edition the journal reports in detail on bridges made of cast iron. The first such bridge in Prussia had been built by the Scottish pourer Baildon in the province of Silesia in 1794. The periodical would only survive until 1806 and the Prussian defeat at the hands of Napoleon. Up till then it reported regularly on the progress of iron construction methods in Great Britain, France and Prussia. The copperplate prints included with the text give a clear impression of the changing construction principles.

In the early phase of cast iron bridges, there was a rapid change in fundamental construction forms. The most important factor was the experiences of the foundries that were beginning to develop cast iron parts. The demands of bridge planning played only a secondary role.

Because of the early difficulties connected with forming flawless arch structures, an early bridge in Stamford (Worcestershire), which had been built along the lines of the famous Coalbrookdale bridge, collapsed. The poor quality of the iron used in the ribbed arches was responsible for the mishap (Heinzerling 1870, 95). The English architect Payne chose to replace these unstable, long ribbed arches with much more stable cast iron sections. The individual parts of the vault structure consisted of relatively short cast elements (Riedel 1798). In 1793–1796 Rowland Burdon employed this principle for the Wearmouth Bridge across the Wear at Sunderland (span 71.92 m) (Sammlung 1798, 1, 1: titleplate; Heinzerling 1870, 95). The engineer Wilson was responsible for its planning and execution. Wilson also worked on a bridge with a span of 54.85 m over the Thames at Stains. In spite of numerous efforts at a repair, it collapsed in 1819. Telford also planned an enormous bridge in London using the same methods: span 183 m, height 20 m). The plan received much positive interest, but in the end it was not realised.

It was however not the «frame» construction form that would eventually take priority. Rather, it was John Nash’s patented method of constructing bridges by means of slab-formed arch elements. The slabs contained flanges and were bolted together. J. Rennie’s Southwark bridge of 1814–1819 became a widely recognised exemplary construction. As late as 1844, Stephenson’s first draft for the Menai Railway Bridge with a span of 145 m was planned according this design (Heinzerling 1870, 98).

The oldest construction principles are described in the «Collection of useful essays». But because of the repercussions of the Napoleonic wars, there is a gap
in the communication process beginning in 1806 and ending after the war with the publication of the writings of Langsdorf (1817), Röder (1821) and others. Here reference is made to new publications from France (for example Gauthey 1813).

In 1818 August Ludwig Crelle attempted to revive the journal under the title «Archiv der Baukunst» (Architectural Archive), and then again more successfully in 1829 with his «Journal für die Baukunst» (Journal for Architecture). Whereas the «Collection of useful essays» was affiliated with the inception of the «Bauakademie» (established 1799) and was edited by the members of the General Building Administration (Oberbaudepartement), Crelle’s later journal was associated with efforts of Oberbaudirektor J.A. Eytelwein at reforming the academy in 1824.

J. F. W. Dietlein began to hold lectures on bridge building in the winter semester of 1824 here. They were published by Crelle in the period from 1830 to 1832. (Dietlein 1830–1832)

By examining the published version of these lectures (1830–1833) or some of the student lecture notes, we can arrive at a relatively good impression of what constituted an archetypal bridge construction in the context of Prussian civil engineering in the 1820’s (Richter 1862).

In 1830 J. A. Eytelwein turned over the leadership of the Prussian General Building Administration to K. F. Schinkel and the directorship of the Bauakademie to Christian Beuth, director of the Institute for Commerce (Dobbert and Meyer 1899, 45). The examples published since 1830 in the «Bauausführungen» assisted Beuth and Schinkel in their efforts to raise the standard of archetypal structural standards for construction administrators in Prussia. In a manner similar to Beuth’s edition of «Vorbilder für Fabrikanten und Handwerker» (Archetypal Models for Manufacturers and Craftsmen, since 1821) dating back to his work as head of the Technical Deputation for Commerce, the field of engineering was now to be presented in an exemplary fashion for building administrators.

THE «LONG BRIDGE» AT POTSDAM

The first cast iron bridges in Prussia — Laasan (1794/96), Berlin (1797), Berlin-Charlottenburg (1801), Potsdam (1802) up to and including the constructions of the 1820’s, the Frederick’s Bridge (1822/23) and the Weidendammer Bridge (1823) in Berlin— employed the Coalbrookdale ribbing technique. The Long Bridge in Potsdam, planned by Günther and Becker, used the new methods of the Southwark Bridge. From the beginning it was designed to take a representative function and was discussed in the «Bauausführungen». The architectural colored drawings that are preserved in Potsdam give a clear picture of the high standards that were set for this structure.

Two iron bridges had been built previously in Potsdam. The first of these was the Helen’s Bridge (1802), soon also called the Iron Bridge, and the second was the Berlin Bridge (1822–1824). The Helen’s bridge had a length of 45 feet, which made it in 1802 the longest cast iron bridge in Germany. An examination of the historical documents reveals that an estimate of the quantity of iron required was made on the basis of test-castings, which shows that a precise calculation was not possible in advance (BLHA. IHA Rep. 96A/12J/BL44).

The latter was built virtually simultaneously with the Long Bridge (1822–1825), but in accord with the older ribbed-arch method. The iron was ordered from the Royal Foundry in Gleiwitz in September 1821. Because of various mistakes (for instance, the plastering had not been taken into consideration), the individual elements had to be re-cast after completion in 1822. The iron was then transported to Potsdam in the summer of 1823. But then one of the arch sections fractured, so that the bridge was only completed in 1824 after a replacement arch had been sent from Gleiwitz. The finished construction consisted of nine arch elements in two large sections that were bolted together in the middle.

By comparison with the new iron casting technology, the role of construction was relatively insignificant up to the 1820’s. Everything depended on the proficiency of the foundry workers at producing iron components that were not fragile. When malformed casting elements were bolted together, rapid temperature changes or severe strains could lead to «fissures or fractures of such pieces» (Vollhann 1823, 12–13).

With the construction of the Long Bridge in Potsdam the role engineering design took a predominant role for the first time. This was on
account of the innovative construction methods using iron plates. It was elaborated by the chief engineering inspector, Günther, who wrote most of the articles in the «Bauausführungen». Günther describes the construction with the aid of three illustrations. One of these drawings is remarkable for the fact that it is isometric, which was unusual in its day.

The structure included of a row of eight bridge sections, each of them 18.83 m in length, supported by stone piers. The passing of ships was made possible by employing a drawbridge at one end. All of the parts were bolted together, so that including the draw bridge a length of 166 m was achieved. Each bridge section consisted of seven consecutive arches, giving the roadway a depth of 9.5 m. One special feature of the bridge was the fact that each arch was formed of three slab-like iron elements. At their points of contact transvers transverse elements were added. This bridge in Potsdam «with its consummate form» would become an archetype for many railway bridges, of which the double-tracked Kinzig Bridge near Offenburg (built from 1843 to 1845) was the most famous. It consisted of five such arches, each spanning 12.66 m (Heinzerling 1870, 103).

The Long Bridge in Potsdam was dismantled and replaced in 1888. The erstwhile «archetypal structure», of which Heinzerling made a laudatory assessment in 1870, had revealed structural faults «from the very beginning», according to an 1888 report in the «Centralblatt der Bauverwaltung» (Müller 1889, 187–189). Even the first inspections after the completion of the bridge had revealed fissures and cracks in its superstructure. The last inspection before the dismantlement showed that 21 of the 56 elements cracked. Because of the rigid connections between the eight bridge sections and the foundations the entire edifice was incapable of accommodating itself to varying temperatures. If we assume that the assembly of the parts took place under normal summer weather conditions, then low winter temperatures must have led to contractions in the tightly bound connecting elements. The cast iron elements ripped out the joining bolts, so that many needed to be renewed after virtually every winter. The arches also broke. The inner arches at the center of the bridge suffered the greatest damage. And when they suffered damage, the pressure was transferred to the next arches as well, which now had to bear even greater force. The bulwarks of the supports were also put under so much pressure that the supports of the arches were entirely destroyed.

Of course, this led to the question why the builders of the 1820’s did not take temperature tensions into consideration. After all, the influence of temperature on iron was already well known at that time, as the quotation from Vollhann cited above clearly shows. The answer is that the constructors of that day were using cast iron, but still thinking in terms of arch support systems made of stone. Stone is more flexible in the joints and the variation in its dimensions is insignificant in comparison with that of iron. At the other extreme are suspension bridges, where
temperature differences have considerable effects on the expansions and contractions of the support cables or chains. Even here one began with the concept that these new constructions were «systems», where the equilibrium needed to be determined. The different parts could withstand variant temperatures by balancing out the different forces. The problems were obvious especially for cable-stayed bridges, and not so much for «weighted suspension bridges», where the cables hang freely. — We can now address this matter by examining the development of suspension bridges.²

**Suspension Bridges**

What might well be the reason for the fact that our second example, the suspension bridge in Malapane, soon faded into forgetfulness? By comparison with other suspension bridges of the 1820’s this structure managed to maintain itself very well over the years. Its span was only 31.56 m and could not boast the sensational lengths of contemporary English bridges. In an almost unaltered form, it still serves as a means of transportation in modern times (Pasternak 1996).

The bridge was built by the machine inspector Schottelius in the Malapane foundry in Silesia and opened on the 12th of September, 1825. An examination of its form reveals that it was constructed on the basis of an essay by Stephenson published in 1822 in the «Verhandlungen des Vereins für Gewerbefleiß» von 1822 (Stephenson 1822). At the same time it must have been built on the basis of information coming from Navier’s 1823 essay «Sur les ponts suspendus».³ It employed connected cast iron pylons in the form of portals and bore certain similarities to Newhaven’s debarkment bridge at Trinity Piers (1820/21). Navier’s essay gives excellent, indeed superlative depictions of the bridge. The suspension chains in the Newhaven Bridge did not slide, but were rather attached to the pylons. Sadly, this particular detail has never been accurately described or depicted, and was merely theorised in Navier’s text. He compared the idea of moveable chains or chains that could be attached to rollers with those that might be attached to pylons and concluded that the latter idea was superior. This was then the idea that was employed in Malapane.

Navier’s work was first presented in German language in 1824, Dietlein, whom we have already mentioned, discussed Navier’s novel conception in his lectures series on bridge building at the Berlin Bauakademie in the winter semester of 1824–25 and published it in 1825 (Dietlein 1825). At the same time, the «Oberbaudeputation» (General Building Administration) made an assessment of the Malapane bridge and brought attention to certain defects.

In the first place the criticism concerned the chain anchors, which should have been placed lower and

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2. The...suspension bridges.

3. Stephenson...1822 (Stephenson 1822).

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Figure 2
Malapane Suspension Bridge 1825 (Bauausführungen 1842 plate 25)
«under the abutments of the of the last arch», so that the anchors better would be able to take up the tensile force. Secondly, one could have spared the expensive underpinning of the «anchor pillars» (the foundations were not in danger of sinking, but of being ripped out). Thirdly, the saddles where the chains passed ought to have had mobile pivots (Bauausführungen 1842, 69). This idea had been introduced by the Union Bridge of 1819–20, which Stephenson had praised highly (Stephenson 1822, 123; Berg 1824, 21–22; Malberg 1857, 235). This design change had been suggested, but it had been forwarded to General Building Administration too late to be taken into consideration during construction (Bauausführungen 1842, 69).

It must be noted, however, that the comments made on the Malapané suspension bridge in the «Bauausführungen des Preußischen Staats» are dated 1832, and this suggests that they merely offer comments made after the fact. 3 It is no longer possible to confirm whether the first expert opinion of the General Building Administration of 1825 was actually formulated in the manner in which it was stated in 1832. But it is possible to show that the professional opinions concerning the value of early suspension bridges changed rapidly, so that after a few years they had a different status than at the beginning.

As an overview we can note the following chief events in the timeframe 1823 to 1832 in point form.

1) 1823: Through Navier’s influence, the concept of a chain-line suspension bridge that is stabilised by means of its own weight became predominant. Inclined cables or chains came to be seen as disadvantageous. One was still unsure as to how to evaluate many engineering details (whether one ought to use weight or form to reinforce the roadway, whether to employ chain bars or cables, roller bearings or inflexible anchors for the chains, single or double pylons, the kind of hanger fastenings, or the means employed to attach the chains, etc.). —Navier offered precise drawings for four structures: S. Brown’s Union Bridge at Berwick of 1819/20 (plates II, III), the Trinity Bridge at Newhaven (plates IV, V, VI), the two bridges for the island of Reunion by Brunel (plates VII, VIII, IX), and, Navier’s own project for the «Pont des invalides» in Paris (plate XII) (Navier 1823)

2) 1824: Many chain bridges and suspension bridges are under construction throughout mainland Europe. The most well-known are Seguin’s and Dufour’s cable bridges, Traitteur’s Panteleimon chain bridge in Petersburg, Schnirch’s March Bridge in Bohemia (Berg 1824, VII). In Germany the first foot-bridge was built by Kuppler in Nuremberg. Many publications appear (z.B. Berg, Seguin, Burg). In the winter semester of 1824/25 Dietlein begins his lectures on bridges at the Berlin «Bauakademie».

3) 1825: Navier’s work is translated into German by Dietlein.

4) 1825, 10th of August: the diagonal chain suspension bridge in Nienburg on the Saale river is examined. (Gerstner 1831, 470). On the 6th of December the left half of the bridge collapses, leaving many persons dead.

5) 1826: A sharp criticism of the Nienburg Bridge that had been written before the bridge’s collapse is published in the «Verhandlungen für Gewerbeblei» (Beuth 1826, 66).

6) 1826: Telford’s Menai suspension bridge is completed. Chains over the saddle, resting on roller bearings.

7) 1826, September: Just as Navier’s great project from his book of 1823, the «Pont des invalides», was nearing completion, one of the piers shifted, leading to fractures which were then exacerbated by a break in a water pipe. The bridge is torn down.

8) 1827: The Hammersmith Bridge (under construction since 1823) with roller bearings for each of the chains is completed. It becomes the model for the new «Pont des invalides» that is built by the engineer de Verges 1827–1829.

9) 1827: Krahe builds a cable bridge across the Oker river (Grunsky 1999, 132).

10) 1829, 31. of December: Schierlinger’s chain bridge in Bamberg is opened for traffic (with ornamentation by Klenze, span of 64 m) (Röbling 1824; Anonymus 1830, 4). Like Navier’s construction it had «isolated pylons» and soon after its completion, it displayed
fractures on account of its «immovable form» (Gerstner 1831, 469).

The disaster of Navier's bridge in September of 1826 did not throw suspicion on the entirety of his remarkable theoretical book of 1823, but certainly on some of his detailed solutions. This was true in particular for the rigid and inflexible saddle across which the cables were stretched. Since the completion of Samuel Brown's Union Bridge in 1820, there was a successful alternative: a moveable saddle on rollers. This kind of saddle was also used on Telford's Menai suspension bridge of 1826. The transition to individual arrangements of chains on rollers, which would become the standard solution, was adopted with Hammersmith suspension bridge in 1827.

One widely discussed question was whether the problems with Navier's structure were caused by the extreme weight of the over-sized bridge or by the lack of rollers and by the «independent» pylons. After its dismantlement, the engineer de Verges travelled to London to learn from the construction solutions of the Hammersmith Bridge (Heinzerling 1870, 190; Gerstner 1831, 465–468). It takes on an archetypal function, especially in the matter of the anchoring of the chains (Heinzerling 1870, 184) and the roller bearings (Gerstner 1831, 451 and 469). The new Invaliden bridge was completed in 1829 on the basis of this example, a result that raised the reputation of the Hammersmith.

Dietlein and Röbling

The question as to what information was available to planners and master builders is raised anew, if we look at some forgotten documents that have come to light concerning a chain bridge across the Ruhr river and concerning two plans for suspension bridges dating to the 1820's (Grunsky 1999). Some partial answers can be offered by referring to Röbling's lecture notes from Dietlein's course on «Bridge-Building» in the winter semester of 1824–25, as well as supplemental notes added around 1830.²

We know very little about the building superintendent Bruns, who built the 1839 chain bridge over the Ruhr near Haus Laer. Grunsky's assessment of the building plans suggests that its measurements were influenced by Dietlein's German-language edition of Navier's work in 1825, as well as by knowledge of a project by Johann August Röbling designed in 1828, but never brought to fruition. We can conclude from Bruns' bridge, which is still standing, and from the relevant building plans that it was modelled after Marc Isambard Brunel's 1822 structure on the Island of Reunion, since it was a lightweight construction fitted with reverse chains. Another detail, the cast iron pylons, were similar to those of Trinity Piers Bridge near Newhaven (1819–1820, built by Samuel Brown), just as the pylons of the suspension bridge at Malapane. Both construction forms had been drawn up by Navier, along with detailed descriptions.

A further discovery by Grunsky concerns two plans for a suspension bridge in Höxter, dated the 16th of December, 1824 by the building superintendent Eberhard, who was also working in the Prussian province of Westfalia. These drafts were also based on knowledge of Navier’s reference work and of the Trinity Bridge in Newhaven, as well as Navier's own project for the «Pont des invalides» (of which Dietlein failed to provide an illustration in his translation).

Furthermore, the drafts for a suspension bridge across the Ruhr near Freienohl planned around 1828 by Röbling (89 pages) include a variant in Navier's style, but with decisive differences: a rigid roadway and displaceable chains, as well as a variant on a wire rope bridge. Here again work proceeded on the basis of a knowledge of Navier's book of 1823 or Dietlein's German version of 1825.

Röbling's lecture notes of 1824–25, as well as his later supplements, reveal how and why the perception of the suspension bridge changed substantially in such a brief time frame of five years. Röbling went to the Academy in the spring of 1824. Here he attended the lecture course by Dietlein on bridge building, which dealt with stone, wood and cast iron bridges. It also included a discussion of suspension bridges and Navier's method of calculation.

Although the printed lectures were primarily descriptive (the mathematical calculations were already given in the translation from 1825), several remarkable new theoretical insights appear. In his printed lecture, Dietlein distinguishes between the basic principles of the diagonal chain bridge and the suspension bridge. Although the mishap of the Nienburg Bridge had already taken place, which
might lead one to think that he would put the diagonal chain variant in question. Dietlein gives no priority to either of the principles. In the meantime, Navier, who was responsible for the negative opinion of diagonal chains, had lost his reputation in the field of engineering practice.

Saint-Venant complained about the regrettable, even dubious discussion since the 1820's that there might be an «antithesis» between theory and praxis in the field of technology. The chief cause of this false claim was the misfortune of the «Pont des invalides» (Navier 1864, xviij). In point of fact, the subject of suspension bridges was largely discussed in the 20's outside of Great Britain and America by mathematically oriented, younger students, who for the most part had little experience in construction. Konrad Georg Kuppler, who built the Nuremberg chain bridge in 1824, taught mathematics and mechanical engineering at the Polytechnical School in Nuremberg (Grunsky 1999, 101). The building inspector Eberhard was judged by his superior, the Oberpräsident von Vincke, to be too «inactive» in supervising his building task force and preferred that he devote himself to calculations (Grunsky 109).

And yet with time, the traditional opinion that a good engineer was someone who had developed a reputation for building stable structures was replaced by a judgement based on the capacity to calculate all potential elements. In 1829, Bandhauer published a vindication of his work on the collapsed Nienburger Bridge. He defended himself with the claim that his bridge had not been built for such a large crowd of people. This led Gerstner to defend Bandhauer and to make positive remarks about the diagonal cable bridge (Gerstner 1831, 471). In a similar fashion, Navier was defended by the claim that his misfortune was caused by a broken water pipe and the hostility of the city administration in Paris (Prony, G. 1837, St. Venant 1864).

On the other hand, the mathematician and engineer August Ludwig Crelle, who edited the «Journals für Baukunst», clearly cautions builders from preferring suspension bridges to traditional building forms. He lists their disadvantages, in particular concerning safety and durability. He notes that «here and there a predilection for this form seems to have arisen, . . . with the consequence that based on this prejudice, it is actually preferred to other kinds of bridges» (Dietlein 1830, 462). An indirect reference to the Nienburger incident is made: «It is not merely folly, if a construction puts human life in danger, merely in order to realise a project that requires clever algebraic calculation» (Dietlein 1830, 464). Crelle demonstrates in his commentary on Dietlein that the loading cases were in fact quite different as in the calculations being used: Even the conventional material tests for completed structures cannot in fact give a realistic assessment of sudden impact loads or of accidentally occurring fissures in the materials being used. Crelle anticipated reductions in strength by means of «incessant vibration» (that is, fatigue) and concluded that the security of bridges was «being assessed purely arbitrarily» and that «there is no rule available» for calculating it. «The concern . . . to build bridges economically» often leads to the acceptance of inadequate safety factors factors of safety «multipliers») (Dietlein 1830, 463).

In spite of Crelle’s sceptical, but justified criticisms, there had in fact been considerable progress since 1823. So for example, testing materials by means of hydraulic presses had become standard practice (Stephenson 1822, 127): In Malapane this method was used to test the chains (Bauausführungen 1842). In his lectures, Dietlein does not discuss the technological and construction details, but he does refer to the fundamental distinction between «tensile» and «suspended» constructions, whereby, as we noted above, he does not criticise the diagonal chain principle. But it seems that the principle of «reinforcement through bracing» was being perceived more and more as a progressive construction method. Dietlein states for instance that the roadway in a cable stayed structure has to be so stiff, that it should not be «stretched or . . . pressed together» (Dietlein 1830).

RÖBLING’S LECTURE NOTES AND HIS SUSPENSION BRIDGE

Dietlein states in his lectures that the primary condition of the diagonal chain bridge is the
construction of a rigid roadway, whereas the suspension bridge depends on weight (Dietlein 1830, 444). For Röbling, who may well have heard this opinion in Dietlein’s lectures, this is a very important stipulation. He emphasizes the faultiness of the principle: «reinforcement through weight», which had directed Navier. Although he knew that suspension bridges are liable to suffer greatly from changable pressures (varying winds and travel loads), Navier took on the challenge of designing a difficult construction with his «Pont des invalides», which needed to withstand high tensions on the chains and their abutments.

Röbling took a different approach with his Freienohl project. He reinforced the roadway and yet at the same time strove for movability of the chains by means of roller bearings and by avoiding mutually interactive connections between the chains. The distance of the chains between the pylons is greater than the breadth of the roadway. The inclination of the suspensions adds to the lateral reinforcement. By contrast to the Union Bridge, he did not couple the chains together: «each line of the chain should be able to move without external force and maintain its balance within itself», as Grunsky writes, citing Röbling’s report (Grunsky 199, 135). The parallel chains were not to be bound to one another, so that they would not jam each other when temperatures changed.

We have good reason to believe that the collapse of the Nienburg Bridge was at least in some measure caused by a load shift caused by temperature variation in the triangular cable-system. (Roik 1986, 4). Since the collapse occurred at 8 p.m., we can assume that cooling air brought about an unequal contraction of the inclined iron chains. The roadway of the structure at Nienburg was not backantered in itself but to itself, consequently it did not have stiffness independent of the suspension construction. In the manner of weighted suspension bridges, the suspension cables were connected to the guy cables, which were in turn anchored to the base. This led to some unclarity in the static relationships.

Unfortunately, we do not know if Röbling made an assessment of the Nienburg accident. But the remark we have noted above shows that he had an intuitive feel for the connection between the structural estimation of a bridge and the tensions produces by temperature and loading variation. He disputes Navier’s claim that a complete separation of the chains leads to oscillation of the roadway. This objection is insignificant and the reasons for introducing this practice are of greater importance for Röbling. «In my opinion, the reinforcement of the roadway should not be sought by the alignment of the chains, which cannot be achieved without force, but rather in construction itself» (Grunsky, 1999, 135). For this reason, Röbling attempted to solve the problem of oscillation by reinforcement of the roadway itself. He did not attach the hangers to the cross-beams in the conventional manner employed by Brown, Dufour and Seguin, but rather to the longitudinal stringers of the roadway, which resulted in increased stability (Röbling 1824, 372).

The design plans for Röbling’s project at Freienohl are missing; only a few of the sketches have been found. But the supplemental lecture notes do help to augment his arguments, and they show where he got his ideas from. It is clear that Röbling developed many of his concepts and construction details through his knowledge of the Hammersmith Bridge, as he learnt of it through the «Magazin der neuesten Entdeckungen und Erfindungen» 3(1828) (Magazine of the most recent discoveries and inventions) (Röbling 1824, 370). Here the railing reinforcement marks one of the most significant innovations—an innovation that he developed further in his later suspension bridges in the USA.

Röbling did not lay his emphasis solely on mathematical calculation, but also on the intuitive-geometrical thinking that arose from the construction itself. We can see how a kind of «thinking in terms of reinforcement» evolved in his work. So for example, in his addenda to the lecture notes he adds remarks on «C. Steiner’s system for an iron «bridge without abutments», where all the parts are accessible», together with a sketch, which he took from the journal «Der Künstler and Handwerker» 3(1828) (Röbling 1824, 360). The sketch illustrates a cast iron arch fitted with a tensile lower cord, forming a bowstring truss of six panels with cross bracing. The idea of using girders «without external abutments» was spread widely in the 1830’s by Laves—using the same principle, but with the difference that they were executed in the well known lens-like form. Röbling added the form of the roller bearings in his notebook following the example of the Hammersmith Bridge (Röbling 1824, 374).
He continued the notes by discussing the Bamburg suspension bridge. He remarked on its opening for traffic on December 31, 1829. On the next free page he made a pencil drawing of a suspension bridge «one thousand feet wide», which included a drawbridge for the passage of ships between a two-part pillar. Telford had already proposed such a 1000-foot suspension bridge for the Mersey-Gap near Runcorn back in 1813 (Stephenson 1822, 117). George Buchanan had also proposed a 400-foot suspension bridge at Montrose including a similar kind of drawbridge opening, which interrupted the suspended roadway (Buchanan, G. 1826). It is clear that Röbling introduced this unusual pillar construction in order not to reduce the stability of the roadway by means of interrupting it for boating traffic. The foundation elements of his giant bridge are elaborated with further drawings. He sketched a foundation with a base of about 50 by 50 feet and with a passable chain conduit. The guy chains are anchored not vertically, as in Navier’s «Pont des invalides», but in the same angle as they came from the pillar.

Since the first wire bridge in Germany was built in 1827, Grunsky argues that the idea of using cables of wire-ropes form for large bridges was an particularly significant step (Grunsky 1999, 114). This is certainly the case, especially if we take Röbling’s later wire-rope bridges into consideration. However, it is also worth our interest to look at the sources for Röbling’s ideas. For example, while we know that he had a copy of Dufour’s book on the wire rope suspension bridge at Geneva (1824), we can only assume (albeit with good cause) that he knew of Berg’s book about wire rope bridges including a report of the bridges of Seguin and Dufour (Berg 1824). It was published in Leipzig in 1824 and mentioned 1826 in the Journal of the Gewerbefeißverein in Prussia (Beuth 1826, 73), which means that it was widely known.

CONCLUDING REMARKS

The efforts of the Prussian General Building Administration to promote and encourage distinct archetypal constructions has led me to examine the question of the role played by assessments of new constructions in the communication networks of architects and engineers.

The chain bridge at Malapane, which at first served as the archetype for a new form of chain bridge, soon disappeared from contemporary consciousness — as the example of Röbling shows, who knew of the bridge, but did not consider it important. It was passed over by new developments. The journals and periodicals that experienced such a boom in the 1820’s and 30’s, with their lively discussion of the newest ideas, soon replaced the concept of «archetypes» that bore the stamp of official approval. We can also briefly mention the fate of the third type of an iron bridge, that was promoted as an archetype by the «Bauausführungen». This was the pipe bridge construction favoured by Reichenbach and Wiebeking, and which was discussed both by Dietlein and all of the other relevant publications of the 1820’s, but which soon lost favour on account of stability problems of the numerous pipe elements. Many of these bridges collapsed or needed to be dismantled soon after construction. On the other hand, Polonceau’s further development of this style of bridge construction in France had greater success. Polonceau built the Carousel Bridge in Paris from 1834 to 1836 by means of elliptical pipes of greater diameter. This served as a model for many road and railway bridges in France in the following years (Heinzerling 1870, 107).
At the same time, we should not underestimate the influence of the «Bauausführungen», as well as the journals and books in the years around 1830. They were produced just before many of these new structures were erected. At that time, even a small amount of information about new design methods was of great assistance, especially if they were combined with high-quality and detailed drawings. Precise engineering blueprints and the discussion concerning them arose at a time when engineers in central Europe had very few visual objects for developing their designs, and consequently they had much greater importance than in later years.

In matters pertaining to engineering construction, the «Bauausführungen» with their «archetypes» lagged behind actual developments in the 1840’s, and in the next decade it was decided not to continue them. Instead, journals took their place, one of which had a special place at that time. The «Zeitschrift für Bauwesen» served the General Building Administration as a mouthpiece, substituting in a way for the «Bauausführungen des preußischen Staates». In the end, this administrative apparatus was not prepared to give up its influential role in supervising Prussian building construction.

NOTES

1. The script of W. Richter’s script is dated from 1862. The content of the convolute refers to the late 1820’ies. Dietlein’s examples of cast iron bridges were: Coalbrookdale, Warmouth, Lissan, the «Bridges at Potsdam of the same construction». Wilson’s bridge at Stains 1802, Cessart’s Pont des arts at Paris 1803, Pont d’Austerlitz at Paris 1800–1806, the early truss bridge at Cron (St. Denis) 1808, and the pipe arch bridges of Wiebeking and Reichenbach.

2. It is interesting to note that the modern solution for maintaining the movability the supports was probably due to developments with the suspension bridge. One of the first such examples is roofing of the Walhalla at Regensburg, where Klenze introduced the first roller bearings in Germany. Can it be that Klenze’s experience with the tynes on the pylons of the Bamberg suspension bridge caused him moveable connections for the chains—he had participated in its construction—led him to this innovation?

3. In Stephenson’s book (Stephenson 1822, plate VI) the bridge is illustrated without diagonal chains, in Navier’s they are included (Navier 1823, plate IV). Malberg writes that this were added subsequently in order to minimize vertical oscillation (Dietlein 1825, 3 and 5; Malberg 1857, 236)

4. The commentary is dated «February 1832», but the author’s name is not given.

5. Röbling left Mühlhausen in May of 1831 and emigrated to America.

REFERENCE LIST


Grunsky, E. 1999. Von den Anfängen des Hängebrückenbaus