The small city Tczew (German name: Dirschau) is situated about 30 km south of Gdańsk on the western banks of the river Vistula. Here remarkable parts of the Old Vistula Bridge which was constructed from 1851 – 1857 for the so-called Prussian Eastern Railway from Berlin to Koenigsberg still exist, Figure 1.

This bridge was a true milestone in the development of civil engineering and was recognised by the engineering community of that time. Still, in the 19th Century the increasing railway traffic made the construction of a second parallel bridge necessary. When in the early morning of the 1st of September 1939 the German attack on Poland took place, both bridges were partially blown up. So today the three remaining original spans of the old bridge portray a unique historical monument of the beginning of the Second World War.
**EARLY BUILDING HISTORY**

To understand the technical importance of the Old Vistula Bridge it is necessary to remember the long development of building history before.

For thousands of years earth, wood and stone were the building materials available, and only the stone buildings were durable. Looking at the Egyptian and Greek temples we find very simple structures: Enormous stone cylinders placed on one another to form massive columns, topped by stone beams allowing only small spans. The Romans were, as is well known, the first great masters of arch and vault building and by this they succeeded in bridging larger spans.

We like to call the Roman master builders Roman Engineers. However we must remind ourselves that the structural systems of their impressive buildings were derived from experience, obtained by success and failure.

As is well known, the art of vault-building was refined in the Gothic Age. The bold and filigree structures of the great cathedrals can hardly be surpassed. Finally, the cupolas of the Renaissance have to be mentioned, which are quite impressive: So the cupola of the cathedral in Florence from 1420, which was designed and built by Brunelleschi. And the design and construction of the Cupola of St. Peter’s was carried out in Rome at the end of the 16th Century by Michelangelo and della Porta.

When looking at these magnificent buildings it is hard for us to imagine that the builders had to work without a scientific basis all through the centuries. Construction took place only on the basis of the empirical knowledge of craftsmen and traditional experience, won by trial and error. This is proven by numerous collapses.

**IGNORING EARLY SCIENTIFIC RESEARCH RESULTS**

Nothing changed in this construction practice up to the beginning of the 19th Century. This is actually quite astonishing, as since the Renaissance, questions concerning structural statics were dealt with by the arising natural sciences piece by piece. No one less than Galilei made a start with his famous deliberations on the ultimate strength of a bending beam. Those who looked into such questions in the following 150 years, such as Hooke, Leibniz, Bernoulli and Euler, were not builders, but mathematicians and physicists. Their motivation was scientific curiosity, but not the desire to open new doors for the builders. For example, Euler sought a field of use for his mathematics when he investigated deflection curves and the buckling of members. Although the results were published, the builders of the time took no notice, or even declined to use such methods in practical constructing.

Informative in this light are the statements passed down in connection with the reinforcement of the Cupola of St. Peter’s. The dome increasingly obtained cracks in the first half of the 18th Century, due to faults in the structural statics. Pope Benedict XIV was concerned and called for expert reports from three mathematicians, monks in Rome (Le Seur, Jaquier and Boscovich 1743), and from Giovanni Poleni, a professor of mathematics in Padua and on the side a hydraulic engineer of the republic of Venice (Poleni 1748). The three mathematicians wrote in their expert report: „We may be obliged to excuse ourselves to the many who not only prefer experience to theory, but also think the former alone to be necessary and appropriate, and hold the latter possibly even for dangerous.“

A person remaining anonymous reasoned: „If the Cupola of St. Peter’s could be built without mathematics and moreover without the mechanics so popular in our time, then it should be possible to repair it without the help of mathematics and mechanics . . . Michelangelo knew nothing about mathematics and was still able to build the cupola.“ This seemingly narrow-minded opinion can be explained by the fact that the builders had no scientifically sound education up until then.

**THE VERY BEGINNING OF STRUCTURAL ENGINEERING**

A significant change only came around when the advancing development of the economy demanded a better infrastructure, i.e. better roads. One requirement for this were well educated engineers. In 1747 the «École des ponts et chaussées» was already founded in Paris. Navier, who emerged from this school and later taught there, systematically collected the up until then scattered knowledge of statics and developed it further.
Parallel to this development of theory, there was a second impulse for the creation of structural engineering: In the second half of the 18th Century iron became available in larger quantities and therefore as a new material alongside the traditional building materials.

It began with cast iron, which could only be used for compressed members in structures, for columns in buildings and for arch-like structures in bridges. The latter, such as the well-known Coalbrookdale Bridge from 1779, first were orientated in their conception on stone bridges built up to then. Soon however, forgeable iron which could also be used for members under tension was produced using the puddle method, which was invented 1784 in Great Britain by Henry Cort. It therefore became possible to construct large bridges of a whole new dimension in the form of suspension bridges. Notable examples are the chain-bridges built in Wales by Thomas Telford in 1826 over the Menai Strait with a span of 176 m and over the Conway. The new order of magnitude of these bridges required a careful engineer-like work-through of the construction design and the utilization of material. At the same time the construction of cable-stayed bridges took place in the USA and on the continent.

The development obtained another strong impulse due to the arisal of the railway and the rapid expansion of the rail network in the middle of the 19th Century. Many bridges had to be built, including several which had gigantic proportions for that time. They not only had to carry large loads, but also had to be rigid enough at the same time to avoid larger deformations.

A milestone of technical progress was the Britannia Bridge in Wales, which was completed in 1850 and built under the direction of Robert Stephenson, Figure 2. For the first time an iron beam bridge which spanned 140 m was designed. This bridge and a similar, but smaller one at Conway Castle, were called tubular bridges. They had a closed box-girder section and formed a tunnel for the trains passing through. The webs, the bridge deck and the roof of the cross section were riveted together from relatively small plates and L-shaped sections, the only material available at that time. The bridge deck and the roof had a cellular structure and the high and thin walls were stiffened by vertical ribs made of L-shaped sections to avoid buckling. The pillars, which were built above the level of the beam, show that Stephenson intended to reinforce the structure with suspension chains had it turned out not to have enough load-bearing capacity, which was not the case. The success of the project required an extensive testing programm, which was carried out with scientific precision.

![Figure 2](image)

Britannia Bridge over the Strait of Menai in Wales, built 1846–50 by Robert Stephenson (1803–1859)

**Planning and Design of the Old Tczew Bridge**

Directly after the Britannia Bridge, the Vistula Bridge at the city of Tczew (Dirschau) was built from 1850 to 1857 in the course of the Eastern Prussian Railway from Berlin to Koenigsberg.

The route of the railway planned after 1840 runs right through the Vistula Delta, Figure 3. Two bridges that were extraordinary for their time became necessary: one to cross the actual Vistula in Tczew and a shorter bridge to cross the Nogat at Malbork. Because of regular flooding and especially due to drifting ice in winter, bridges with large spans were necessary to reduce the clear opening as little as possible.

The construction of the Eastern Railway was carried out by the Prussian State under its own direction, and the management of the bridge projects was handed over to a high-ranking ministerial official, Senior Government Building Officer Carl Lentze. Lentze planned at first the construction of a chain suspension bridge similar to
the one he had learned of on the occasion of an information trip to Great Britain, where he visited the bridge built by Thomas Telford over the Menai Straits in 1826.

Soon after starting, construction work at Tczew had to be stopped again in 1847, due to financial difficulties of the State and to unrest leading up to the year of revolution in 1848. Carl Lentze used the time during the break in construction work to undertake a second informative trip to Great Britain, where he in particular visited the site of the Britannia Bridge in Wales and intensively studied this project of Robert Stephenson.

After his return, Lentze abandoned the project with the chain suspension bridge and decided to build beam bridges in Tczew and Malbork as well. Whereas the Britannia Bridge, which was completed in 1850, was as already mentioned a so-called tubular bridge with a cross section of box girders with solid webs, Lentze chose a non-solid superstructure of fine-meshed lattices for the bridges of the Eastern Railway, using six spans in Tczew, each 131 m long, Figure 1. His inspection of the site of the Royal Canal Bridge of the railway from Dublin to Belfast when it was under construction may have played a role in his decision, Figure 4. However this lattice bridge in Ireland, which was completed in 1845, only had a span of 43 m and was constructed differently, which led to some damage (Pollack 1848).

This Irish bridge was built similar to American wooden lattice bridges. When Culmanns travel report on the construction of the wooden bridges in the United States was published in Europe in 1851, it may have been a confirmation for Lentze of the decision he made.

Figure 5 shows the layout map of the Tczew Bridge with the adjacent railway routes. To reduce the length of bridge necessary, the clear opening for flooding was reduced in the eastern flooding area by new dikes.

The statical analysis and the construction detailing was carried out by Eduard Schinz, an exceedingly capable engineer, born in Switzerland. Schinz died during construction, was buried in Tczew and received a grave monument made of granite from the government in appreciation of his achievement.
Figure 6 shows two cross sections of the old bridge: in the left half a cross section over the supports and in the right half a span cross section. A footway was placed on 1 m wide outriggers on each side. Lentze and Schinz constructed the upper and lower girders as so-called «open-celled booms» consisting of angle bars and horizontal and vertical rolled plates riveted together. The finely meshed lattice-work can be found between these two chords.

Lentze and Schinz realized that the area around the intermediate support of the two-span beam called for special constructive measures. All the cross sections were chosen proportional to their load according to the theory of Carl Culmann and Johann Wilhelm Schwedler. Therefore they reinforced the upper chord by using wider chord plates. The lower chord was reinforced near the support by using additional levels of chord plates in a stepped form to adapt it to the increased load. The dimensions of the lattice bars increases from the middle of the spans towards the supports. The vertical angle bars are chosen according to the variable shear force, so that the distance from bar to bar decreases towards the supports. They stiffen the 11.82 meters high lattice walls and prevent the bars from buckling.

Lattice-like cross beams on the bottom side and sectionalized cross braces on the upper side additionally join both the main beams. Three horizontal planes of wind braces are additionally used: one on the bottom level of the lower boom and one each on the top and bottom level of the upper boom, Figure 6.

CONSTRUCTION OF THE OLD TCZEW BRIDGE

In 1851 the ceremonial laying of the cornerstone by the Prussian King took place at the abutment on the Tczew side, Figure 7. Construction went by plan, and the bridge could be opened for traffic in 1857.

Although the construction of the old Vistula Bridge was carried out by the Prussian government, it was incorporated in the international development of bridge construction and is counted as a true milestone of structural engineering, Figure 8.

By the chosen system with finely-meshed lattice-work, in spite of having almost the same span, a third
of the weight was saved in comparison to the Britannia Bridge. The six spans in all were connected two-by-two to create three continuous beams over two spans.

Therefore this pioneer achievement became a model for a large number of big and small bridge constructions in Europe. Here only the first railway bridge over the Rhine at Cologne shall be mentioned. It was completed in 1859, two years after the bridge at Tczew, and only had a span of 105 m.

**FURTHER DEVELOPMENT UP TO THE SECOND WORLD WAR**

The view of the portal of the old Tczew Bridge, Figure 9, shows that the bridge was for both railway and road traffic with horse-drawn carriages. The railway track was embedded in a wooden carriageway made of planks.

Of course before each train passed, the bridge had to be closed to road traffic in time. In the following decades the amount of railway traffic, which was
sparse at the beginning, increased rapidly, and so gradually caused intolerable conditions for road traffic. Consequently, it was decided to erect a second bridge, which was built from 1888–1891 as a two-track railway bridge for rail traffic alone, 40 m away from the old bridge which from then on served only for road traffic. In order not to additionally disturb the clear section of the Vistula, the new bridge obtained piers in the same position as the old bridge. Large fish-belly girders were chosen for the six spans, Figure 10 (Goering 1890).

When the danger of a German invasion of Poland grew in the summer of 1939, the Polish army prepared to blow up both bridges as a measure of defense, which became known to the German side. When the German attack on Poland began in the early morning hours of the 1st of September 1939, the German „Wehrmacht“, i.e. the German Army, tried to take over the bridges undamaged in a surprise attack. This action failed, the bridges were blown up after several battles, and three spans of each of the bridges from 1857 and 1891 were lost, Figure 11.

At the beginning of the 20th century, heavy flooding forced new measures to be taken to regulate the flow of the Vistula and the Nogat. The artificial measures which had been taken to narrow the Vistula at Tczew were removed again. As a result both bridges had to be extended at this place by about 250 m, which was done from 1910–1912 by erecting three additional spans with simple parallel-chorded trusses, Figure 8.

**EVENTS AT THE BEGINNING OF AND DURING THE SECOND WORLD WAR**

In this prolonged configuration the bridges survived the time up to the Second World War. Since the end of the First World War, the bridges belonged to Poland and the region of the Vistula Delta belonged to the Free City of Gdańsk.

During the war the German side supplemented the railway bridge in only a few weeks with an auxiliary bridge which was turned out of the longitudinal axis of the railway bridge, Figure 12.

This auxiliary bridge was replaced by a permanent construction in the axis of the railway bridge within one year. The old bridge remained as a rudiment. It was only used as a pedestrian bridge and was for this purpose connected at its end by a foot bridge to the railway bridge, Figure 13.

At the end of the Second World War the railway bridge was blown up once again, this time by the Germans.

**FINAL REMARKS**

The Polish reconstruction after the war led in single steps to the current condition, Figure 14, which now
Auxiliary bridge built in 1939 by the German Army

The Tczew Bridges during the Second World War consists of many different parts from which its turbulent fate can be read.

In the foreground of Figure 14 the row of spans of the old bridge can be seen. It begins on the left with two spans over the Vistula River, which today consist of girders from the British military system developed by Bailey.

The next three spans are the original parts from 1857. Further to the right there are small trusses, replacing the destroyed sixth span of the old bridge. At the right end, three spans from the prolongation of 1912 can be seen.

Behind the old bridge, Figure 14 shows the railway bridge constructed later. No parts of the original bridge from 1891 exist today. At the right end a part of the remaining prolongation from 1912 can still be seen. The other parallel chorded trusses are the remaining parts of the reconstruction work done during the Second World War.

The research of military history has shown that the start of the German action against the Tczew bridges was possibly the very first fighting of the Second World War (Schindler 1971). Therefore the bridge is also a memorial of the younger European history, which reminds us of the beginning of that terrible war.

Above that, the three spans of the old Vistula Bridge from 1857 which remain in their original state, Figure 15, portray a truly unique technical monument of early structural engineering, after the Britannia Bridge in Wales has been replaced in recent times. It should be the unconditional European task to support Poland in preserving the building substance of this exceptional legacy.

REFERENCE LIST


Figure 15
One of the remaining spans of the Old Tczew Bridge from 1857

Le Seur; Jaquie and Boscovich. 1743. Parere di tre matematici sopra i danni che di sono trovati nella Cupola di S. Pietro sul fine dell’Anno 1742.
Poleni, Giovanni. 1748. Memorie istoriche della Gran Cupola del Tempio Vaticano.