Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 64 (1991)

Artikel: Long span bridges of the new railroad lines in Germany

Autor: Zellner, Wilhelm / Saul, Reiner

DOI: https://doi.org/10.5169/seals-49357

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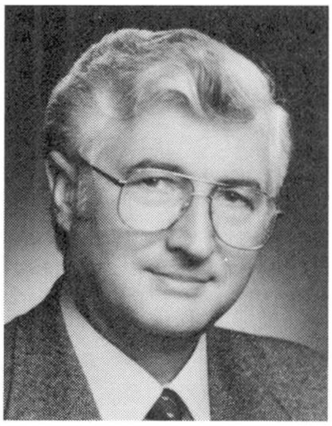
Long Span Bridges of the New Railroad Lines in Germany

Ponts à grande portée des récentes voies ferroviaires en Allemagne

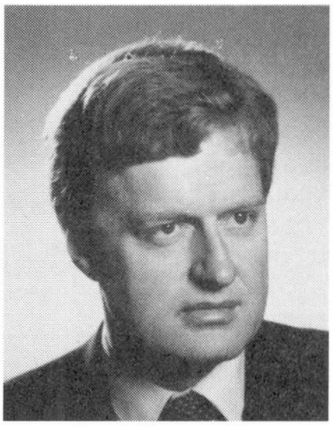
Weitgespannte Brücken der Neubaustrecken der Deutschen Bundesbahn

Wilhelm ZELLNER
Managing Director
Leonhardt, Andrä & Partner
Stuttgart, Germany



Wilhelm Zellner, born 1932, received his civil engineering degree at the University of Vienna, Austria. For two years he was in charge of the supervision of a big prestressed concrete viaduct in Vienna. In 1962 he moved to Leonhardt & Andrä to Stuttgart and in 1970 became a partner in this firm.

Reiner SAUL
Senior Supervising Eng.
Leonhardt, Andrä & Partner
Stuttgart, Germany



Reiner Saul, born in 1938, received his civil engineering degree at the University of Hannover, Germany. Four years with a steel contractor, since 1971 senior supervising engineer with Leonhardt, Andrä & Partner. He was responsible for the design, technical direction and checking of numerous long span bridges, including also major rehabilitation works.

SUMMARY

The German Federal Railway Authority built two new railroad lines with a total length of 427 km in the years 1980 to 1991. These lines are designed for speeds of 250 km/h, which is the envisaged speed for the future, also on other lines. The topography is hilly and the new alignment is rather straight. Therefore about 10% of the new lines are on bridges and 30% in tunnels. Six special bridges with spans longer than 75 m had to be designed and built, which are briefly described.

RESUME

Les Chemins de Fer Allemands ont construit au cours des années 1980 à 1991 deux nouvelles voies de 427 km de longueur, sur lesquelles les futures générations de trains rapides doivent pouvoir circuler à une vitesse de 250 km/h. La topographie du site est mouvementée. Le profil en long est plutôt rectiligne, donnant lieu à un pourcentage en ponts et tunnels par rapport à la longueur totale du tracé de 10 et respectivement 30%. Six ponts spéciaux d'une portée de plus de 75 m ont été étudiés et construits. Ces ponts font l'objet de la présente communication.

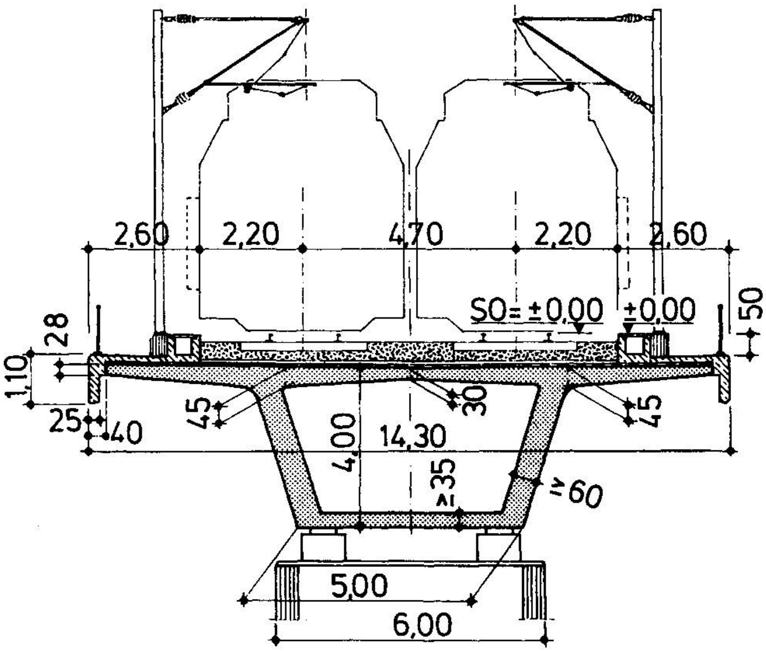
ZUSAMMENFASSUNG

In den Jahren 1980 bis 1991 baute die Deutsche Bundesbahn zwei neue, zusammen 427 km lange Eisenbahnlinien für den 250 km/h schnellen Verkehr der Zukunft. Wegen der topografisch schwierigen Mittelgebirgslandschaft laufen die grosszügig trassierten Strecken zu etwa 10% ihrer Gesamtlänge über Talbrücken und zu 30% in Tunnel. Sechs Sonderbrücken mit Spannweiten von über 75 waren zu planen und zu bauen, worüber hier berichtet wird.

1. INTRODUCTION

The New Railroad Lines for the fast trains require many bridges and viaducts. Due to the hilly topography, about 10 % of the total length of the lines are bridges in Germany. Most of the viaducts have been built according to the so-called "General Design" (Rahmenplanung) by simple supported concrete box girders with a distance of the piers of 44m or 58m and a depth of the girders of 4.oo m or 5.3o m resp. (Fig.1).

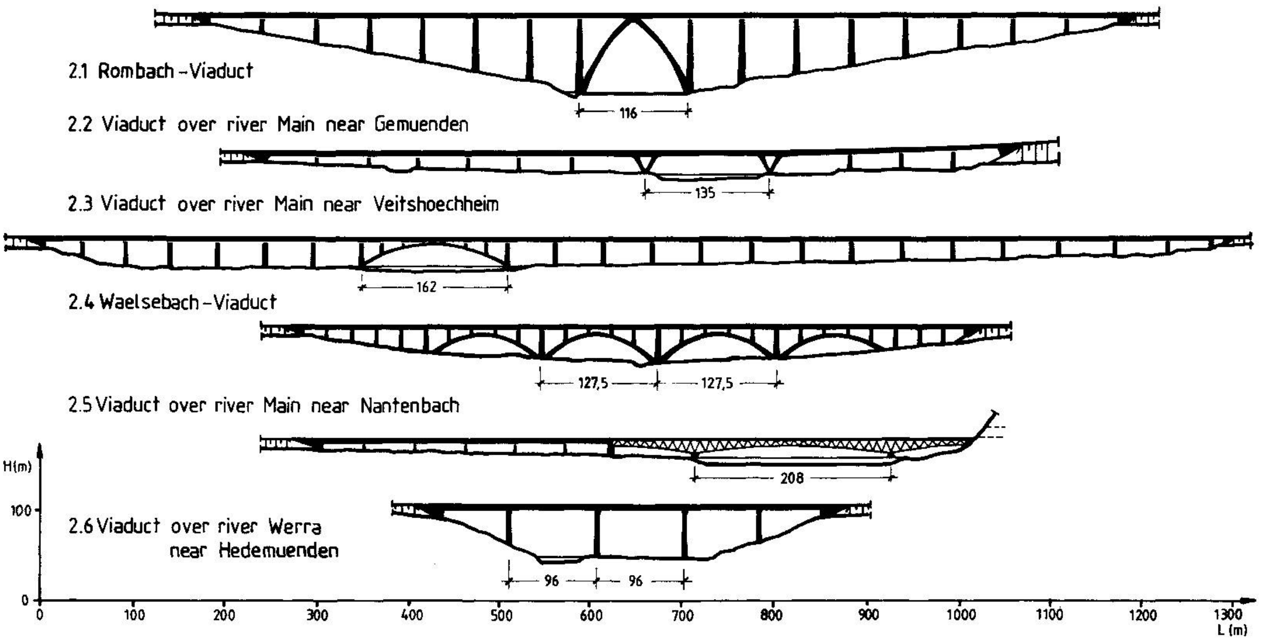
Fig.1 Standard cross-section of simple supported girders ℓ = 44m



Such bridges can be built with joints between the girders but without joints in the rails and in ballast, if the piers are not higher than 20 to 25m. In this case the big horizontal braking forces can be transmitted to the ground by the piers. If the piers are higher than 25m, then the piers become too flexible and the braking forces would be transmitted via the rails to a stiff pier or a stiff abutment. In this case the stress in the rails from the big longitudinal force becomes too big and one has to find other solutions for the transmission of the braking force.

High viaducts or long spans over rivers can not be built with jointless rails. Rail expansion joints are developed and in use in Germany for expansions up to 800 mm, that means the fixed point of the bridge may be in a distance up to

Fig. 2: Long Span Bridges of the New Railroad Lines in Germany (Spans > 75m)



650 m from this expansion joint. In consequence of this basic considerations, several bridges had to be designed which are beyond the "General Design", because of its span (>58m) or its height above ground (>25m).
Six bridges have spans of more than 75m. These bridges are called the long span bridges and this article will deal with them. Three of them have been designed by Leonhardt, Andrä & Partner (Gemünden, Veitshöchheim, Nantenbach). One bridge has been preliminary designed by this consulting firm (Hedemünden). Two of them have been designed by others (Rombach and Waelsebach Viaduct, Fig.2).

2. ROMBACH VIADUCT (Fig.2.1 and Fig.3)

The total length of this bridge is 17 x 58 = 986 m. The maximum height of the rails above the valley is 94m. It was not possible to transmit the braking forces via vertical piers to the ground. If the bridge would have been fixed to one abutment, the distance to the rail expansion joint would have been more than 650 m. Therefore, the superstructure has been fixed at the center of the bridge above a huge concrete A-shaped trestle. Two rail expansion joints have been provided, one each above the abutments. The legs of the trestle are curved in order to counteract the dead weight of the leg.

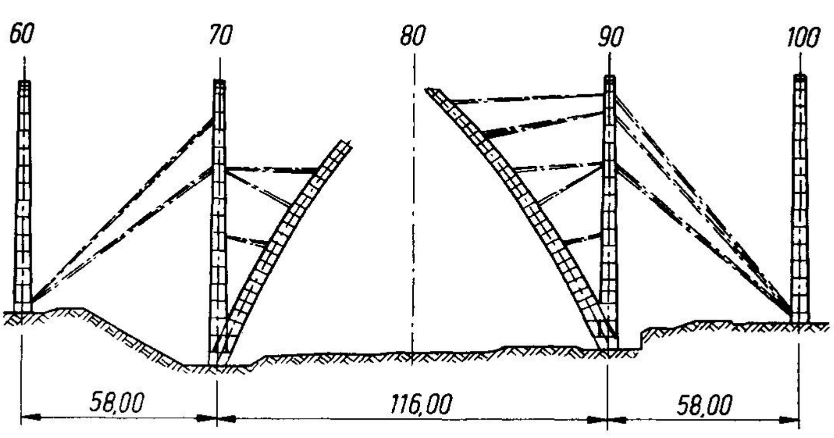


Fig. 3 Construction of concrete A-trestle

The superstructure consists of 17 simple supported girders with spans of 55.75 m and a depth of the girders of 5.3o m. The girders are longitudinally coupled in the center of gravity of the cross-section. The couplers consist of 8.2o m long tendons for the transmission of longitudinal tension forces and neoprene bearing pads for the transmission of compression forces.

Should it ever be necessary to replace the superstructure by a new one, the work can be done in 58m long parts. It is assumed that a new simple supported girder will be built aside of the old one on auxiliary piers and the replacement can be done within two days by simultaneous lateral shifting. The same system with an A-shaped trestle in the middle of the total bridge length has been used for two more bridges: the Mülmisch and the Pfieffe Viaduct with 15 x 58 = 870 m and 14 x 58 = 812 m length, resp. The A-shaped trestles for those bridges have been built by the use of a total formwork, resting on a huge wooden scaffolding. The superstructure of these 3 bridges have been built by a special formwork, bridging the full length of a span of 58m and launched from span to span [1].

3. VIADUCT OVER THE RIVER MAIN NEAR GEMÜNDEN (Fig.2.2 and Fig.4)

This viaduct consists of a 299 m long main bridge over the river Main, a 330.5 m long northern approach bridge and a 164 m long southern approach bridge. The approach bridges have been built by the incremental launching method. The main bridge was built by the free cantilevering construction method. The longitudinal horizontal forces (from braking and from the friction at bearings) are transmitted to the abutments. The braking forces, acting onto the main bridge are transmitted to the ground by frame action of the double V-shaped struts of the frame. Under the V-shaped struts are concrete hinges for working forces up to 123 MN.

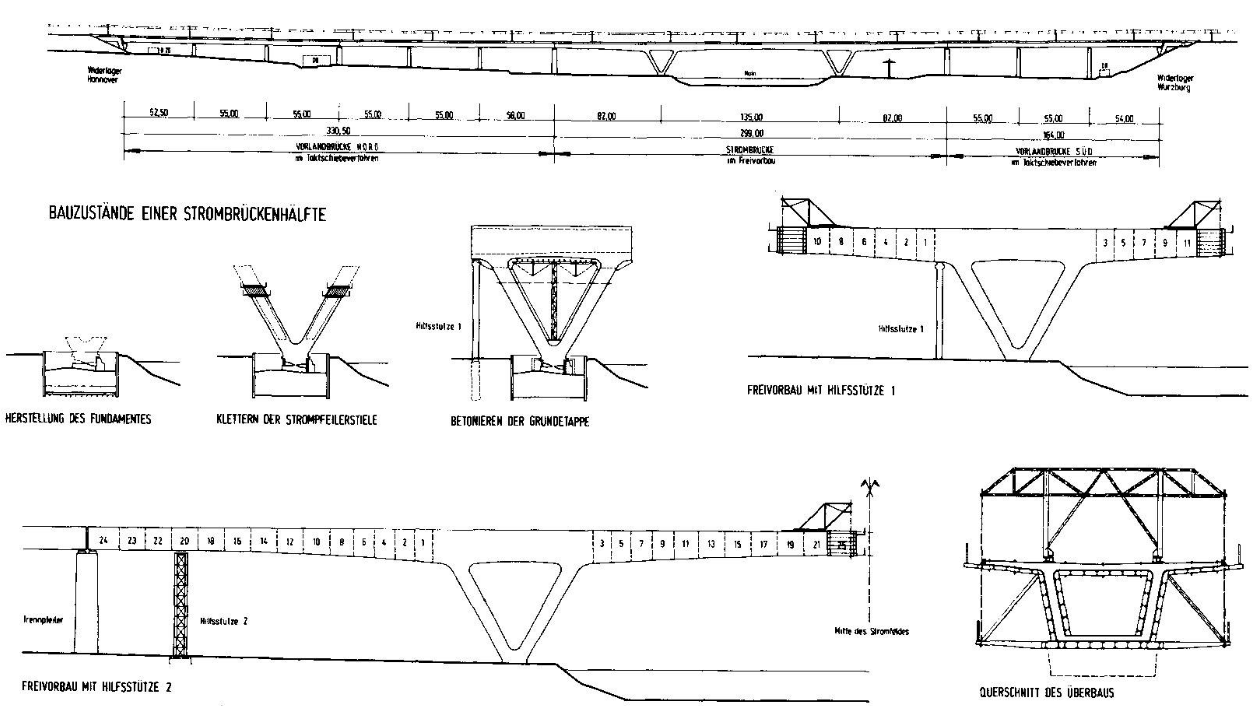


Fig. 4 Viaduct near Gemünden: Overall view and construction

Should it ever be necessary to replace the 299 m long main bridge, a new bridge will be built aside of the old one. The concrete hinge will be cut, one inch deep, then broken by lifting the bridge with jacks about 15 mm. The replacement will be done by simultaneous lateral shifting. The hinge will be repaired by epoxy mortar. The rail traffic will be interrupted by about three days.

The two rail expansion joints are at the ends of the main bridge. The depth of the girder is 4.5o m in general, but 6.5o m above the V-shaped struts. Without the frame action the beam over a span of 135 m would have been min. 9.5o m deep for the heavy live loads from the trains (80 kN per lin.m per track) and the dead load from the ballast and the concrete structure itself.

There has been too much opposition from the public against the 9.5o m deep beam close over the bottom of the valley. The frame solution, therefore, is considered to be an essential improvement with regard to the aesthetics [2], [3].

4. VIADUCT OVER THE RIVER MAIN NEAR VEITSHÖCHHEIM (Fig.2.3 and Fig.5)

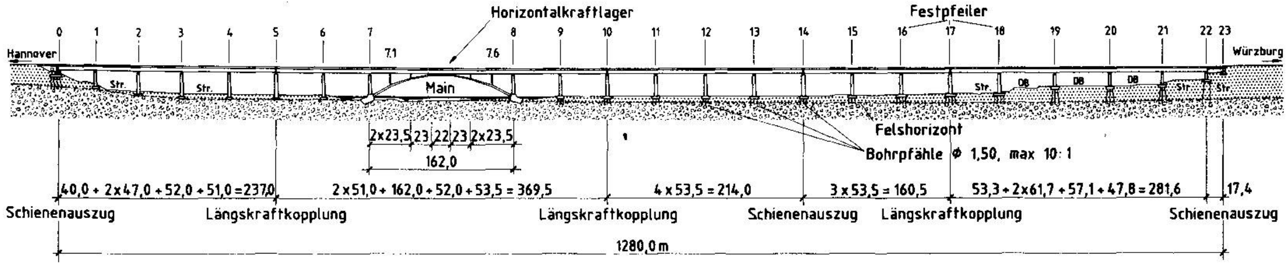


Fig. 5 Viaduct near Veitshöchheim: Elevation view

This bridge is explained in detail in the report on the Poster Sessions W1.

5. WAELSEBACH VIADUCT (Fig.2.4 and Fig.6)

The New Railroad Line from Hannover to Würzburg crosses the Waelsebach valley on a 721.2 m long viaduct in a maximum height of 40m above the ground of the valley. The alignment is curved in plan with a radius of 5100 m and the gradient in elevation is 1.2458 ‰. The soil under the bridge generally consists of solid sandstone and limestone. At four locations this rock formation has fallen into deep caves and the gaps in the rock, called chimmneys, have been filled with soft clay. The gaps are up to 60m wide and could not been used to carry foundations. Two gaps near the abutments have been bridged by earth-covered concrete box girders, so-called chimney-bridges. Two other gaps have been bridged by visible concrete arches.

Thus the bridge appears with 4 main arches at spans of 127.5 m each. Piers have been built at a distance of 25.5 m for the approach bridges and on the arches. The piers and the two abutments support 28 simple supported girders, thus the total length of the bridge is 3x 27.9 + 25x25.5 = 721.2 m. There is no expansion joint in the rail and the ballast on the total length, which is considered as an advantage of this bridge system. The four arches are stiff enough to transmit the big longitudinal braking forces to the ground, without too big deformations of the arches and too much stress increase in the rails [4]

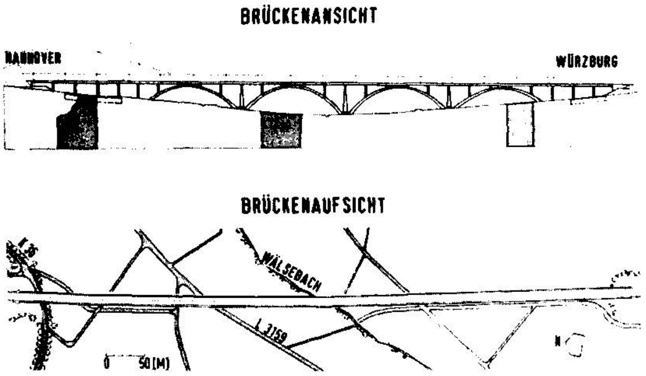


Fig. 6 Elevation and Plan

6. VIADUCT OVER THE RIVER MAIN NEAR NANTENBACH (Fig.2.5)

The New Railroad Line from Hannover to Würzburg is connected to the existing line from Gemünden to Frankfurt by a new 8 km long feeder line, which is under construction from 1990 to 1995. For this line the bridge with the longest span (208 m) of all railroad bridges in Germany, has been designed by Leonhardt, Andrä & Partner. Many different solutions with arches and trusses above the alignment have been studied during preliminary design stage. Finally a steel truss under the railroad has been chosen for tender and execution. The steel structure is in composite action with the concrete deck slab.
More details please find in the report on the Poster Sessions W1.

7. VIADUCT OVER THE RIVER WERRA NEAR HEDEMÜNDEN (Fig.2.5 and Fig.7)

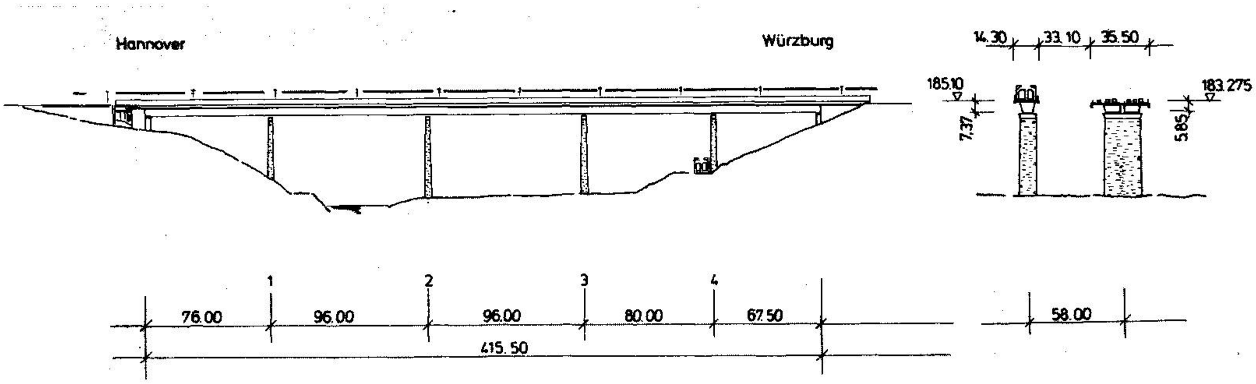


Fig. 7 Werra Viaducts: Elevation and cross-section

This 416 m long bridge for the New Railroad Line crosses the Werra valley 60m above the river. At the same location a similar bridge in length and height was built for the motorway from Kassel to Göttingen 1936/38. The superstructure of the highway bridge had become too narrow and deteriorated. Therefore, it has been decided in 1982 to replace the superstructure of the highway bridge by a new and wider one.

Five consulting engineering groups have been invited for a design competition in order to get the best solution for the complicated task to build a new railroad and a new highway bridge, using the old substructure of the highway bridge and maintaining the highway traffic with 80,000 vehicles per day. This competition was won by Leonhardt, Andrä & Partner with a combined highway and railroad bridge. This design consisted of a steel truss with a wide concrete deck to carry the highway traffic. Steel and concrete had to act together in the so-called composite action. The railroad should have been under the concrete deck between the two planes of the steel truss girder.

Later this bridge has been considered to be too vulnerable and sensitive in cases of accidents, fires or terrorist attacks. Therefore, it was decided to build the highway and railroad bridge separated, parallel in a distance of 50m (Fig.7). New piers had to be built for the railroad bridge in the same distance as of the old highway bridge, i.e. 96m. The new piers were cladded with masonry similar to the old piers of the highway bridge. Such stone works are normally not made nowadays in Germany.

Composite box girders have been used for the superstructure of both bridges. Trusses are aesthetically an excellent solution if only two planes of diagonals have to be made. The solution is not good if there are four planes of diagonals with different distances of the planes and different depth. Prof. F.Leonhardt has been the advisor for the aesthetics of these bridges [5].

8. ACKNOWLEDGEMENT

The New Railroad Lines in Germany cross many wide and deep valleys, requiring big and long span bridges. The Federal Railway Authority was open for new solutions which contribute considerably to the progress of the art to design and build modern long span bridges.

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