First Munich Bridge Assessment Conference
MBAC 2005
N. Gebbeken, M. Keuser, I. Mangerig
Munich, 20.-25 June 2005

REFURBISHMENT AND REPLACEMENT OF MAJOR STEEL AND STEEL COMPOSITE BRIDGES

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Key words: refurbishment, replacement, steel bridges, steel composite bridges, suspension bridges, valley bridges, masonry piers, cable-stayed bridges, highway bridges, railway bridges, widening, lateral shifting.

Abstract. *The refurbishment and the replacement of major steel and steel composite bridges is in the vast majority of the cases required by the increase of the traffic volume and of the life loads and not due to fatigue and poor maintenance. Steel, in comparison with prestressed concrete with reduced weight, allows to erect and dismantle greater sections and the reuse of existing piers and foundations - what reduces the inconveniences to the users to a minimum.*
The refurbishments described herein have the aim to double the traffic width. Basically two alternatives are existing for this:

- *The existing bridge is transformed into a directional roadway and a new and independent bridge is built for the other direction.*
- *The existing bridge is widened by adding additional elements.*

The examples for the replacement of steel and steel composite bridges have in common that parts of the original bridge, for instance the piers, the abutments and the foundations remain in use and or the axes of the original and the new bridge are coincident. According to the phases of construction in the transverse direction the following procedures may be distinguished

- *lateral shifting of the complete section*
- *lateral shifting of the superstructure for one or both roadways*
- *construction of the bridge for one roadway after the partial demolition of the existing bridge*
- *demolition of the old bridge and construction of the new bridge in slices*
- *special procedures which have in common that the existing bridge is used in order to erect the new bridge and the new bridge is used in order to dismantle the existing bridge.*

1 INTRODUCTION

Whereas in the past the world of construction was dominated by the construction of new roads, railways, bridges and buildings, during the last decades the maintenance, the refurbishment and the replacement of existing structures have become always more important.

The refurbishment and replacement of steel and steel composite bridges are much more often required by an increase of the traffic volume and of the live loads than by fatigue or bad maintenance. Their – compared with bridges of prestressed concrete – reduced weight allows to dismantle and to erect big sections and to reuse existing piers and / or foundations what reduces the inconveniences to the users as far as possible.

2 REFURBISHMENT

2.1 General

The refurbishments shown hereunder have the goal to double the traffic width. This can be achieved basically by two alternatives

- the existing bridge is transformed into a directional roadway and an independent bridge for the other direction is built on its side.
- the existing bridge is widened by adding or inserting new elements.

2.2 Transformation of the existing bridge into a directional roadway

Example: Köln-Deutz Bridge across river Rhine [1], Fig. 1

The Köln-Deutz Bridge, built 1947/48, has spans of 132,1 – 184,5 – 120,7 = 437,3 m. The total width of 20,6 m is shared by 2 street cars, cars, bicycles and pedestrians. The bridge has a 3-cell box-girder with a width of 11,56 m and a construction depth of 3,3 m at the center and 7,8 m at the piers.

In order to overcome the daily traffic jams it was decided to give a separate lane to the street cars and to widen the bridge by 12 m to 32,6 m. In a first step a twin bridge from prestressed concrete was built upstream and afterwards the existing bridge was refurbished as follows.

- demolition of the upstream cantilevers
- installation of new rails near the upstream border
- demolition of the rails in the center

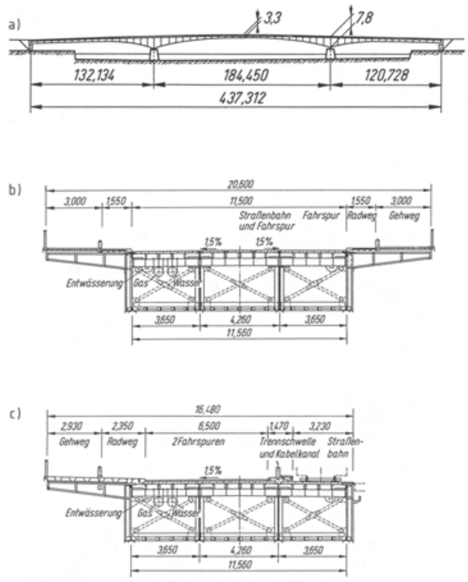


Figure 1 Köln-Deutz Bridge across river Rhine
a) Layout, b) Original cross-ection, c) Transformed cross-section

- installation of a guardrail and cable ducts on side of the rails
- replacement of the prefabricated concrete deck of the downstream walkway by an orthotropic plate
- installation of a 7 cm thick asphalt layer and of watertight expansion jointings.

2.3 Widening of bridges

Example: Köln-Rodenkirchen

This suspension bridge has a main span of 378 m and was built from 1938 to 1941. After destruction in 1945 it was rebuilt from 1951 to 1954 with a steel composite bridge deck. From 1990 to 1994, the width of the bridge was doubled from 26,4 m to 52,8 m by adding a third cable. In order to avoid overstressing of the centre cable, the concrete slab was replaced by an orthotropic plate and the continuous cross beams were superelevated, so that part of the load was transferred from the centre cable to the outer cables.

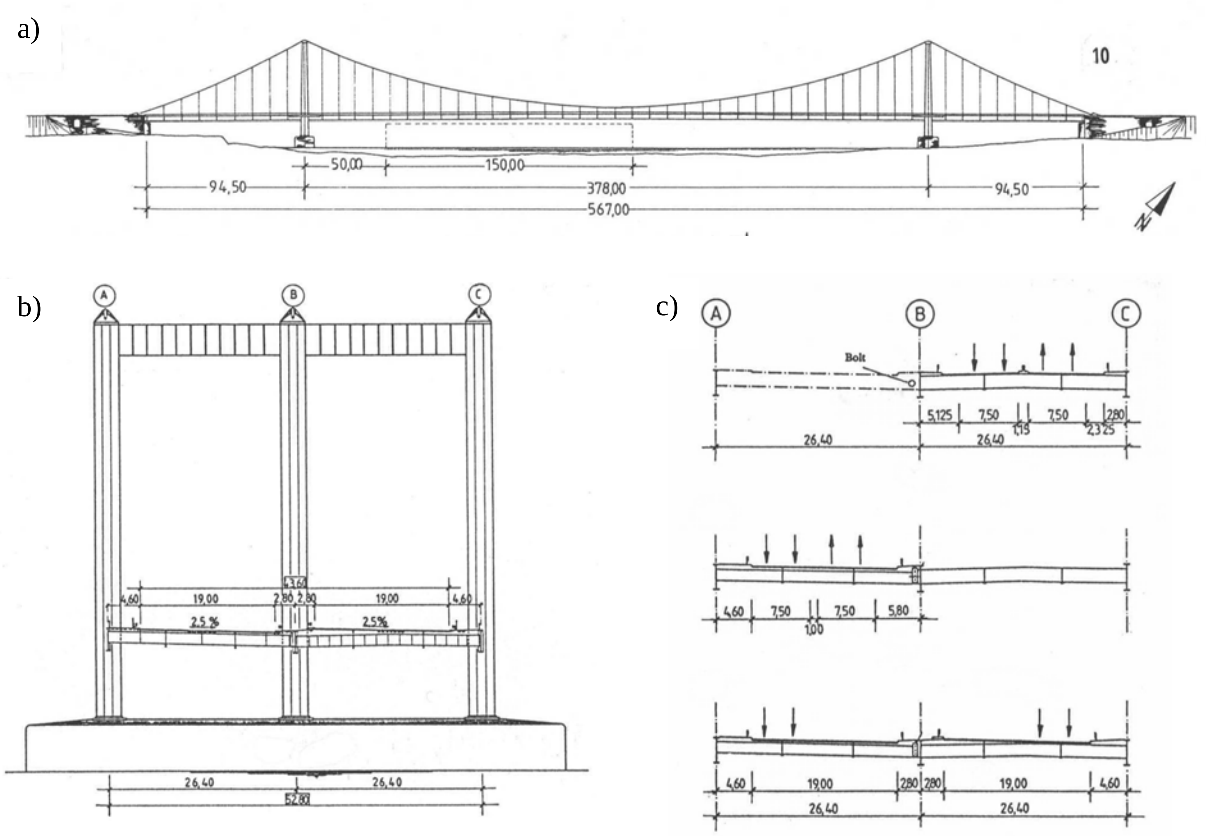


Figure 2: Köln-Rodenkirchen Bridge, a) Layout, b) Tower, c) Construction Sequence

3 REPLACEMENT

3.1 Lateral shifting of the complete cross-section

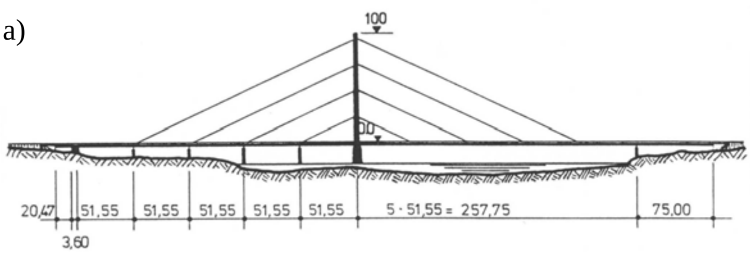
Example: „Oberkasseler Bridge“ across river Rhine at Düsseldorf [3], Fig. 3

The main spans of the Oberkasseler Bridge at Düsseldorf were reconstructed after World War II as truss girders with 4 spans of 94,5 m each and a traffic width of 12,5 m. The insufficient traffic width and the danger caused to ship traffic by the small spans required the construction of a new bridge in the early seventies.

The new bridge is a single-plane cable-stayed bridge with a total length of 590,50 m, a main span of 257,75 m and a single tower on the left embankment of the river. The 35 m wide superstructure consists of a 20 m wide box girder with long cantilevers. The single-cell steel tower has a height of 100 m above the bridge deck, and the 4 cables have a harp arrangement.

The new bridge was built 47,5 m upstream of the old one. After diverting the traffic to the new bridge, the old bridge - including the piers - was dismantled, and new piers were built in the axis of the old bridge. After that, the provisional and final abutments, tower piers and embankment piers were linked by sliding tracks.

a)



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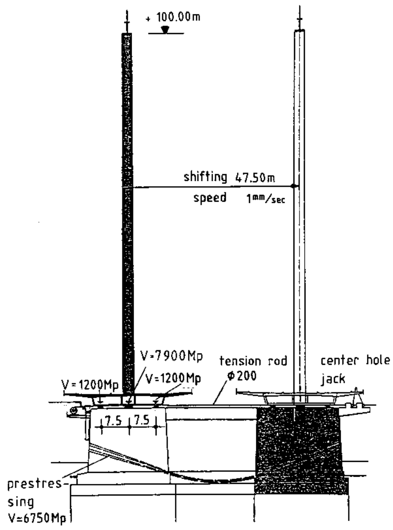


Fig. 3 “Oberkasseler Bridge” across river Rhine at Düsseldorf
a. New bridge view, b. Cross-section at main pier.

Sliding tracks at the backstay cable anchorages (pendulums) were not required, as they are without load under permanent loads. After releasing the pendulums, the bridge was pulled to its final position on 7 and 8 April 1976. A total weight of 12.700 t had to be moved, 10.300 of them at the tower pier.

3.2 Lateral shifting of the superstructure for one roadway

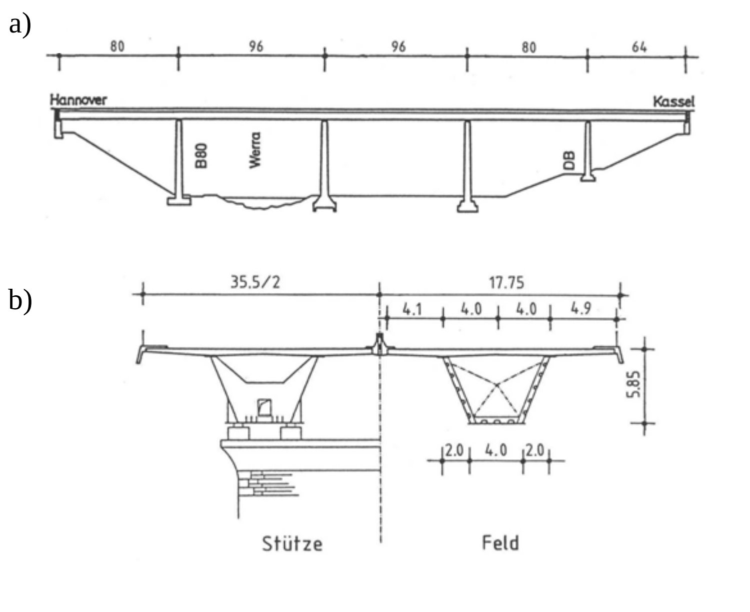
Example: Highway bridge across the Werra Valley at Hedemünden [4], Fig. 4

The first highway bridge across the Werra Valley was built from 1935 to 1937 with a width of 21,5 m. After its destruction during World War II the bridge was reconstructed with a width of 22,3 m.

The increased traffic required to widen the bridge to 37,5 m in the early eighties. Both roadways have now steel composite superstructures with trapezoidal box girders. The existing piers were capable to carry the increased loads of the new bridge and widened at their top like a hammer head.

The new superstructure for the traffic towards Kassel was built on auxiliary piers and abutments, and later the total traffic was diverted to this bridge.

After the dismantling of the existing superstructures and the refurbishment of the piers and abutments, the second superstructure was built in its final axis. After diverting the total traffic to this bridge, the first superstructure was laterally shifted into its final axis.



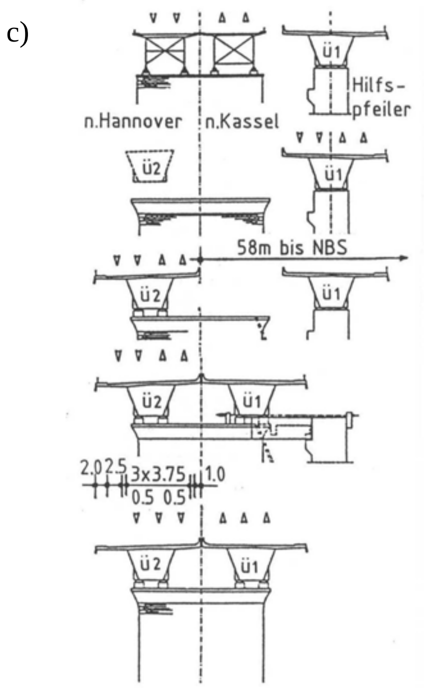


Figure 4. Highway bridge across the Werra Valley at Hedemünden: a. View; b. New cross-section; c. Construction procedure

3.4 Construction of the new superstructure for one roadway after partial dismantling of the existing bridge

Example: Highway bridge Wilkau-Haßlau [5], Fig. 5

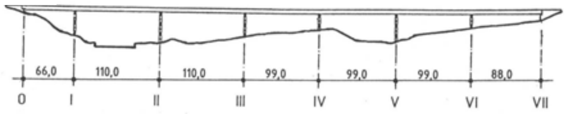
The bridge, built in 1938/39 crosses the valley of the „Zwickauer Mulde". The bridge deck was a plate girder with 4 webs and a width of 24,5 m. As usual at the time of construction, the piers were constructed solid and received a cladding of natural stones.

As the adjacent highway had not been completed yet, only the northern part of the bridge was under traffic.The new bridge has a width of 30 m. Both roadways have steel composite superstructures with trapezoidal box girders. The old piers are maintained, but they have at their top a new 2 m deep bearing block from reinforced concrete.

In a first step, the bridge half which was not under traffic was dismantled. After that, one half of the abutments and the top of the piers were adapted to the new bridge, and the first new superstructure was constructed by incremental launching.

Due to the extremely reduced construction time, the complete cross-section was launched on the final and auxiliary piers. After the dismantling of the second half of the existing bridge and the adaptation of the rest of the abutments and piers, the second new superstructure was built as the first one.

a)



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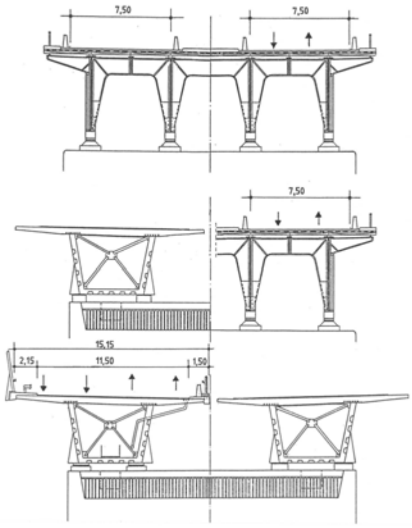

Figure 5. Highway bridge Wilkau-Haßlau:
a. View; b. Construction Procedure

3.5 Removal of the old bridge and construction of the new one in slices

Example: Heinrich-Erhardt Bridge at Düsseldorf [6], Fig. 6

The Heinrich-Erhardt Bridge was built in 1909 and had a truss girder and a 10,5 m wide roadway. The insufficient traffic width and load-carrying capacity required the construction of a new bridge at the end of the seventies.

The new bridge is a single-plane cable-stayed bridge with a total width of 39 m

In order not to restrict the railway traffic underneath nor the road traffic on the bridge during the replacement, the following construction procedure was used

1. Dismantling of the cantilevers of the existing bridge.
2. Construction of the southern third of the new bridge by launching from east to west. For this, auxiliary piers could be provided at the places of emergency piers of the old bridge, which corresponded fairly well with the cable anchorage points.
3. Construction of the northern third of the new bridge as before.
4. Dismantling of the old bridge with a portal crane running on both parts of the new bridge.
5. Launching of the centre third of the new bridge, coupling of the three parts, construction of the towers, erection and stressing of the cables.
6. Final arrangement of traffic.

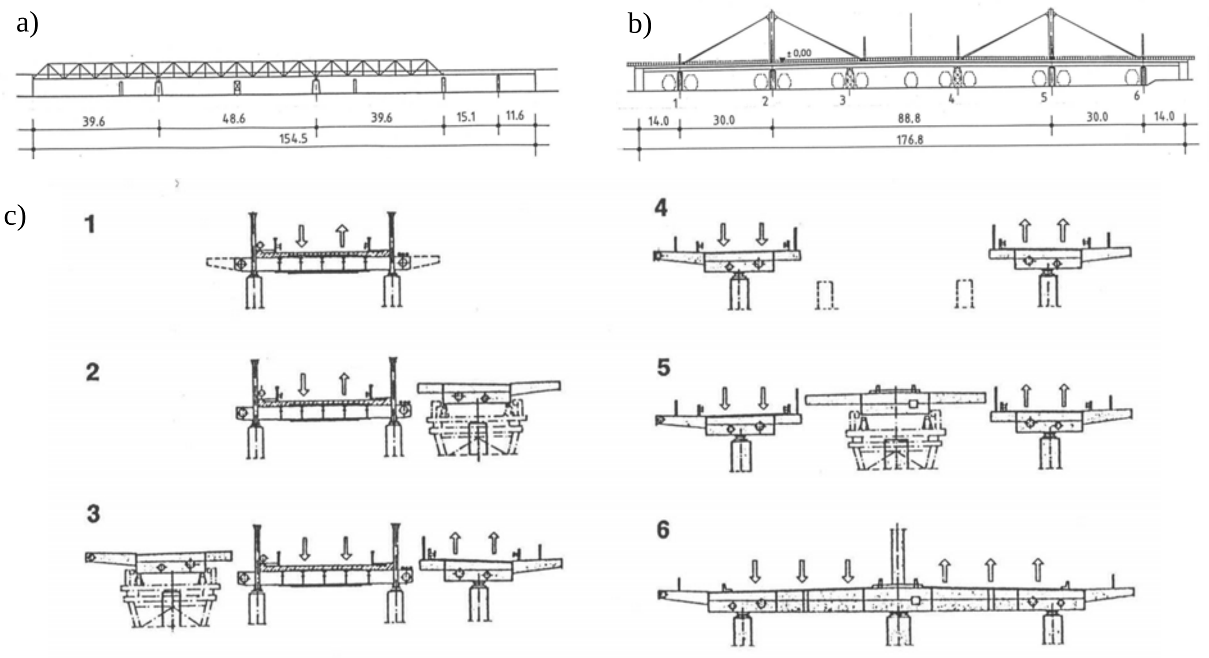

Figure 6. Heinrich-Erhardt-Steel Bridge at Düsseldorf: a. Old bridge; b. New bridge c. Construction sequence

3.6 Special procedures

Example Schwarzbach Valley Bridge at Wuppertal [7], Fig. 7

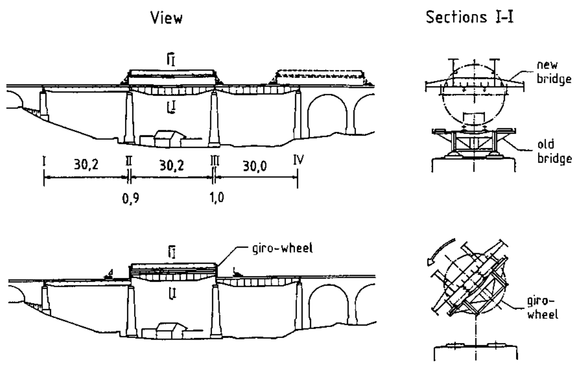

Figure 7. Schwarzbach Valley Bridge at Wuppertal, Construction procedure

The Schwarzbach Valley Bridge built in 1885 crosses two streets and a residential area. The superstructures of the three main spans, of about 30 m each, had a fish belly shape and were from St 48. Considerable corrosion damage required a substantial refurbishment of the superstructures in 1980. Following an alternative proposal of a steel contractor, the superstructure were not refurbished, but replaced.

In a first step, the ballasted track of the existing bridge was removed and the new superstructure rolled into its final position upside down.

At their ends, both superstructures were attached to giro-wheels and later rotated by 180°. After that, the old superstructure was rolled out. Due to this sophisticated construction procedure, the traffic was interrupted for only 2 months.

4. SUMMARY

The preservation of the capacity and durability of bridges by refurbishment and replacement is a requirement of our days. Compared with the design of new bridges, this task is, at a first glance, ungrateful. But the many boundary conditions, given by the existing bridge and the necessity to maintain the traffic, convert the refurbishment and replacement of bridges into a demanding and attractive engineering task. They require often to deviate from the codes written for every day bridges and to reflect the basis of the design completely anew.

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