The Widening of the Aare Bridges at Ruppoldingen

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Summary

A solution is shown for the widening of existing highway bridges with almost no disturbance and interruption of the traffic. In addition the solution is also economic. Only a few new bearings are necessary and due to the reduced self weight corbels at the piers are possible to transfer the vertical load.

Keywords:, Composite bridge, Widening of bridges, Triangular girder

1.   Introduction

1.1   The existing bridge

The highway A1 Zurich – Bern crosses near Ruppoldingen the river Aare and the adjoining Aare canal. In 1965/67 two three span bridges were built with the denominations Z66 over the Aare canal and Z67 over the Aare with the following dimensions as shown in fig. 1.

Z66 is consist of two posttensioned concrete bridges with a single cell cross section each, and Z67 are two composite bridges with open cross section made out of two steel girders each. All four bridges have no curb lane and have a skew angle at the abutments.
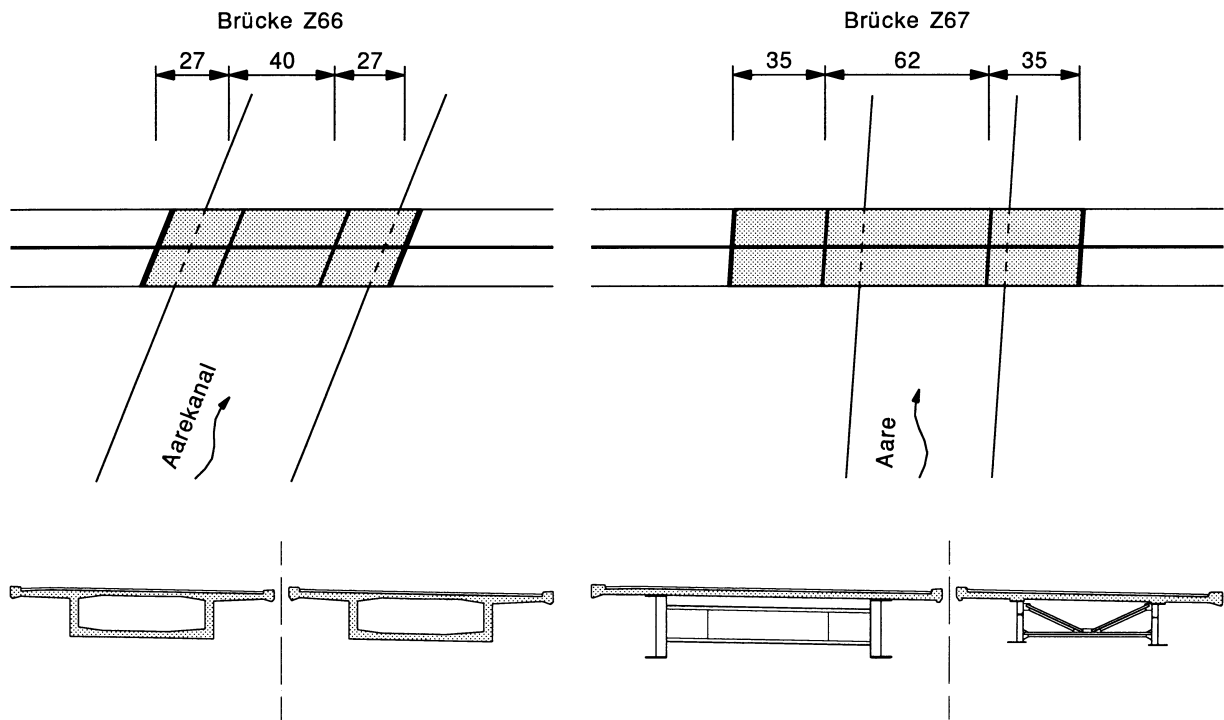
Figure 1: Cross section and situation of the existing bridges

1.2 Restrictions by the Owner

The bridges are to be widened to accommodate a curb lane.

The construction work has to be executed in a minimum of time and the traffic should not be disturbed to a big extend. This construction goal should be achieved by a good organization, optimization of the way of construction, working in shifts etc. In order to motivate the contractor and to limit the disturbance of the traffic, the contractor has to rent the roadway surface for any traffic disturbance in the following way:

A   No changes in lane (2 lanes), safety walls sideways   SFr.   900,--/day

B   Only one lane open on the bridge   SFr.   9'000,--/day

C   No lane open on the bridge   SFr. 15'500,--/day

Cost estimation showed very quickly that the renting costs are very expensive. The solution A was the only reasonable.

In addition the following statements by the owner had to be considered.

- Since the old posttensioned bridge Z66 is critical for shear, **no additional load shall be applied** by the widening. If possible the old bridge should even be relieved from some load.

- The additional load of the widening has to be taken by the piers with external corbels over the water line. So **no construction work in the river** is necessary.

- The differential deformation of the old and the new bridge should be minimized in order to **reduce the risk of cracking** of the concrete deck at service loading.

2.   The solutions

2.1   Conforming design

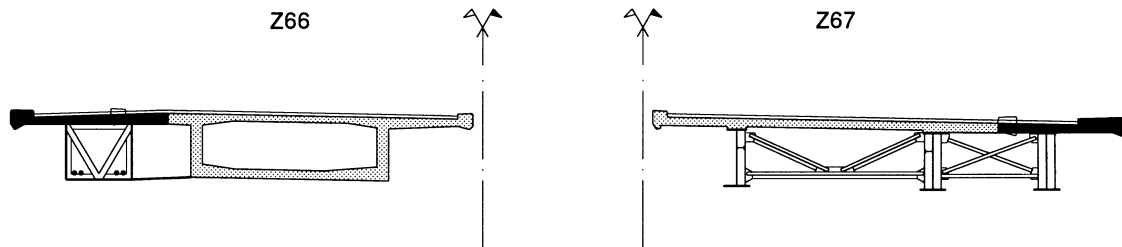The conforming design is shown below (fig. 2):

Figure 2: Conforming design of the widening

- Z66, a hollow box steel girder with external longitudinal prestressing. The steel box partly undercuts the existing cantilever of the bridge and therefore demolition work within the roadway has to be done, in order to place it.
- Z67, additional steel I-girder beside the old bridge which is only after installing the cross bracing's stable. The demolition work on the concrete slab is hindered by this steel I-girder.

2.2   Alternative design

The contractor alternative is based on the following concept:

1. The new steel girders will be placed besides the old bridge with the help of a temporary bridge adjacent. No disturbance of the traffic.
2. The girders should have enough torsional and bending stiffness to be stable by themselves, and easily to be lifted by two mobile cranes.
3. Only the curb will be demolitioned with the steel girder acting as a working platform. No disturbance of the traffic.
4. The formwork load for the widening shall be taken by the new steel girder. The differential deformations will be minimized.

This concept resulted in the following solution (fig. 3) which was chosen by the owner.

Both bridges Z66 and Z67 will receive for the widening a new steel concrete composite girder, with a triangular shape for the steel box and a concrete deck slab. These new girders are connected with the old bridges over a few cross bracing's (every 10m to 12m). These bracing's allow the loading and unloading to be done without bending of the deck slab.
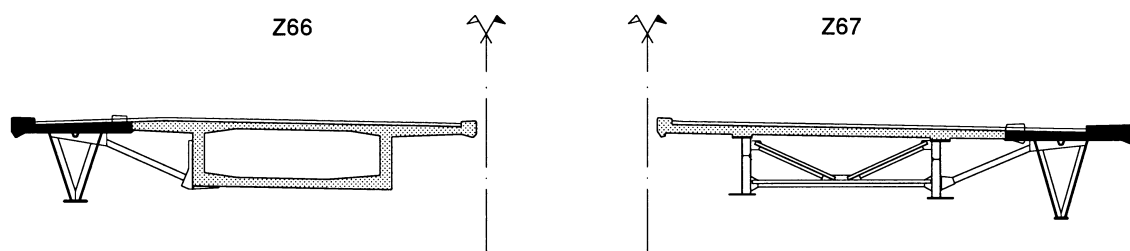

Figure 3: Alternative design

3. Project

3.1 Steel girder

The steel girder has a triangular box section with no bulkheads (fig. 4). The buckling stiffeners are sufficient in the almost closed triangle to obtain enough frame stiffness needed.
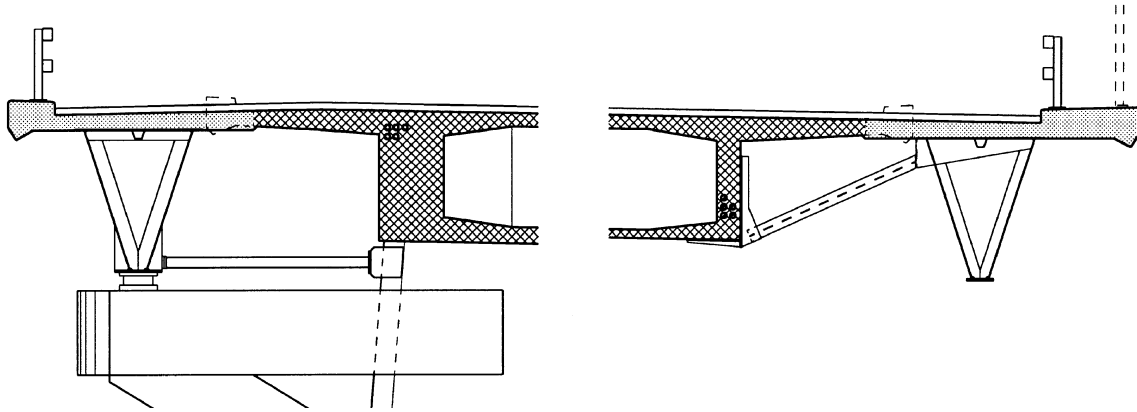

Figure 4: Detail of the cross section

The triangular box section was chosen for the following reasons:

- Erection of the girder: **Stability** of the girder
- Demolition of the curb: Top plate as **working platform**
- Concreting the eccentric deck slab **Torsional stiffness** of the triangular girder
- Formwork Reduction of **formwork** (top steel plate)
- Corbels at the piers: **small lever arm**
- Concrete deck slab: **increased ultimate load**

3.2 Cross bracing

Only very few cross bracing's in midspan are needed.
- There are four at Z66, 12 to 15 m spaced (fig. 5).
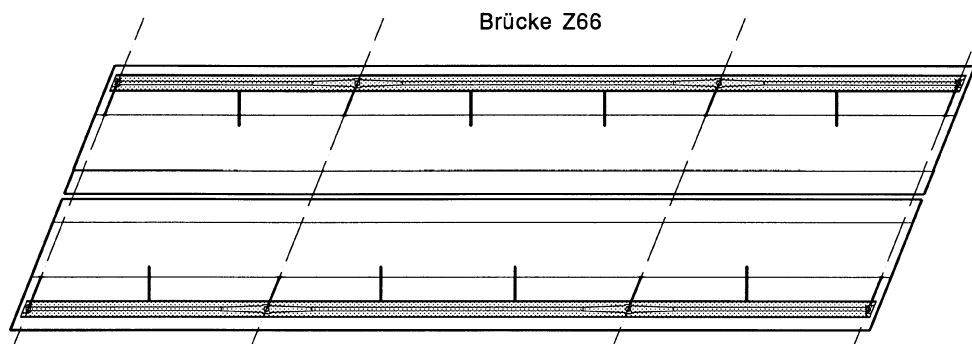
Figure 5: Position of the cross bracing's for Z66

- There are eight at Z67, 11 to 13 m spaced (fig. 6).
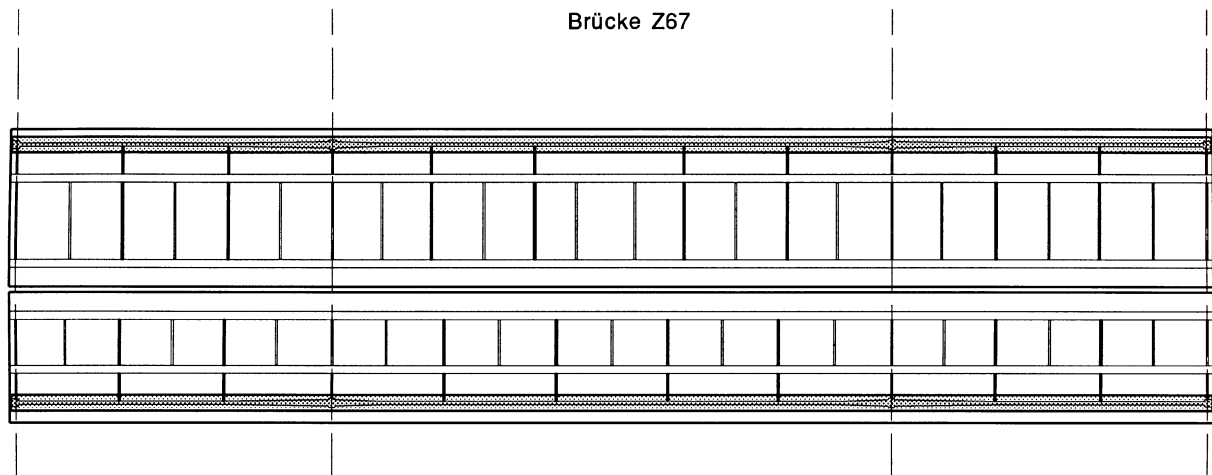
Brücke Z67

Figure 6: Position of the cross bracing's for Z67

This few cross bracing's are sufficient to reduce the differential deformation to practical zero which means no bending in the deck slab. The cross bracing's consist of a steel diagonal and the concrete deck slab as top chord.

3.3   Corbels at the piers

The existing piers and abutments had to be widened to accommodate the new bearings of the steel girders.

The abutments are constructed in the same way as the existing ones and rest on slab foundations. For the piers a solution without construction work in the water was chosen. This corbel solution uses the present capacity of the existing pier foundations.

The capacity of the piers themselves were sufficient. The horizontal force is taken by external prestressing tendons which follow the side of the pier walls and at the same time connect the two single piers. The external prestressing tendons are protected by steel tubes.

Figure 7: New support at the pier

4. Statical calculations

4.1 New girder

The calculations of the continuous girder were based on:

- The girder has to take his own self weight, and in addition he has to take one full lane load according to the code. No load distribution is assumed.
- Increase the stiffness to limit deformations.

The ultimate limit state of the composite section is done n-free after the method EER (elastic-elastic-reduced). The service limit state was verified by superposing the stresses including the secondary order effects. For the sectional forces cracked and uncracked concrete section were considered. The unfavorable of the two values was chosen for the design.

4.2 Cross bracing's

The following calculations were applied:

1. Calculation of a grid with three main girders and linear cross influence line by hand (assumption: cross bracing rigid).
2. For Z67 computer calculations on a grid with beam members (MICROSTRAN 3D).
3. For Z66 calculations with a finite element program MAPS for shells, plates and beams.

The results from the computer calculations are about 40% below the results obtained from the calculations by hand.

4.3 Deck slab

It is always a problem to change the statical system of the cantilever slab to a continuous slab, and especially when the slab is designed and reinforced as a cantilever slab.

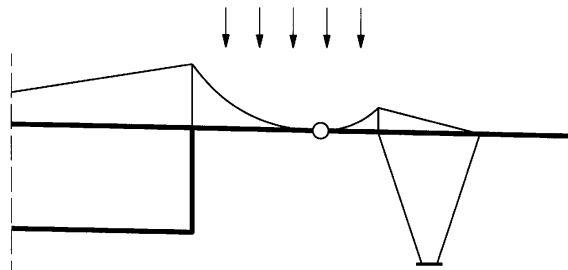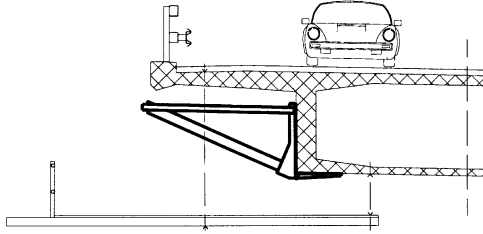For the ultimate limit state the system as shown below was chosen (fig. 8).

Figure 8: Statical system for the deck slab

For the service limit state the stresses in the bottom reinforcement was calculated with the program MAPS.
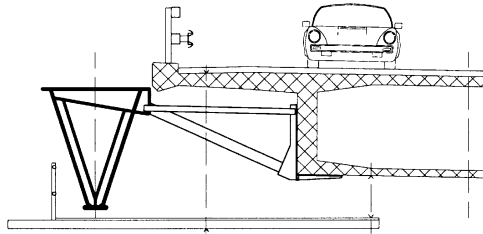
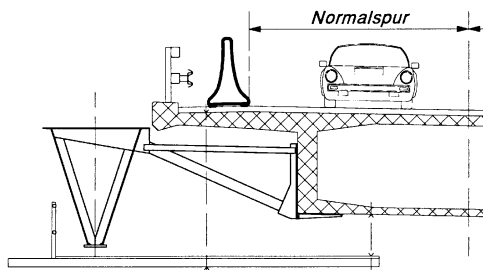# 5. Construction

5.1 Construction phases

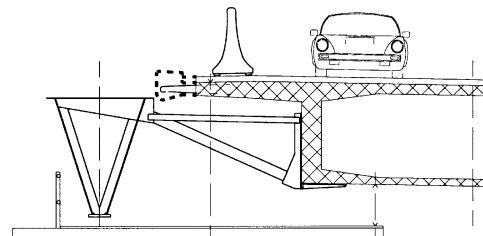**Phase 1:** Install the cross bracing's to the existing bridge.

Phase 2: Install the new steel girder (fig. 9 and 10).

Phase 3: Install concrete barriers on the roadway surface.

Normalspur

**Phase 4:** Demolition of the curb, using the steel girder as working platform

Phase 5: Reinforcing and concreting of the deck slab. The steel girder can move freely vertical to deform independently (only restrained in horizontal direction by the cross bracing).
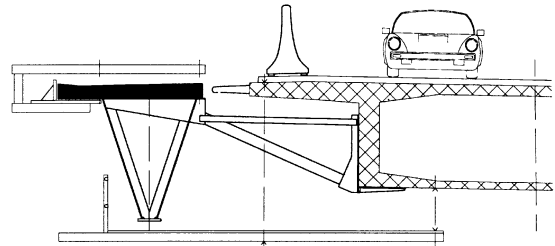
Phase 6: Fixing vertically the cross bracing's to the girder. No differential deformation during concreting of the slab connection. Concreting during the night without any traffic.
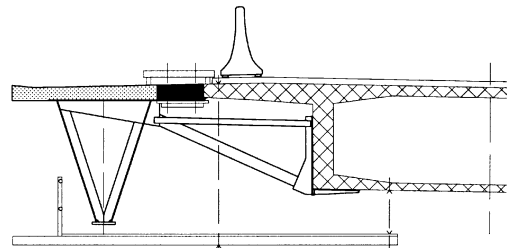
Phase 7: Concreting of the curb and remove of the temporary construction members.
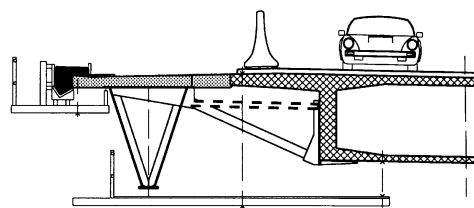
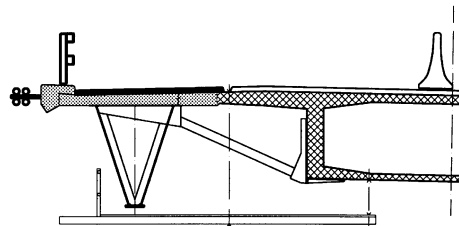**Phase 8:** Install the movement joint and pave the road surface with only one lane traffic.

Figure 9: Positioning of the girder   *Figure 10: Situation*

5.2 Construction cost

The total construction cost including pavement barriers and drainage was for both bridges (Z&& and Z67) SFr 10'260'000.-- . Based on an increased surface area of 7'016m2 the total cost is SFr. 1'462.-- / m2.

6. Acknowledgment