The Baregg bridge near Baden

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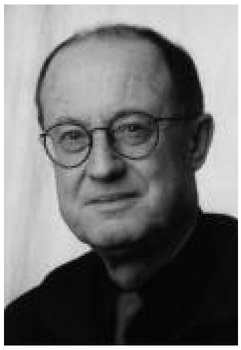

Summary

A design philosophy emphasizing speed of construction, gain of overall cost and aesthetic apearance will be realized in the Baregg Bridge near Baden. It will combine both tubular space truss and precast deck element techniques to obtain a high standard of quality.

Keywords: road bridge, composite bridge, tubular space truss, precast elements,

1. Introduction

The highway A1 between Zurich and Bern has to this day been plagued by heavy traffic and regular traffic jams in the region of Baden. This is due to the joining of highway A3 from Basle with the A1 to Zurich. To improve this situation the Kanton of Aargau is now building a third tunnel at Baregg and the adjoining approaches, which consists of new bridges and ramps. After completion the highway will have 4 lanes in the direction of Zurich and 3 lanes in the direction of Bern. Within the scope of this paper, only the bridge on the north side of the tunnel will be discussed.

Since the construction time (the new tunnel, bridges and ramps) is very critical, a solution was approached which allows for the building of new bridge as quickly as possible so as to use it as a construction ramp to start the new tunnel.

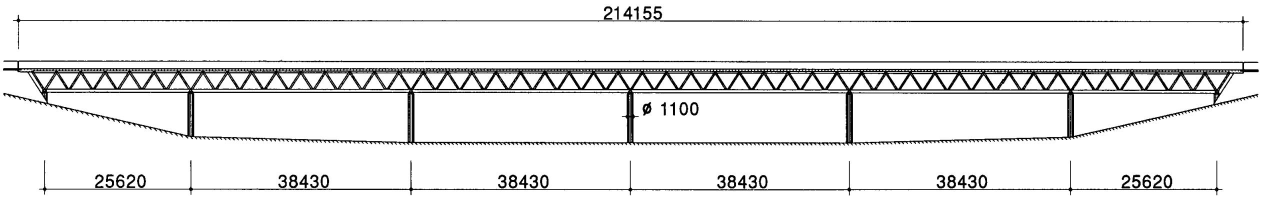

Fig. 1 Elevation of the bridge

2. Design

The viaduct has 6 spans – one 25.62 m at the west end, four 38.43 m main spans, and a 25.62 m span at the east end – for a total length of 204.96 m bearing to bearing (Fig. 1). The bridge deck has a longitudinal slope of 1% and a cross slope of 2.5% with an angle break at the curb lane. The clear roadway width between curbs is 15.5 m consisting of 3 lanes 3.75 m, one curb lane 3.0 m and a banquet of 1.25 m (Fig. 2).

The bridge is constructed from a tubular steel truss, precast concrete deck elements and two cast in situ deck pours at both abutments. The design of the bridge was greatly influenced by the constraint to build the bridge quickly in order to use it as construction ramp for the building of the tunnel.

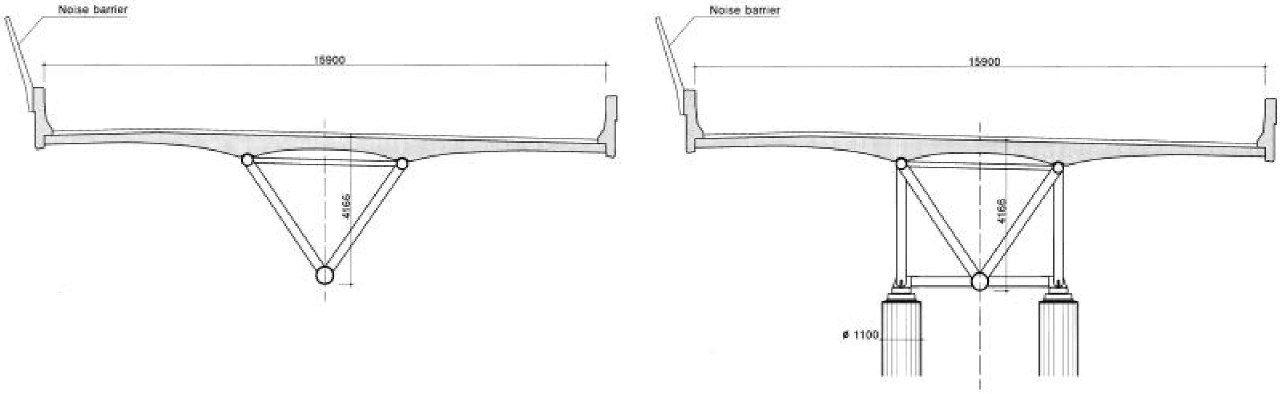

Fig. 2 Typical sections at midspan and over the pier

The tubular steel truss, which has a triangular cross section, is supported by slender reinforced concrete columns 1.1 m in diameter. The columns are designed to take the deformation of the superstructure since there is only a pin connection to the bridge. The fix point of the bridge is on the west abutment.

2.1 Tubular steel truss

The steel truss forms a continuous structure of six spans. The upper chord is made from two tubes of diameter 323.9 mm in diameter with a wall thickness varying from 16 to 36 mm, the lower chord is made from one tube with a diameter 508 mm and a wall thickness varying from 25 to 40 mm. The diagonals are made from tubes with a diameter of 267 mm and a wall thickness varying from 11 to 25 mm (Fig. 3 and 4). All joints are fully penetrated welds. A wind bracing from tubes with a diameter of 101.6 mm and a wall thickness of 11 mm was needed during construction and was left in place.

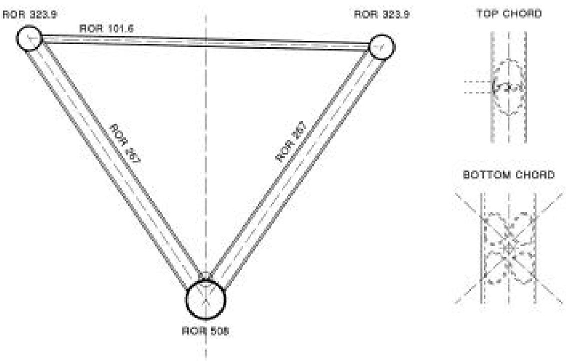

Fig. 3 Node details for top and bottom chord

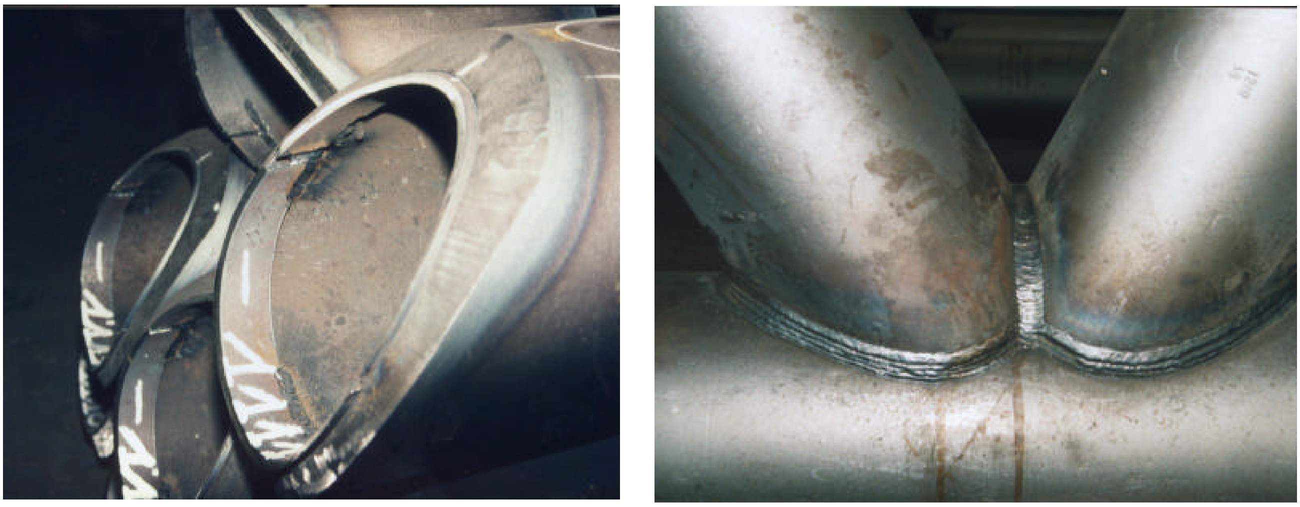

Fig. 4 Fabrication of steel truss

2.2 Precast deck segments

The precast deck segments have a constant cross section and were concentrically posttensioned in the transverse direction (4 strands 0.6” per tendon, spacing approx. 60 cm) for handling, erection and live load. The segments have a width of 15.9 m, length of 2.135 m and a weight of approximately 32 t. The deck is supported by the two upper chords of the steel truss. For handling and erection only 50% of the tendons were stressed. This also resulted in a favorable condition for the creep and shrinkage of the slender cantilever wings spanning 4.9 m. Twenty two ducts from ∅ 86 mm HDPE were placed into each segment in the longitudinal direction (Fig. 5). This void will allow, after completion of the deck, the installation in each duct 7 monostrands 0.6” from one abutment to the other over the full length of the bridge without any coupler.

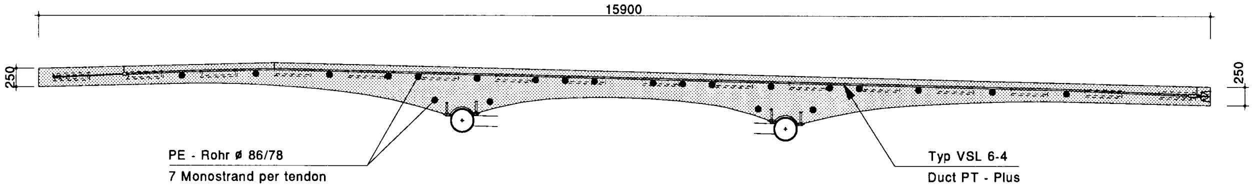

Fig. 5 Tendon layout

At each abutment a portion of the deck 7.8 m long is cast in situ. This allowed the thickening of the deck for the placement of the movement joint and the anchorages of the longitudinal tendons. In addition, no special anchorage segment with difficult geometry was necessary and there are only two segments. A last abutment pour will be needed for the construction tolerances. The longitudinal prestressing consisting of 22 cables with 7 monostrands 0.6” each. It is concentrically over the concrete cross section and the compression stress at time infinity in the element joints under live loads is always guaranteed.

The advantage of the monostrands is, that each strand is protected individually (PE sheeting and anticorrosion grease) and the strand can be removed at a later stage for inspection if any corrosion has occurred, and a new strand can be inserted and stressed (Fig. 6). After stressing the longitudinal tendons and the remaining transverse tendons, the continuity weld between the steel truss and the deck is executed, the void in the space between the steel tube and the deck element will be pressure grouted and the opening at the east abutment will be cast.

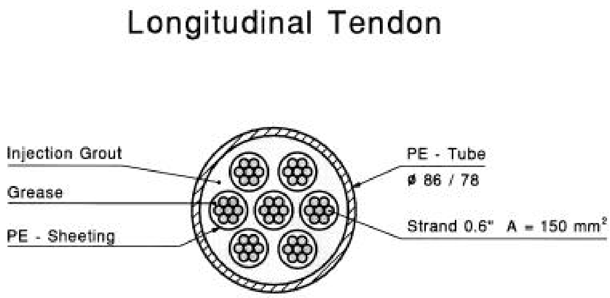

Fig. 6 Longitudinal tendon, 7 monostrands 0.6"

On both cantilever ends, concrete barriers are cast in situ with a length of 11.6 m. After completion the concrete barriers are prestressed with one tendon consisting of 7strands 0.6".

2.3 Connection steel truss concrete deck

The final shear connection between the upper chords of the steel truss and the concrete deck elements was done only after the longitudinal tendons were fully stressed. Since the segments are resting on neoprene pads with a Teflon sliding area against the upper chord they will slide due to the prestressing force. The full prestressing force is applied to the deck and only approximately 3% is diverted into the steel truss due to friction of the sliding pads. Then the continuity weld is added, assuring the behavior of the whole structure under live load as a composite bridge.

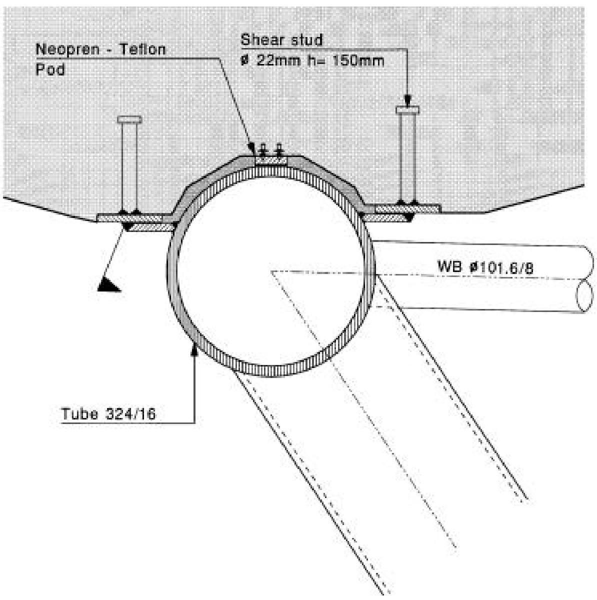

Fig. 7 Continuity weld

3. Static Analysis

The static analysis was completed in the traditional practice using programs for plane or space frame and additionally by FE-shell elements mixed with bars. A space frame modeled the steel truss and the deck was modeled as a beam grid. The girder was fixed to the piers.

Two different structural models were used for the calculation of the space truss:

1. Hinged diagonals with continuous chords for structural safety design
2. Rigid nodes for fatigue and serviceability design

The bridge deck had to be converted into a plane grid model (Vierendeel), made of two longitudinal chord and vertical members placed at the intersection with the diagonals of the space truss.

The structural safety of the members and joints was verified with the internal forces of the hinged model.

No standard recommendations could be found to check fatigue resistance, or an empirical method for computing local stresses at the circular hollow tube intersection, nor a fatigue category considering the backing shell.

The following criteria were adopted after discussion with the owner and the expert engineers

1. Fatigue load according to SIA 160
2. Calculations of internal forces with
   - full and cracked composite section (with $n = E_{steel}/E_{concrete} = 10$)
   - rigid nodes

The problem specific to this bridge lays in the determination of the local stress range at the joints under traffic load. It involves complicated analyses taking into consideration:

- the geometry of the connection
- the diameters of the elements
- the width of the tube

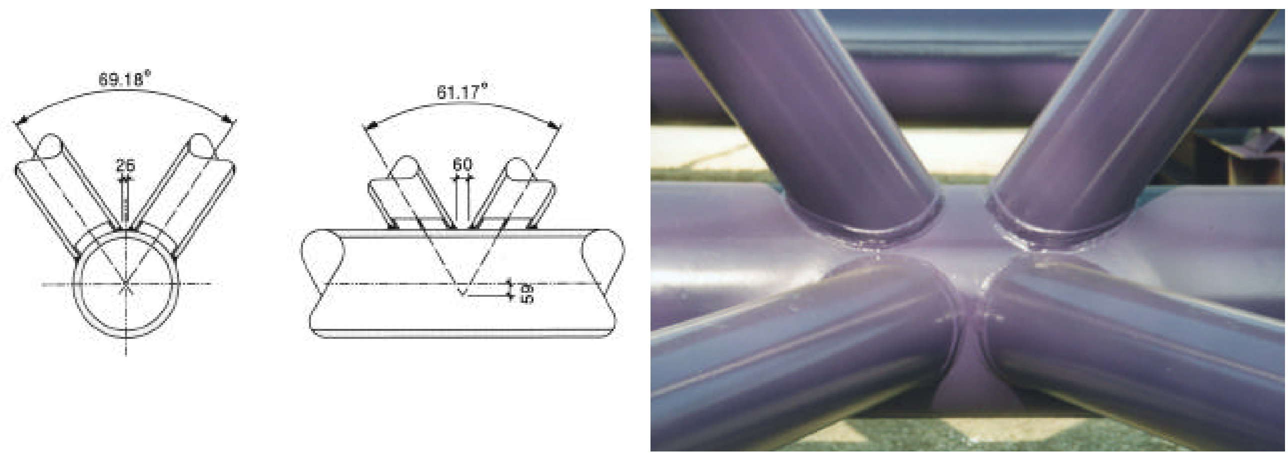

Fig. 8 KK – shaped joint geometry (lower chord)

4. Construction

The combination of fast steel truss erection and precast deck segments resulted in a total bridge construction time, including the foundation, of about 7 months. The construction can be separated into the following phases.

Phase 1
Starting construction of the abutment west followed by the piers and the abutment east. At the same time erection of the steel truss can already start from abutment west without interfering with the concrete work. The steel truss is split into 13 parts with a length of 23.62 m and a weight of up to 35.0 t for construction (Fig. 9). The construction joints are welded on site. With the help of one temporary support tower, the parts will be erected, geometrically adjusted and welded together. The construction time for the steel truss is 6 weeks.

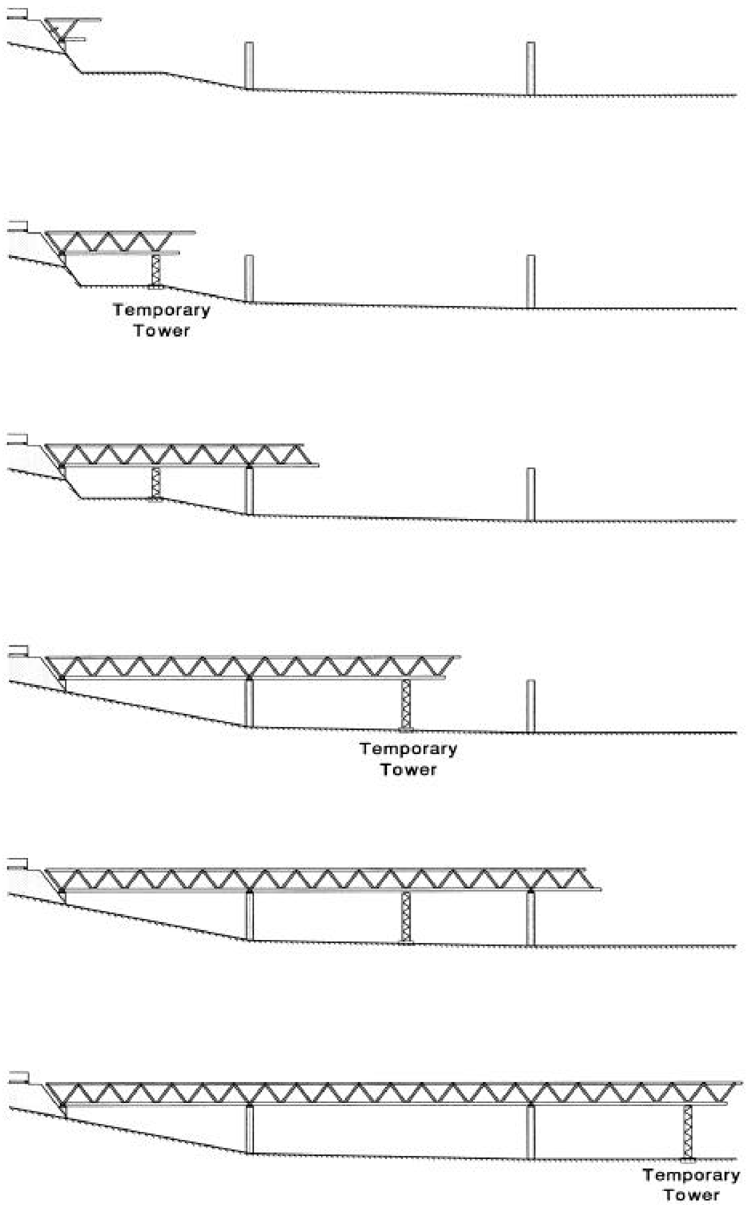

Fig. 9 Steel construction sequence

Phase 2

Placing the first element at the abutment west and pouring the cast in situ portion against it. Placing the elements over a full span for preloading the steel truss. In the meantime, epoxy glue will be applied to one element after the other and stressed against the already erected deck by temporary prestressing tendons using the ducts for the final prestressing tendons. The temporary prestressing assures that the average stress in the segment joint remains below –0.2 N/mm2. After finishing the last span the portion at the abutment is poured.

Phase 3

Installation of the permanent posttensioning tendons consisting of 7 monostrands 0.6” each tendon. The monostrands are bundled together behind the abutment west to form the tendon. Then all the tendons will be pulled into the ducts over the whole length of the bridge of 214.0 m. Stressing the tendons to the required forces from both ends and vaccumgrouting the void between the monostrands and the duct. Weld the 4 continuity welds and vaccumgrout the void between the tubes and the concrete segments and cast the openings at the abutment east.

Phase 4

Install the expansion joints and cast the concrete barriers at both cantilevers with 2 movable scaffolds. Install the noise barrier and finish by washing the steel structure and applying the final coat of paint on the steel truss.

Except for temporary use of falswork support while erecting the steel structure and the falswork for the cast in situ portion near the abutments, no other falswork was needed because the steel truss served as the platform for deck construction.

5. Technical data

Concrete	1'450 m3
Mild steel	170 to
Prestressing steel	43 to
Construction steel	315 to

6. Final comments

The construction time could be reduced by approximate 25 % by using prefabrication for the steel truss and the concrete deck and using the precast segmental technique for erection of the deck. In addition the solution remained very light and aesthetically pleasing as shown in Fig. 10.

7. Acknowledgement

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Fig. 10 Computer rendering of the bridge