Bridge over the Danube in Günzburg

Outstanding arch in the course of federal road B 16

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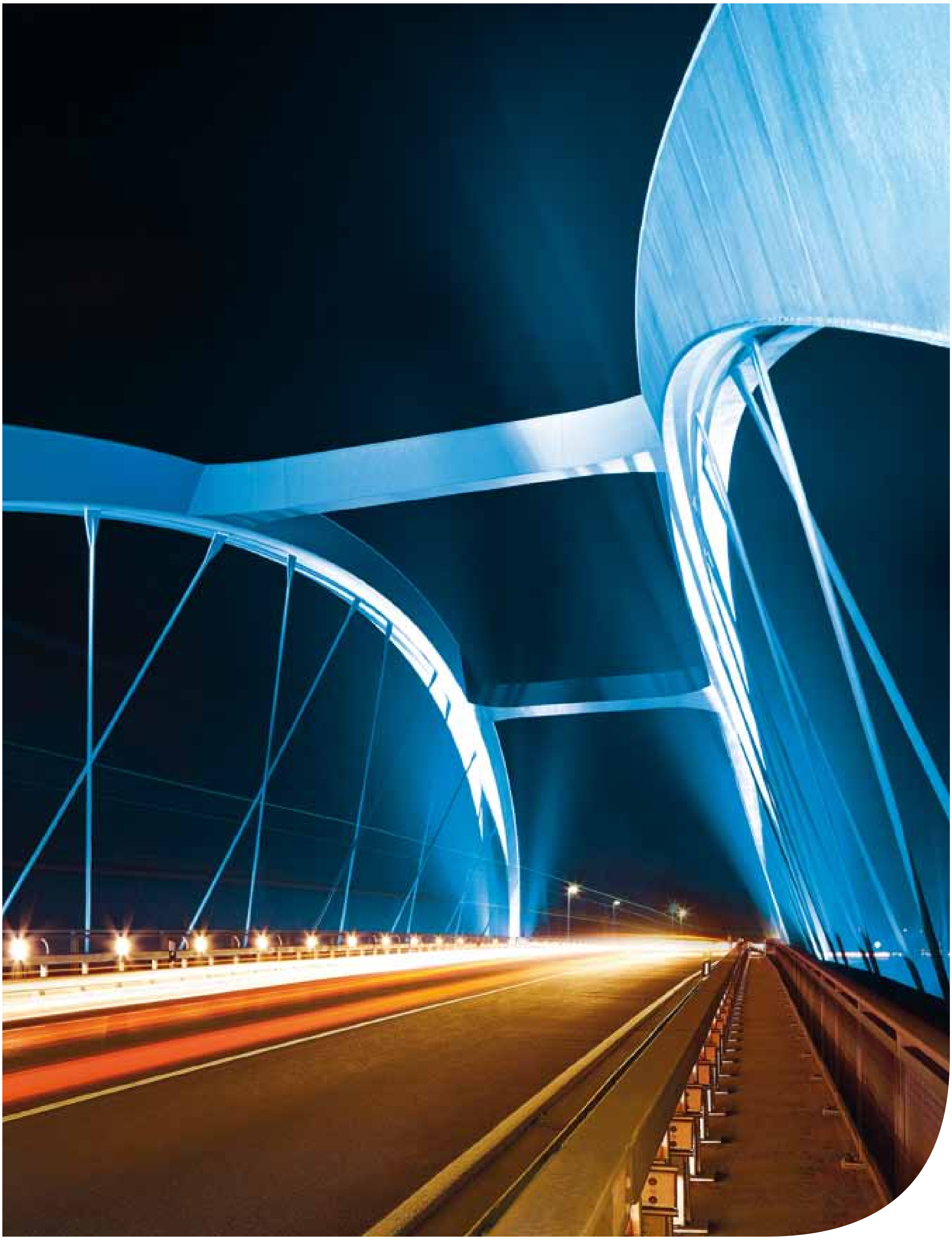
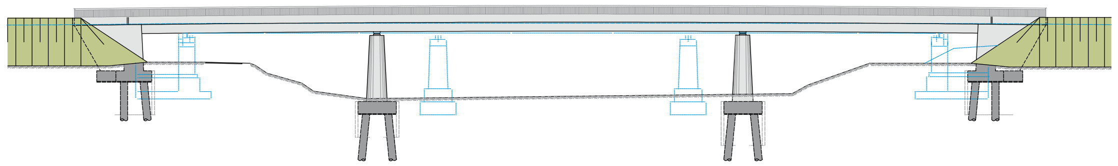
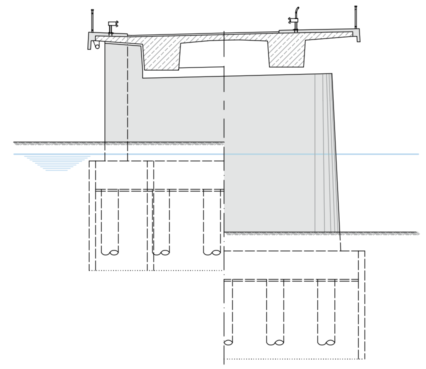


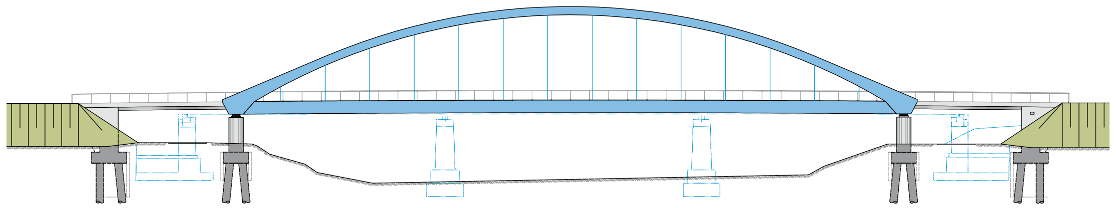
The condition of the old Danube Bridge Günzburg, a steel truss structure from 1948, had deteriorated considerably over the years. The load-bearing capacity did no longer correspond to growing traffic requirements. For this reason, a new construction became necessary after 62 years. Günzburg is situated halfway between the state capitals Stuttgart and Munich as well as between the central cities Ulm and Augsburg directly at motorway A 8. Moreover, federal roads B 10 and B 16 as well as roads St 1168 and St 2020 intersect here.

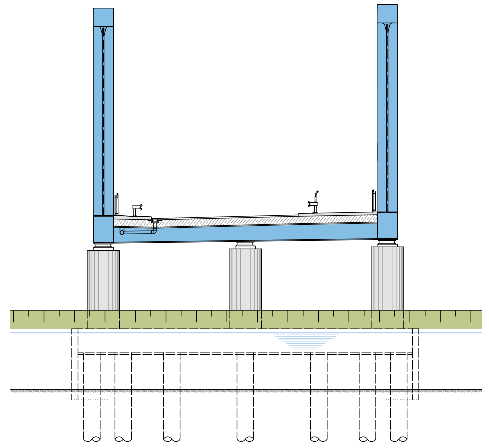
Data and facts	
Client	Construction authority Krumbach
Span widths	13.50 + 83.00 + 13.50 m
Total length	110.00 m
Construction type	Tied-arch bridge as single span girder with two foreland bridges
Construction costs	approx. 4.4 m
SSF services	Project planning: basic evaluation, preliminary and draft design, preparation and evaluation of tenders Structural engineering: preliminary and draft design, approval design and preparation of tenders Design of temporary assembly structures

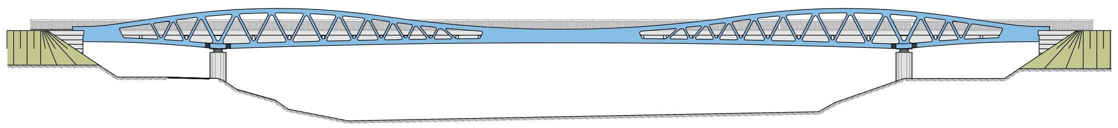
View of finished bridge

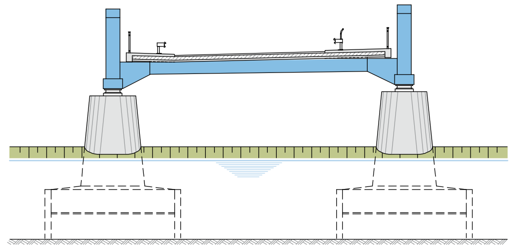


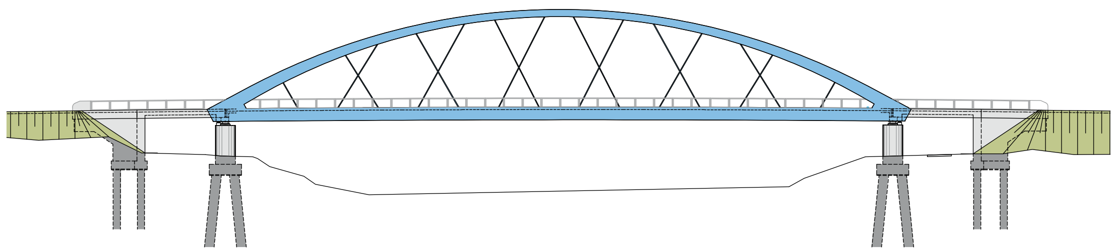


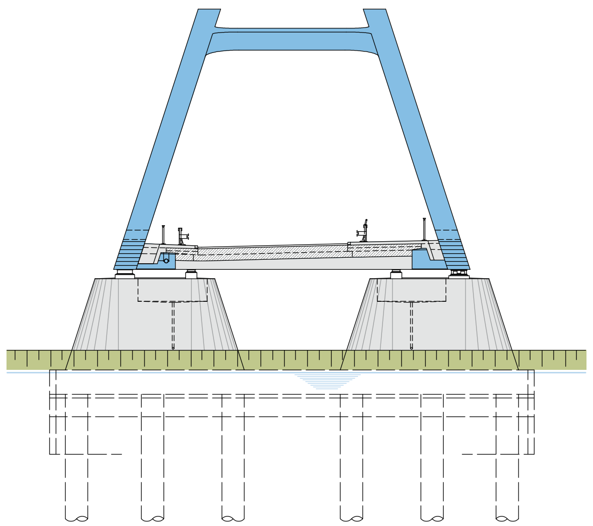












Representations: SSF Ingenieure AG

Variant study

For new construction of the Danube Bridge, in May 2008, a comprehensive variant study was executed, which included:

Variant 1 – Deck bridge

3-span deck bridge with span widths of 30.00 + 45.00 + 30.00 m and a total length of 105.00 m. The cross section is a 2-web T-beam in pre-stressed concrete as well as composite method.

Variant 2 – Arch bridge and foreland structures

Bridge over three spans with span widths of 12.00 + 80.00 + 12.00 m.

Variant 3 – Truss bridge "Danube Wave"

Truss bridge over three spans with span widths of 19.00 + 67.20 + 19.00 m.

Variant 4 – Arch bridge with arch slabs inclined to the inside and foreland structures

Bridge over three spans with span widths of 10.50 + 83.00 + 10.50 m.

Comparison of the variants

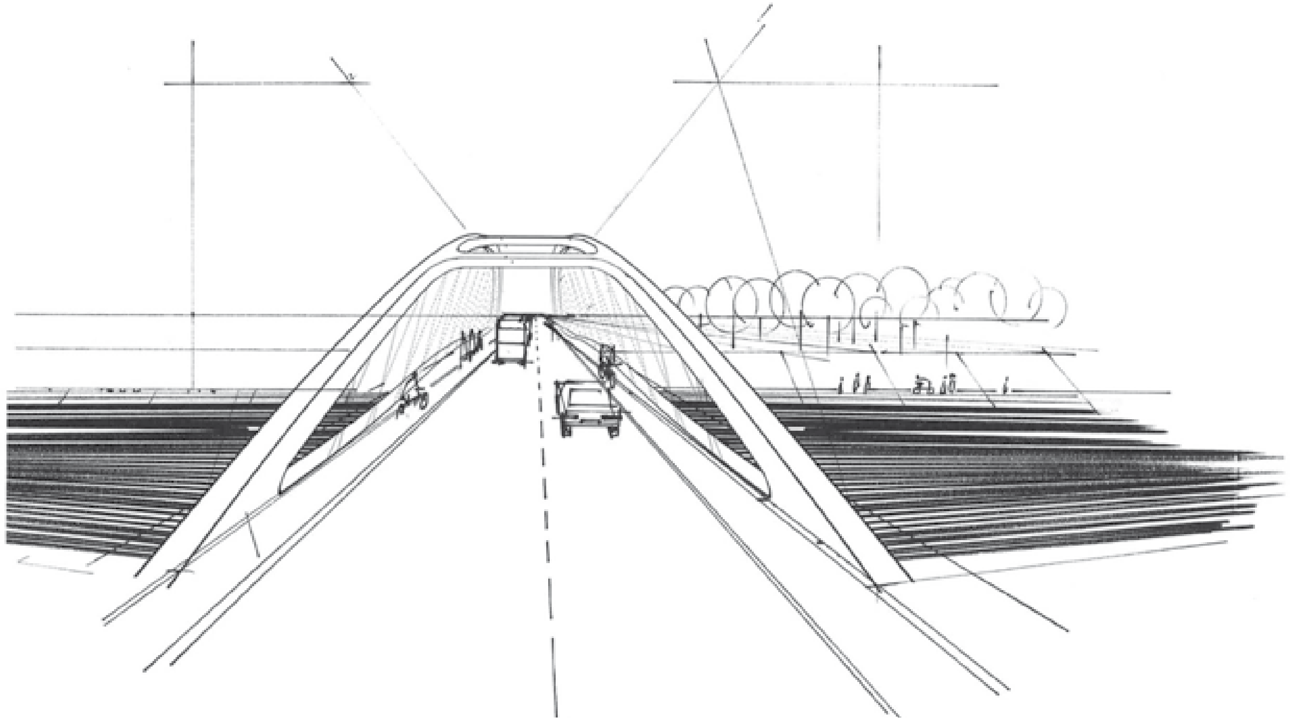
Design

Variant 1 (conventional deck bridge) does not fulfil the required design criteria sufficiently. The intended recognition factor is missing. Variant 2 (arch bridge with foreland structures) provides a prominent sign by the chosen construction type of a tied-arch, the open structure with the straight arch slabs and hangers however does not convey an exceptional visual experience to the viewer. Variant 3 ("Danube Wave") is most significant when viewed from the side. Due to the location of the planned bridge, it is not shown to its fullest advantage. The inwards inclined arch slabs connected one below the other of variant 4 create a gate effect for the viewer and have a high recognition factor. The crossing hangers increase the aesthetic and dynamic effect.

The abutments are clearly accentuated; lateral breast walls in the wings' areas create a well-balanced appearance.

Perspective drawing from the draft phase
Visualisation with gate effect

Drawing: Lang Hugger Rampp GmbH Architekten



Visualisation: edundsepp

Economic efficiency, maintenance

The unclear structure of the ground relativizes considerably the cost advantage provided by the construction type (T-beam) of variant 1. The studies of variants 2, 3 and 4 showed pertinent advantages, as there are no piles in the cross sectional area of the Danube's discharge where scour is to be expected. The existing piles in this area had already to be regularly protected against scour and to be renovated. For a new construction, this would have meant an intolerably high renovation effort.

Decision

After consideration of the criteria design, economic efficiency and maintenance effort, variant 4, the arch bridge with inward inclined arch slabs, crossing hangers and two foreland bridges, was selected as preferential variant to be further elaborated. The town of Günzburg welcomed explicitly the selection of this variant as a new central gate in the north of the town. The alternative was then confirmed after examination by the water authority WWA Donauwörth.

Design

Temporary traffic diversion during construction

It was not possible to divert the traffic on federal road B16, with around 15,000 vehicles per day, via the town centre of Günzburg. During construction, traffic was then diverted on a temporary road arranged upstream of the bridge. The old bridge's superstructures shifted to temporary substructures formed this makeshift bridge.

Design of the bridge and load-bearing structure

The prevailing design element was the tied arches. The arch slabs were inclined towards each other and connected to one other in the upper area by cross girders to create a gate effect. The radius from the hanger to the arch's upper edge is 13.50 m. The structure is divided into one large span above the river with a span width of 83.00 m and two spans at the edges with 10.50 m span width each. The abutments are set back to create a spacious clearance for the ways underneath the bridge.

The two tied arches made of steel and stiffening girders on the side of the carriageway slab form the load-bearing structure of the main bridge. The arch supports the stiffening girders by crossing hangers arranged at regular distances. Arch and stiffening girders form one coherent structural system in longitudinal direction of the bridge so that the abutments do not have to distribute horizontal forces caused by the arch's shear. In transverse direction, the two inward inclined arch slabs are stabilised by two cross girders. These girders, set at distances of 5.0m at the level of the stiffening girders, hold primarily the carriageway slab. The reinforced concrete composite carriageway slab consists of 0.09m thick prefabricated elements made of reinforced concrete between the cross girders and a 0.26m thick cast in-situ supplement. The cast in-situ concrete is continuously connected by shear studs to the stiffening girders as well as the cross girders.

The arrangement of the hangers is essentially based on aesthetic and structural requirements. The crossing of the hangers creates an additional stiffening effect of the load-bearing structure.

The rampant reinforced concrete frames of the foreland bridges are placed on the piles together with the main bridge. It was necessary to arrange the 0.50 m thick reinforced concrete slabs of the superstructures between the arch slabs and to set both final cross girders of the tied arch eccentrically outside of the bearing axes.

Structural elements steel construction

Arches	Single-cell hollow boxes, parallelogram-like geometry in the cross section corresponding to the arch's incline; height of boxes vertically variable between 0.90 m and 1.60 m, increasing in direction of arch bearings; width of lower chords 1.20 m
Stiffening girders	Single-cell hollow boxes, parallelogram-like geometry in the cross section corresponding to the arch's incline; height of boxes vertical 1.60m; width of lower chords 1.20 m.
Regular cross girders carriageway slab	Double T profile with variable heights corresponding to the transversal incline of the carriageway slab (horizontal bottom view), h = 0.75 m ... 1.00 m.
Final cross girder carriageway slab	Box girder with variable height corresponding to the transversal incline of the carriageway slab (horizontal bottom view), h = 0.75 m ... 1.00 m.
Cross girders arches	Arrangement at the third points of the arch, steel boxes at same height as the arches, width 1.00 m; rounded at the connections to the arches.
Hangers	⌀ 90 mm, crossing arrangement, two levels, prestressed.


Image: Florian Schreiber Fotografie / SSF Ingenieure AG

View of piles – joint bearing point of foreland bridge and main bridge

Design process

After preliminary design in 2008, the project was put on hold and integrated into the economic programme in spring 2009. Within 3 month, until July 2009, the design had to be presented to the supreme construction authority. Thanks to a very constructive dialogue between the supreme construction authority, the local construction authority and the design team, the design was approved for execution within 2 month. Preparation of tenders including the elaboration of tender documents took place simultaneously. Already at the end of October, contracts for the construction project (engineering structures and traffic installations) were awarded. Due to the aesthetic requirements to the bridge and to the schedule, the client decided early on to directly charge SSF Ingenieure with the final structural analysis. The aim was to provide a confirmed structural analysis with construction drawings by the time tender documents were completed. This aim was achieved especially thanks to a constructive and collegial cooperation with the inspection engineer.

The whole design process was flawless, aim-oriented because of the very good cooperation of all participants and lead to a positive result; this is well worth mentioning in the tense atmosphere between client, designer and construction company.

Finished bridge with regular cross section

Particularities of the load-bearing structures

In addition to the visual highlight, the crossing hangers are also a structural particularity. They lead to a stiffening of the arch slabs in vertical direction and at the arch's level. Similar to a network arch, they form a sort of shear field at the arch's level and the load-bearing behaviour of the arch comes close to the one of a solid web girder. Inclined hangers are more susceptible to vibrations than vertical hangers, especially to rain-wind induced vibrations. When it rains, the incline causes a rivulet at the lower edge of the hanger, which in case of wind at the same time leads to an unsymmetrical onflow surface provoking transversal vibrations. The German standard DIN-Fachbericht offers an alternate procedure for verification of hanger vibrations. However, only a more precise dynamic calculation could confirm the desired results. Additional measures such as vibration dampeners or profiled corrosion protection were not required. Similar to a truss, hangers that are arranged parallel to the incline of the corresponding line of moments are always exposed to tensile forces. Accordingly, hangers that run vertical to them are subjected to compressive forces. These hangers had to be pre-stressed during assembly.

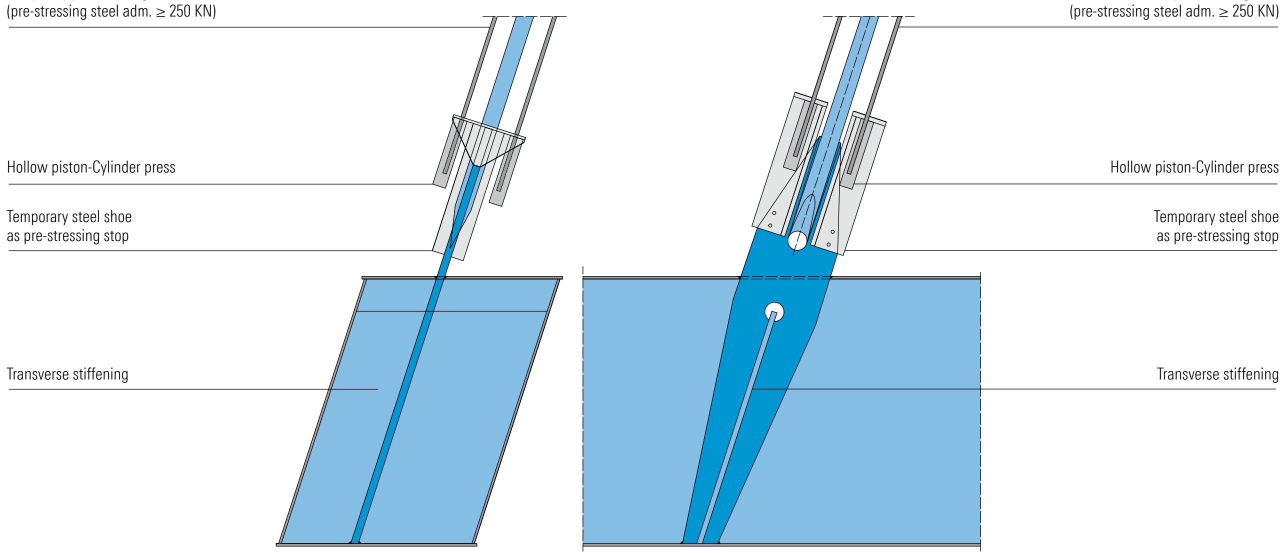
A steel shoe was used to pre-stress the hangers; this shoe was mounted to the gusset plates of the hangers. The calculated pre-stressing force was applied in the steel shoe by force-regulated presses; the hangers were inserted and welded.

Assembly of hangers was executed in three sections

- Assembly of non pre-stressed hangers
- Concreting of carriageway slab
- Assembly of remaining hangers with pre-stress

Images: Florian Schreiber Fotografie / SSF Ingenieure AG

1



1 Representation of pre-stressing device
2 Detail of steel shoe with pre-stressing rods
3 Detailed view of a hanger
4 Detailed view of hanger arrangement in the final area of the tied arch

Construction process

The bridge was built in three construction stages: construction start in 2009

Stage 1 – Setting up of temporary traffic diversion

For the required temporary diversion, the existing truss bridge was shifted by around 19.00 m in western direction onto newly built provisional substructures. The access road was added and traffic directed to this makeshift diversion. The truss bridge underwent an inspection beforehand. After coordination with the inspecting engineer, the result showed that the superstructure could bear the loads from launching and traffic during the construction period without major renovation measures. This solution was much more economic than the planned use of a makeshift bridge device, which would have caused costs for installation and removal, rent and surveillance during construction.

1 Cross section existing piles with added launching track
2 View of added launching track
3 Top view of added launching track with anchoring structure

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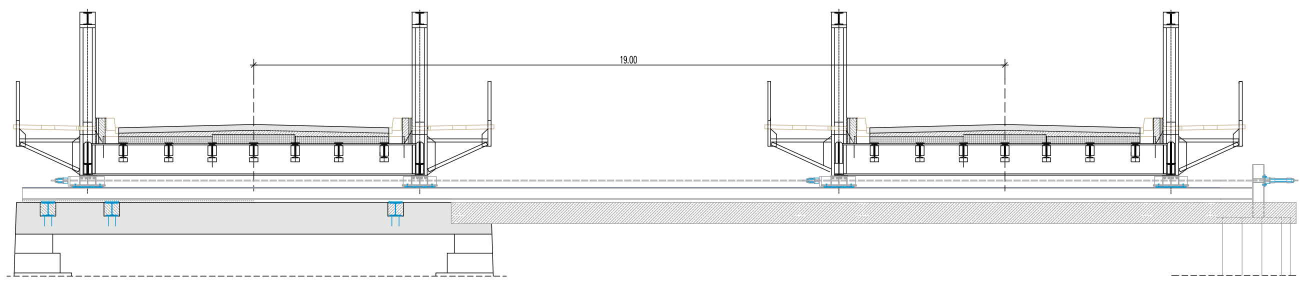

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3

Images: SSF Ingenieure AG

Stage 2 – Construction of the new bridge

After demolition of the existing abutments, the new substructures were erected. The pile caps were built within drained sheet pile boxes. The tied arch was mounted by cranes above the Danube. The existing piles in the river, together with the added launching tracks, were used as support yokes for steel construction. Once the steel structure was finished, the formwork of the carriageway slab was fitted and concreted. Then the road situation was adapted and traffic diverted to the new bridge.

1-3 Assembly of support yokes
4 Assembly of tied arch

1

2

3

4

Stage 3 – Dismounting of temporary diversion and demolition of old bridge

The existing truss bridge was dismounted conventionally by separating the lattice girders above the river piles and lifting the individual elements by auto-crane. The old river piles and all other installations were then removed from the Danube. Finishing works at the flood banks and embankments were completed in spring 2011. The period for construction of the whole bridge, whilst traffic was almost completely maintained, and including all temporary constructions, amounted to 16 months.

Top left: View of the completed bridge from northeast
Bottom left: Bottom view of the steel structure
Bottom right: Gate effect of the finished bridge

Images: Florian Schreiber Fotografie / SSF Ingenieure AG

Lighting concept

The bridge is effectively illuminated by energy-efficient LED technology: 16 spotlights in the bottom areas of the steel arches create different light scenarios. The standard programme has nine different colours of which each one lights up for five minutes and changes smoothly to the next colour.
With the lighting concept, the client intends to make the central northern entrance to the town a remarkable point of identification by using artistically designed lighting, and at the same time to highlight the aesthetic quality of the bridge over the Danube.

Project participants	
Client	Construction authority Krumbach
Construction company	Matthäus Schmid Bauunternehmen GmbH & Co.KG, Baltringen
Steel construction	Bitschnau GmbH, Nenzing, Austria
Engineering structures	SSF Ingenieure AG
Visualisation, consulting	Lang Hugger Rampp GmbH Architekten
Inspecting engineer	Dr.-Ing. Robert Hertle/Ingenieurbüro für Bauwesen

Right: View of finished bridge from southwest
Bottom: View of illuminated bridge

Ingenieurpreis des Deutschen Stahlbaues 2013

Engineering Prize 2013 of the association Deutscher Stahlbau in the category bridge construction

Images: Florian Schreiber Fotografie / SSF Ingenieure AG

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