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Building bridges using the balanced lift method

This article explains the process of developing a new method, called the balanced lift method, for constructing bridges based on an alternative to the bridge construction techniques used nowadays. The most common methods of building bridges are those using falsework or the cantilever method, but a rather uncommon method, the lowering of arches is seen as the origin of the balanced lift method. The idea was to create a method that would allow a bridge to be built in a very fast manner without the need for falsework, using prefabricated elements and assembling all parts together in a position – in this case vertically – that would simplify the construction process. In order to reach the final state of the bridge, the parts assembled vertically are rotated into their final horizontal position. This article contains descriptions of the development of the method, a large-scale test and two bridges already designed using the balanced lift method.

Keywords: precast concrete elements, post-tensioning, bridge construction method, large-scale test

1 Introduction

When comparing construction methods for arch bridges and regular beam-type bridges, it can be observed that in some cases the same construction techniques are used for the production of the arch and the bridge girder. For example, in situations when the height above ground and the size of the arch are not too large, the most economical construction will be the one using falsework.

Fig. 1 shows the falsework used to support the concrete during casting of the arch for the Egg-Graben Bridge. This bridge was designed at Vienna University of Technology with the idea of creating a bridge without mild steel reinforcement in the bridge deck. Post-tensioning tendons encapsulated in plastic ducts and watertight anchorages were used to provide a sound deck slab with a depth of 500 mm. It could be shown [1] that this new design approach could fulfil the serviceability and ultimate limit load states according to the Eurocode [2].

Egg-Graben Bridge (Fig. 2) was a winning structure in the 2014 competition for the *fib* Awards for Outstanding Concrete Structures. In the words of the jury [3]: “The jury



Fig. 1. Falsework for the arch of the Egg-Graben Bridge



Fig. 2. Egg-Graben Bridge (photo credit: Pez Hejduk, Austria)

highly appreciated the consistent application of durability philosophy. The bridge deck is intended to have a long service life with very low maintenance costs because the bridge deck is constructed exclusively with encapsulated post-tensioned reinforcement and watertight anchorages. No other reinforcement is used. Therefore, the electrolytic

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Fig. 3. Hoover Dam Bypass (photo credit: *Jamey Stillings* Photography, USA)

corrosion in the deck is ruled out. In this way waterproofing and pavement were also saved. The concrete itself is meant to resist both physical and environmental loads. The bridge also fulfils high aesthetic expectations.”

Another construction method frequently used for the erection of concrete arches is the cantilever method. The bending moments due to the dead load of the concrete during construction are reduced by using stay cables. The forces in the stay cables can be adjusted for the different construction stages in order to keep the bending moments in the cantilever small. A spectacular example of the application of the cantilever method for arch construction is the Hoover Dam Bypass (Fig. 3). The jury of the 2014 *fib* Awards for Outstanding Concrete Structures [3] made the following statement about this bridge: “As a result of excellent engineering, the Hoover Dam Bypass bridges the Colorado River at 275 m above the water level. The Hoover Dam Bypass is a breathtaking example of civil engineering in the deep canyon of the Colorado River and its rocky cliffs.”

Yet another method for building concrete arches starts with the vertical construction of the arch halves using climbing formwork. There is a hinge at the very bottom of each vertical arch half which enables rotation of the arch half from the initial vertical to the final inclined position. Contrary to the cantilever construction method, where usually several stay cables are fixed to each arch half during construction, only one pair of stays can be attached at one location to an arch half when the method of lowering of arch halves is used so that the structure is statically determinate during the delicate lowering operation. Therefore, compared with the cantilever construction method, larger bending moments occur in the arch when the method of lowering arch halves is employed.

The lowering of arch halves was first used by *Riccardo Morandi* in the construction of the Lussia Bridge in Italy in 1955, as described by *Troyano* [4]. The advantage of this method is the accelerated construction of the arch, which can be done quicker in the vertical position using climbing formwork than in an inclined position using formwork for cantilever construction. Nowadays, the



Fig. 4. Arnoia Bridge in Spain built using the method of lowering arches (photo credit: *VSL Heavy Lifting*, Switzerland)

Table 1. Comparison of construction methods for arches and bridge girders

Arches	Bridge girders
Erection on falsework	Erection on falsework
Cantilever construction method	Balanced cantilever method
Lowering of arch halves	Balanced lift method

method of lowering of arches is regularly used for bridges in Japan [5] and Spain [6]. Fig. 4 shows a picture of the lowering process of an arch half during the construction of the Arnoia Bridge in 2012. Each of the two arch halves was approx. 70 m long and weighed 11000 kN. A tension force of 1100 kN was required to move the arch half from the vertical position to an inclined starting position for the lowering process. Cable elongation during the lowering of each arch half was 33 m and the maximum force in each of the two tendons was 2400 kN.

The comparison of construction methods for arches and bridge girders shown in Table 1 reveals that there are counterparts for construction on falsework and cantilever construction. However, no method with vertical production of the bridge girder has been proposed previously. The idea for the balanced lift method was conceived when a construction method was sought which starts with vertical production of the bridge girders as a counterpart to the method of lowering arch halves. The balanced lift method is a new construction method – a statement is proved by the patents granted in Germany (DE 102006039551), the USA (US 7996944), Russia (RU 2436890), Canada (CA 2661311), China (CN 101535571) and Australia (AU 2007288151). Patents for India, Japan and Europe have been filed.

2 Bridge over River Salzach in Golling

The main advantages of the balanced lift method are that the use of precast elements and compression struts to reduce the spans of the bridge speeds up construction. A quick way of describing this bridge-building method is to

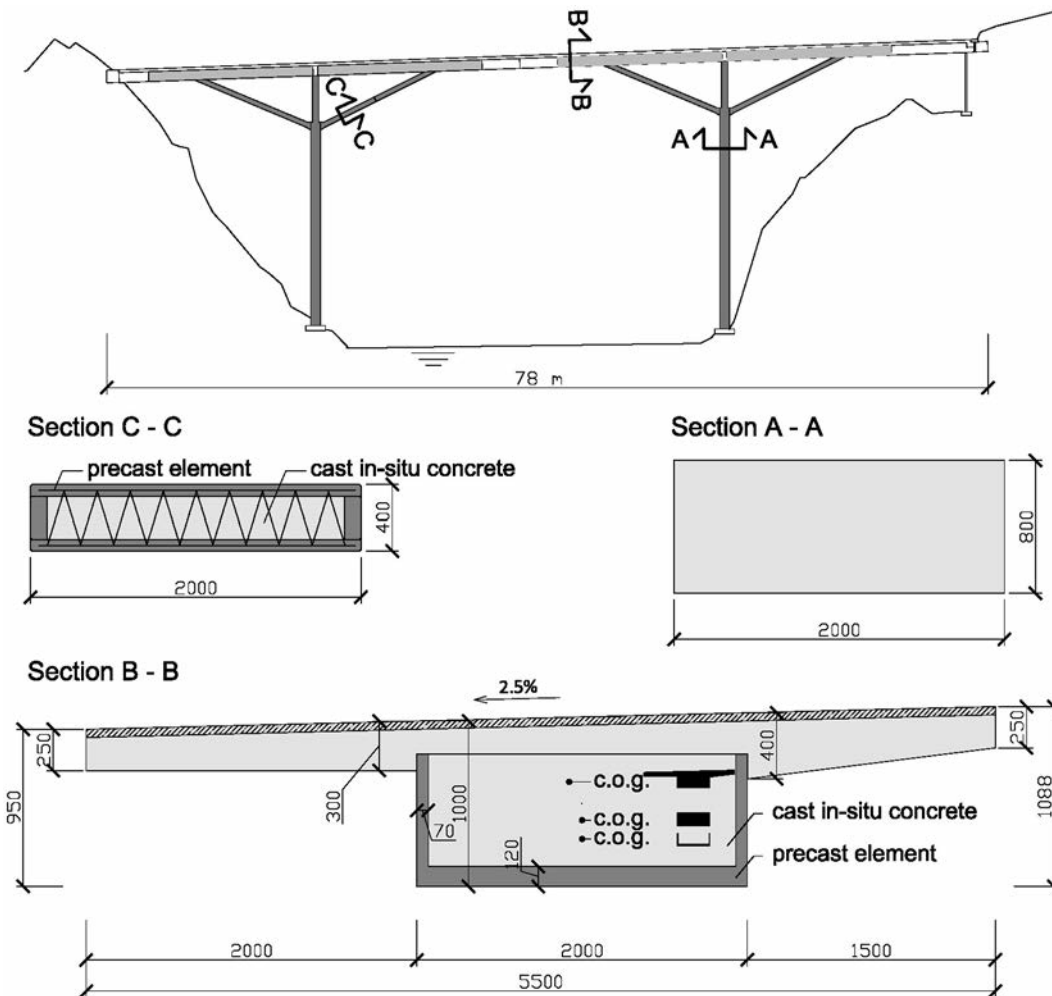


Fig. 5. Elevation of and sections through Salzach Bridge in Golling, Austria

compare it with the process of opening an umbrella – with the bridge girders being the ribs and the compression struts being the stretchers. The method was primarily invented for bridges over deep valleys, i.e. bridges with tall piers, but can – with minor changes – be used for bridges with shorter piers, as will be shown in section 3 of this paper.

In 2013 a bridge over the River Salzach in Golling was designed using the balanced lift method. The client was looking for an innovative design for a bridge since the existing composite bridge will be demolished in near future.

Fig. 5 shows the elevation of the bridge with a total length of 78 m and a central span of 33 m. In order to span the River Salzach, the bridge design makes use of two balanced lift structures, which are indicated in dark grey in Fig. 5. The two piers, with heights of approx. 20 and 22 m, are located on the banks of the river close to the foundations of the old bridge. It is planned to construct the piers with a solid cross-section of 0.8 × 2.0 m using climbing formwork (Fig. 5, section A-A). The width of the section is reduced to 0.5 m in the top part of the pier. The compression struts and the bridge girders were designed as thin-walled prefabricated elements in order to keep the weight of the elements down for the erection and lifting operations.

The compression struts consist of double walls, which are frequently used for building walls in buildings. The double-wall elements, with a length of approx. 13.2 m, have a wall thickness of only 70 mm. Side walls with a thickness of 100 mm are fabricated in the precasting plant in order to obtain a box section that can be filled in situ concrete at a later construction stage (Fig. 5, section C-C).

The side walls of the bridge girder consist of 70 mm thick prefabricated elements. These elements are very popular in the fabrication of concrete slabs because the expenditure for formwork can be saved. For the production of the bridge girders, the 70 mm thick elements with a depth of 800 mm and length of 12 m are placed on a steel casting bed and fixed in a vertical position. When a 120 mm deep bottom slab is cast between the wall elements, a lightweight bridge girder with a U-shaped cross-section is obtained – shown in section B-B of Fig. 5. It can be seen in section B-B that the centre of gravity of the cross-section changes from a low position for the U-shaped prefabricated element to the centre of gravity for the rectangle obtained when the prefabricated bridge girder is filled with concrete. The centre of gravity of the bridge girder shifts again once the deck slab is added.

The construction sequence of the prefabricated elements is shown in Fig. 6. In the first step the compression

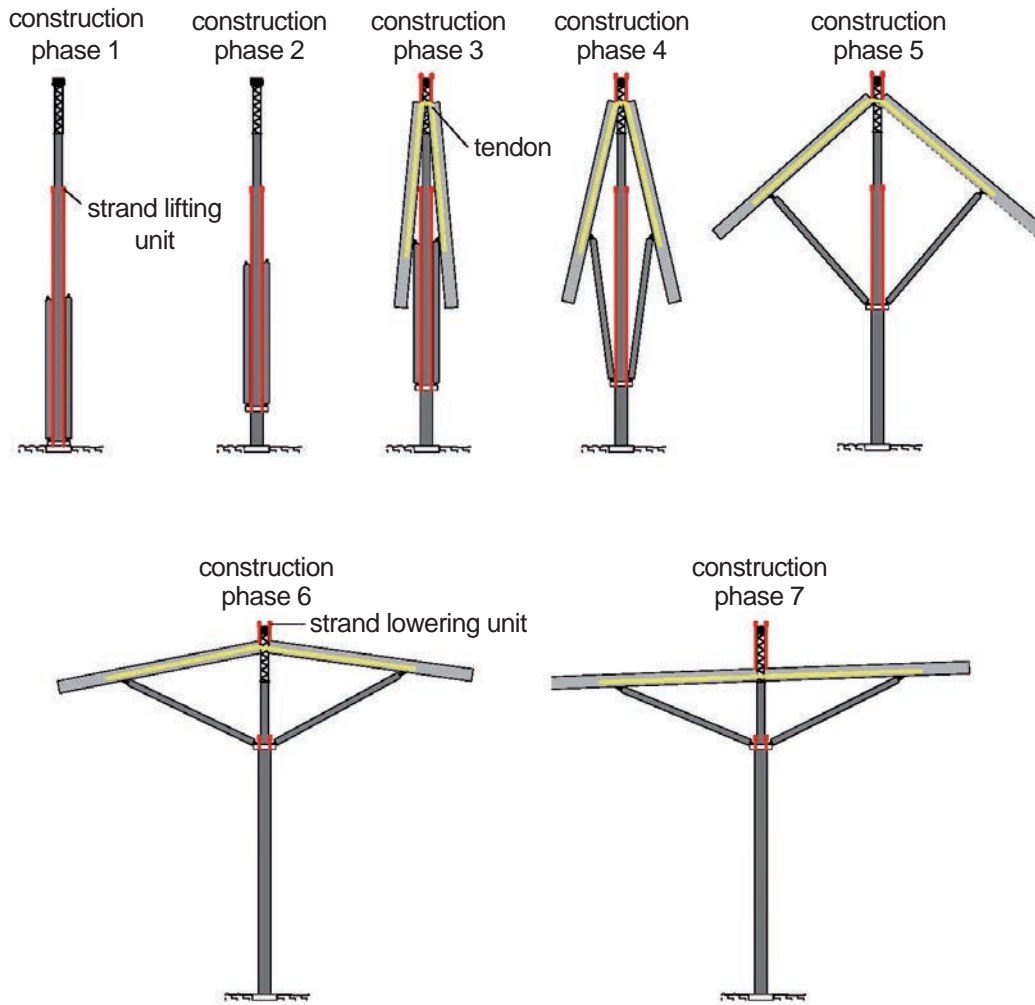


Fig. 6. Construction phases for Salzach Bridge

struts, with a weight of approx. 100 kN per element, are lifted by a tower crane and fixed to a steel frame with bolts. The next construction phase consists of lifting the steel frame and the two compression struts by a few metres with the aid of four strand lifting units (highlighted in red in Fig. 6). In the third step the bridge girders with a U-shaped cross-section and a weight of approx. 120 kN per element are lifted and connected to the upper end points of the compression struts. Strands are attached to the top ends of the bridge girders and connected to strand lowering units (highlighted in red in Fig. 6) at the tip of the auxiliary pier. The two bridge girders are connected by a tendon consisting of four monostrands (shown in yellow in phase 3 of Fig. 6). This tendon has to carry the tensile force that develops during rotation of the bridge girders. The lifting of the lower points of the compression struts leads to a rotation of the bridge girders in phases 4 and 5.

Small auxiliary piers with a height of 4 m need to be fixed at the top of the concrete piers in order to ensure that the end parts of the bridge girders do not touch the rocky cliffs of the Salzach valley during the lifting process. Once the base points of the compression struts have reached the desired height (phase 6 in Fig. 6), the end points of the bridge girders are lowered by 3 m in phase 7 to reach their final position.

After adjusting the position of the elements forming the bridge structure (phase 7 in Fig. 6), which can be done with the aid of the strand lifting or lowering units and by stressing the tension member connecting the bridge girders, in situ concrete is placed in the joints and the compression struts. Construction phases 1 to 7 shown in Fig. 6 then have to be carried out for the second pier. In the next step, the missing parts of the bridge girder, which also consist of prefabricated U-shaped elements, are erected, the longitudinal post-tensioning tendons are stressed and the bridge girder is filled with layers of concrete.

Finally, a deck slab is added to complete the structure. Similar to the design of the deck slab for Egg-Graben Bridge [1] the longitudinal tendons are planned with plastic ducts and encapsulated anchorages. As the deck slab is only 5.5 m wide, no transverse post-tensioning is installed. Therefore, stainless steel is used for the reinforcement in the transverse direction of the deck slab. A 70 mm layer of concrete with the properties required for a road wearing surface is placed “wet in wet” once the deck slab has been cast.

Although the construction of the bridge starts with quite fragile elements, a monolithic concrete bridge with solid cross-sections is obtained in the end. Admittedly, the design for this bridge is at the lower end of the span range for a meaningful application of the balanced lift method.

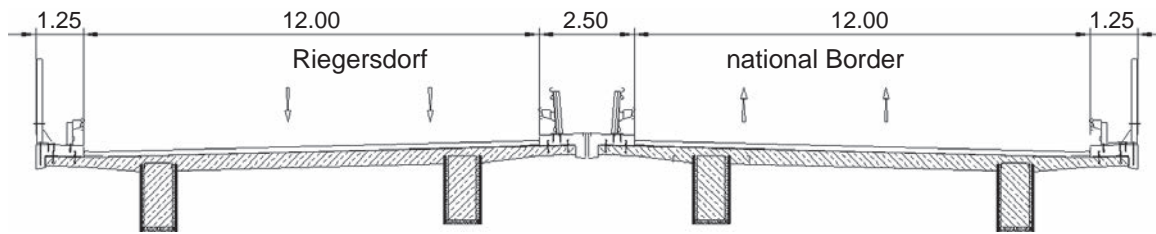


Fig. 7. Cross-section of bridge over the River Lafnitz based on a design using the balanced lift method

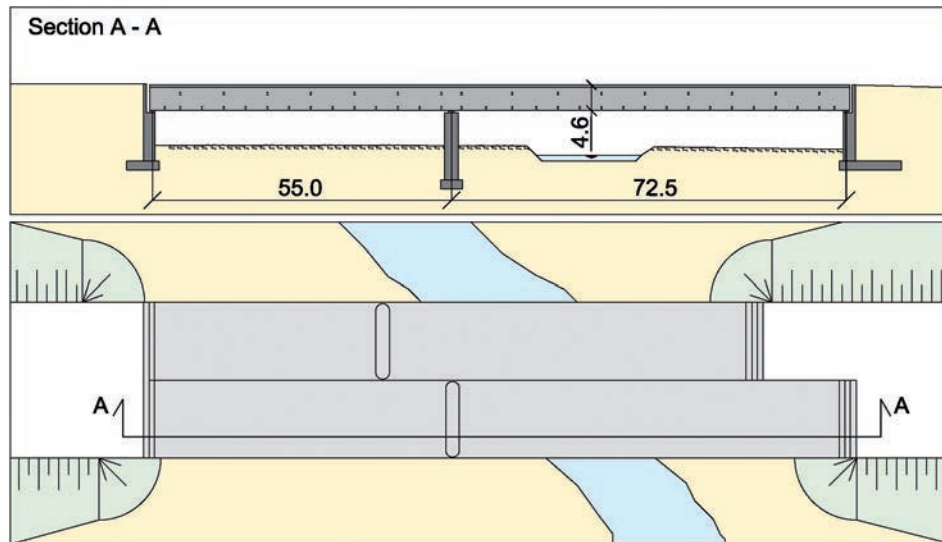


Fig. 8. Original design: a steel-concrete composite bridge over the River Lafnitz

Gmainer [7] suggests a span range of 50–250 m for the application of the balanced lift method.

3 Bridge over River Lafnitz

The design of bridges with short piers according to the balanced lift method will be described in this section using the example of the bridge over the River Lafnitz in the south-eastern part of Austria. The new S7 motorway “Fürstenfelder Schnellstraße” between Riegersdorf and the national border between Austria and Hungary requires crossings over the Lafnitz and Lahnbach rivers. The lengths of Lafnitz Bridge and Lahnbach Bridge are roughly 120 and 100 m respectively. The cross-section through the S7 motorway (Fig. 7) in this section is designed for two separate carriageways and so the bridges, each with a width of 14.5 m, across the rivers should be erected separately to suit the prospective reconstruction measures.

The areas where the two bridges for the S7 motorway are to be built are ecologically sensitive and part of the “Natura 2000” nature reserve. The bridges are needed to cross the rivers and to provide options for a passage for deer. To avoid encroaching on the natural habitat, erection on falsework is not accepted by the highway management company ASFINAG. The construction site should be as small as possible and limited to the central pier and abutments. To meet all these criteria, the balanced cantilever method, incremental launching or the balanced lift method are the only construction options.

Before the alternative design using the balanced lift method was introduced, the plan was to build the bridges by incremental launching of steel bridge girders (Fig. 8). To withstand the bending moments during the launching process, the cross-section was very deep compared with the cross-section depth for the balanced lift method. The big difference in depths, 4.6 m versus 2.0 m, is due to the compression struts, which reduce the spans immensely (Fig. 9). The alternative design for the post-tensioned concrete bridges was based on a cross-section with a plate girder as shown in Fig. 7. It was proposed to build the central section of the webs using the balanced lift method as shown in Fig. 9, to install the end sections of the webs with mobile cranes placed beyond the abutments and to build the deck slab similarly to the original design using a formwork carriage. In the course of preparing the alternative design, the abutments and the locations of the central piers were rotated through 30° on plan with respect to the longitudinal axis of the bridge as a response to the location of the riverbed and in order to provide an improved design for the passage of deer. These changes resulted in a bridge design with two equal spans.

It could be shown that the construction costs for the post-tensioned concrete bridges erected using the balanced lift method amounted to only 70 % of the costs calculated for the composite bridges. After ASFINAG became convinced of the financial benefits of a design based on the balanced lift method, a detailed design for the two

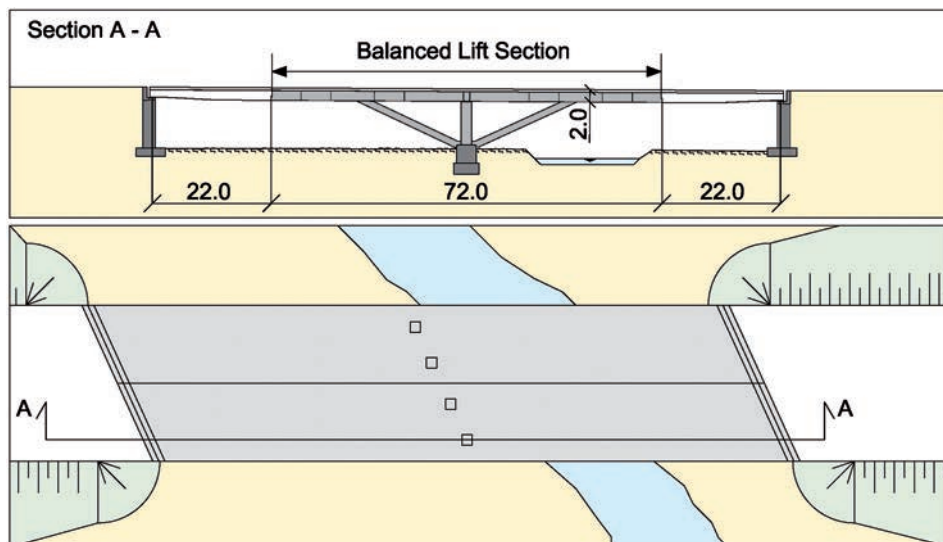


Fig. 9. Design based on the balanced lift method for a post-tensioned concrete bridge over the River Lafnitz

bridges for crossing the Lafnitz and Lahnbach rivers was commissioned.

The first steps in the construction process of the S7 motorway bridges will not be any different from conventional methods. The foundations, the abutments and the piers must be cast. If a bridge with short piers is being built, an auxiliary pier, which is connected to the concrete pier, is needed. The auxiliary pier consists of two sections of a tower crane positioned on both sides of the pier and connected by a platform at the top. The compression struts, which are made from hollow reinforced precast concrete elements with a small element thickness to reduce the weight, are assembled adjacent to the pier (Fig. 10, phase 1). When using the balanced lift method, the weight of the bridge girders during the lifting (for bridges with tall piers) or lowering (for bridges with short piers) operations is of utmost importance. This is why not only the compression struts but also the bridge girders are made from ultra-thin precast elements. A variety of bridge girders with different cross-sections has been developed to enable the construction of bridges of different sizes and spans. The bridge girders with the chosen cross-section are then assembled adjacent to the pier and the compression struts (Fig. 10, phase 2). The bridge girders were designed as U-shaped, thin-walled, prefabricated elements. The wall thickness was 70 mm and the depth of the bottom slab 120 mm, which are identical to the dimensions chosen for the prefabricated parts of Salzach Bridge. The bridge girders with a total length of 35.5 m had to be divided into two parts of 19 and 16.5 m owing to the limited space available at the site. The two parts of the bridge girder are joined by a 20 mm joint with high-strength mortar and four monostrands, which ensure a compressive stress at the joint in the subsequent construction phases.

Two bridge girders must be connected in order to start the lifting or lowering operation. This connection is achieved by tilting the bridge girders and by installing a tendon consisting of 16 monostrands (Fig. 10, phase 3). This tendon, shown in yellow in Fig. 10, has to ensure equilibrium during the lowering process by carrying the

tensile forces. After the monostrands are lightly stressed, the lowering operation begins.

Similar to the method of lowering arch halves, which requires that the arch halves are moved from the initial vertical position to a stable starting position for the lowering process, the bridge girders also have to be shifted to a secure starting position. The rotation of the bridge girders from the vertical to the tilted position, shown in phase 3 in Fig. 10, can be easily achieved by applying small horizontal forces to the top ends of the bridge girders. However, the small change in shape of the mechanism consisting of bridge girders, connecting tendon and compression struts from phase 3 to phase 4 has to be carried out in a controlled, symmetrical manner, either by pulling on the lower ends of the bridge girders or by pushing the compression struts apart. In order to limit the works to the area of the central pier only, the second option was chosen. Two hydraulic jacks have to be fixed to the top of the pier. A horizontal force of 20 kN and a stroke of 275 mm for each jack is sufficient to achieve the transformation from phase 3 to phase 4.

Phase 5 is the lowering process. The relationship between the total force in the strand lowering units and the vertical movement of the top point of the bridge girders, designated joint C in Fig. 10, is shown in Fig. 11. The whole mechanism is a statically determinate system during the lowering process, as in the method of lowering arch halves. An advantage over the method of lowering arches is the fact that in the balanced lift method, all forces are in equilibrium within the structural system consisting of bridge girders, connecting tendon and compression struts, and therefore no forces have to be carried by stays and anchored to the ground. Closer examination of Fig. 11 reveals that the relationship between force and vertical movement is distinctly non-linear and even starts with a negative force of 400 kN. A negative force indicates that at the start of the lowering process, a vertical force pushing downwards on top of the auxiliary pier would have to be applied. After a small movement of only 70 mm, this force changes to a tensile force. Obviously, pushing

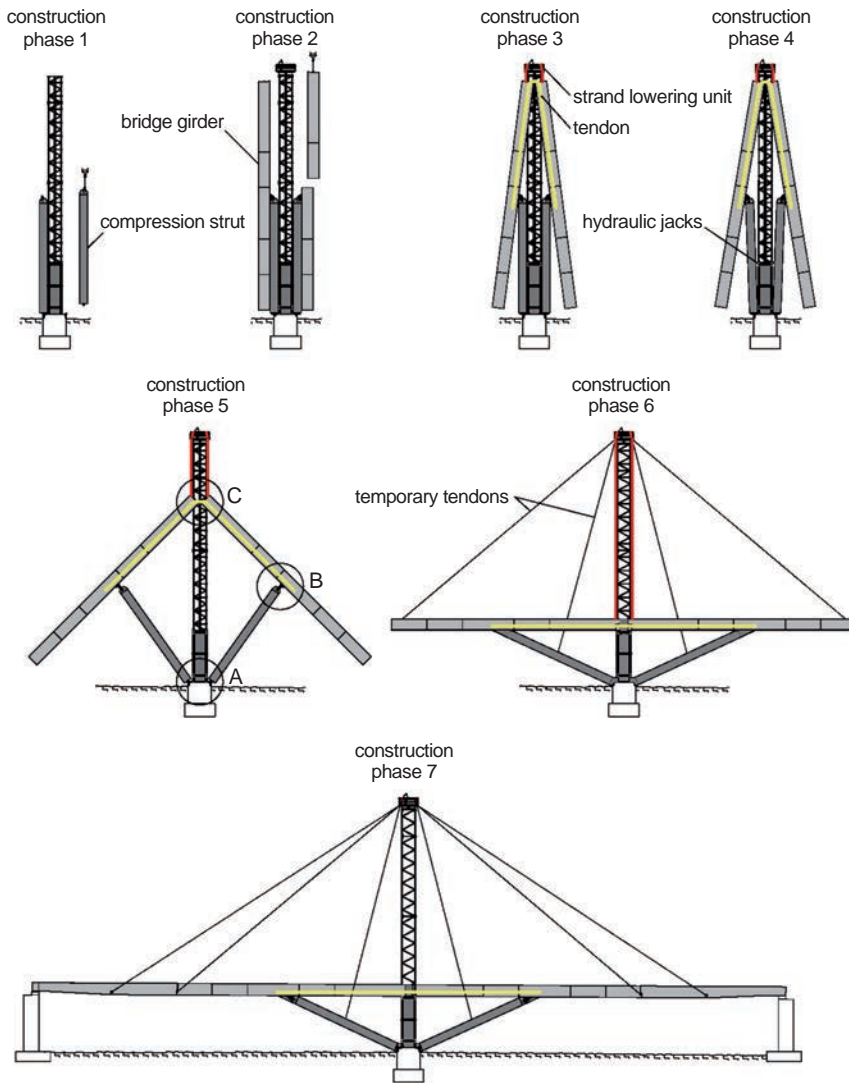


Fig. 10. Construction phases for Lafnitz Bridge

downwards at joint C to start the lowering process is an impractical and even dangerous option. Therefore, a design with two horizontal jacks at the top of the pier was prepared and a method statement was worked out for the interaction between horizontal jacks and strand lowering units. Once the maximum 500 mm stroke of the horizontal jacks is reached, the tensile force in the strand lowering units is already 80 kN.

The bridge girders are then slowly rotated into their final horizontal position (Fig. 10, phase 5). The maximum total force in the strand lowering units during this operation is 450 kN, and decreases to 150 kN in the final position. The compression struts are crucial to the rotation process. Once the bridge is in its final position, the importance of the compression struts does not diminish, since they become an integral part of the finished bridge. Owing to the compression struts, the spans are reduced, which therefore enables the construction of a slimmer bridge in comparison to a bridge without compression struts.

Details of joints A, B and C in their starting and final horizontal positions are shown in Fig. 12. The rotation of approx. 75° and 165° at joints A and B respectively requires careful detailing of the steel plates and the connection to the concrete, taking into account all eccentricities that occur during the change of geometry when the bridge

girders are moved from the vertical starting position to the final horizontal position. Rotation of the bridge girders of approx. 90° at joint C is enabled by a saddle that guides the connecting tendons as shown in Fig. 12.

Once the balanced lift part has been completed, the geometry of the bridge girder is corrected by releasing or stressing the connecting tendon. Filling nodes A and C

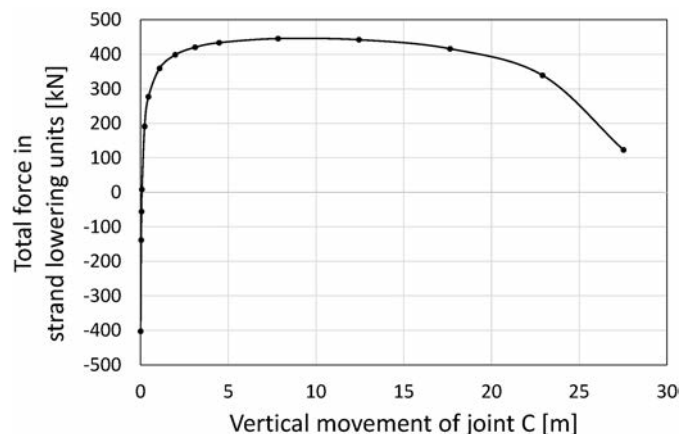


Fig. 11. Relationship between total force in strand lowering units and vertical movement at joint C

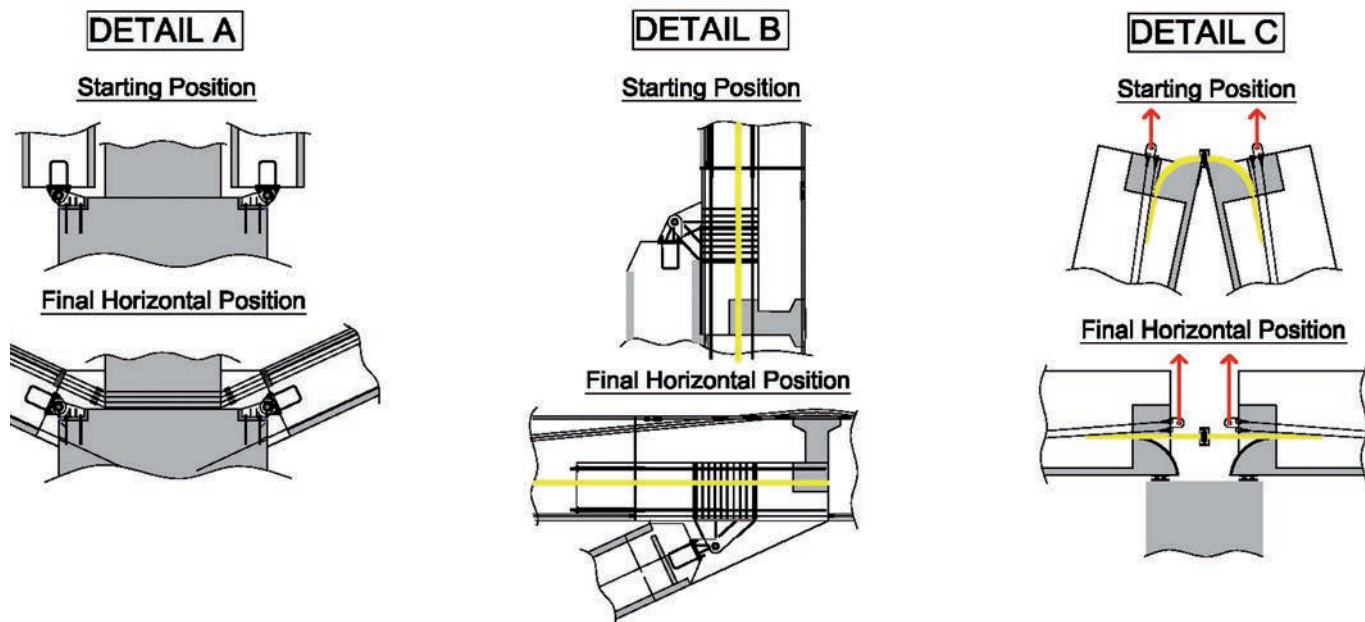


Fig. 12. Joints A, B and C before and after the lowering process

with in situ concrete freezes the geometry of the system. After installing temporary tendons (Fig. 10, phase 6), the compression struts and the bridge girders at node B are filled with in situ concrete. Phase 7 in Fig. 10 shows the installation of prefabricated bridge girder elements connecting the balanced lift part with the abutments. After adjusting the forces in the temporary tendons, the U-shaped prefabricated elements forming the bridge girder are filled with layers of in situ concrete. Once the concrete has hardened, the temporary tendons are released and construction phases 1 to 7 are repeated for the second web of the bridge. The installation of a bridge deck with the aid of a formwork carriage completes the bridge construction (Figs. 7 and 9).

4 Large-scale test of balanced lift method

In the course of a research project exploring applications of thin-walled concrete elements in bridge construction, it became possible to carry out a large-scale test of the balanced lift part of the bridges described in the previous section. The design of all elements (pier, bridge girders, compression struts) was based on a 70 % scaling of the designs for the S7 motorway bridges, so the test structure had a total length of 50.4 m.

As in the original structural design, the bridge parts were made of ultra-thin precast elements in order to minimize the weight of the parts that would be rotated during the balanced lift operation. As explained before, the 25 m long bridge girder walls consist of 70 mm thick concrete elements that are normally used as slab elements in buildings. The outside dimensions of the cross-section of the bridge girders corresponded exactly with the cross-section of the S7 bridges to a scale of 70 %. The girder had a depth of 1.26 m and the width varied from 0.7 to 1.4 m, with the larger width being at the connection points with the compression struts (Fig. 14). However, the thickness of the elements with 70 mm for the side walls and 120 mm for the

bottom slab was identical to the design of the bridges for the S7 motorway.

Since the thin-walled bridge girder, consisting of the U-shaped reinforced concrete only and weighing 208 kN, would have been too fragile for transport, assembly or lifting procedures, the cross-section had to be enhanced. A truss made of reinforcing bars (20 mm dia. transverse bars

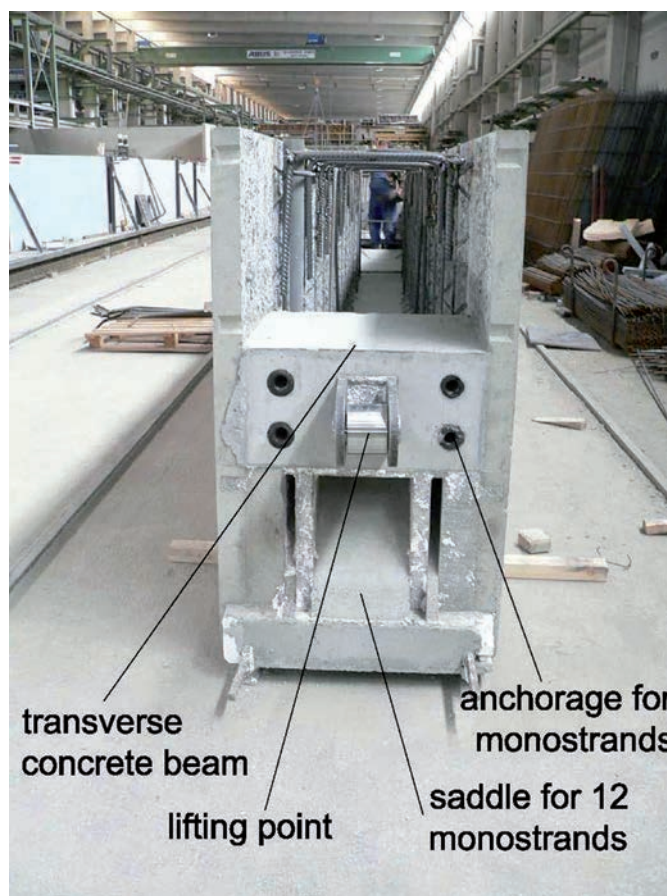


Fig. 13. End view of section of bridge girder



Fig. 14. The large-scale test structure during erection

and 12 mm dia. diagonals) was welded to reinforcing bars protruding from the precast side wall elements at the top of the cross-section. With the help of the truss, the U-shaped cross-section was converted into a box section that turned out to be stable enough for all further assembly and lifting operations. To enable future post-tensioning operations and for the installation of monostrands, the bridge girders were equipped with transverse concrete beams.

The transverse concrete beam and the saddle for the tendon at joint C is shown in the photograph of the end section of the bridge girder (Fig. 13), corresponding to “Detail C” in Fig. 12. The transverse concrete beam carried the force of four monostrands. Two of these monostrands were stressed before the bridge girder was transported to the construction site, the other two monostrands after the bridge girder was erected in the vertical position. The lifting point is also anchored in the transverse beam as can be seen in Fig. 13.

For the compression struts, a U-cross-section would have been impractical during the later filling with concrete. Therefore the 13 m long compression struts were precast as hollow reinforced concrete elements with a width of 1.4 m, a depth of 0.875 m and a weight of 150 kN each. The side walls were as thick as the bottom slab of the bridge girders. The top and bottom slabs were cast with a depth of 112 mm in order to integrate the anchor cones for the tie rods. The tie rods would have the job of carrying part of the concrete pressure during the filling of the hollow compression struts with in situ concrete.

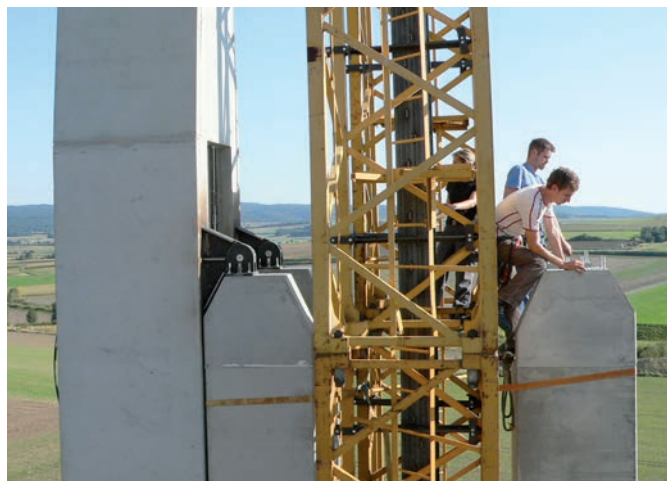


Fig. 15. Detail of connection between bridge girder and compression strut

Owing to the fact that the S7 bridges are bridges with short piers and this test structure is based on the design for the S7 bridge, an auxiliary pier was needed for the erection process. For this reason, two 24 m long tower crane sections weighing 102 kN, with plan dimensions of 1.2×1.2 m, were fixed to the foundation slab to serve as auxiliary piers. Two steel channel sections were used to create vertical guiding rails between the two tower crane sections. The top parts of the steel profiles were not connected to each other and the distance between the vertical guiding rails was 800 mm.

The hinge connection in the bottom of the structure consisted of 30 mm thick steel plates at the ends of the compression struts and concrete-filled steel tubes with an outside diameter of 150 mm placed on the foundation. The steel plates had to be positioned very accurately on the concrete-filled tubes in order to provide a proper hinge connection. After the compression struts had been placed in the correct position, they were temporarily fixed to the pier and the auxiliary piers.

The prefabricated bridge girders could then be transported from the prefabrication plant to the stockyard. A 100 t mobile crane lifted one bridge girder after the other (Fig. 14) so they could be fixed to the top end of the compression struts with four 16 mm bolts. Even though the cylindrical openings in the connecting steel plates only had a tolerance of 1 mm, the assembly operation was carried out without any problems. A close-up view of the connection of the bridge girder to the compression strut, which corresponds to “Detail B” in Fig. 12, can be seen in Fig. 15.

After only four days of erection, the bridge was ready for the balanced lift part of the construction process. In order to start the rotation process, the bridge girders had to be tilted so that the top ends would touch each other. Subsequently, 12 monostrands were installed in the two bridge girders. The monostrands were anchored at the connection points between each bridge girder and the compression struts. In the top section of the bridge girders, circular saddles with a radius of 544 mm had been formed during precasting (Fig. 13). After the installation of the 12 monostrands, the strands were lightly stressed to prevent sagging.



Fig. 16. Lowering the top points of the bridge girders with the help of mobile cranes

The lowering process was carried out by slowly and simultaneously lowering the two top points of the bridge girders with the help of two mobile cranes (Fig. 16). The maximum lifting force, which had been calculated as 270 kN, corresponded well with the lifting force measured by the cranes.

After the bridge had been rotated from the vertical into the horizontal position, the geometry of the structure was checked. The geometry of the structure could be easily adjusted by stressing or relieving the installed monostrands. This turned out to be unnecessary since the test structure's geometry was within an acceptable range. At first it was planned to fill the compression struts and bridge girders with in situ concrete, as would be the procedure when building the S7 bridges. It was then decided to fill the node above the pier only in order to provide a higher resistance against horizontal wind loads. In this way, the ultra-thin precast elements and the node connections would still be visible during inspection (Figs. 17 and 18).

The large-scale test demonstrated that the balanced lift method works and that the joint details can be built using simple connection details with steel plates and bolts (joint B) and a saddle with tendons (joint C). The radius of the tendons at joint C is much smaller than in typical post-tensioning applications. The reduction in the ultimate force as a function of the curvature of the saddle was de-



Fig. 18. Bridge girder with 70 mm prefabricated wall elements

termined experimentally [8]. It could be shown that the monostrands do not lose load-carrying capacity, even for a small radius of only 0.5 m.

In future projects the lowering process should not be carried out using mobile cranes because the lifting force changes with the vertical movement of joint C, as is shown in Fig. 11, for example. This change in force leads to deflections of the telescopic booms of the mobile cranes, which have to be compensated for by the crane operators. It is easier to carry out the lowering or lifting operations with strand lifting units.

5 Concluding remarks

By employing the balanced lift method, the spans of the bridge girders are reduced by the compression struts, thus enabling considerable savings in construction materials. The proposed method will be especially advantageous for bridges with tall piers and spans between 50 and 250 m. The use of temporary piers enables an economic application of the balanced lift method for bridges with piers of modest height, e.g. the two bridges on the S7 motorway.

Another advantage of the balanced lift method is the fact that all assembly and erection operations are concentrated at the pier and that the rotation of the bridge girders can be carried out much faster than by horizontal launch-



Fig. 17. Large-scale model of the balanced lift part of the Lafnitz Bridge

ing of the bridge girders. The small space requirements and the high construction speed might be of advantage when an obstacle such as a railway line or a busy motorway has to be spanned by a bridge and traffic interruptions have to be kept to a minimum.

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