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Steel Construction

European Steel Design Awards 2021



Schuttebusbrug Zwolle

Design, Construction and Engineering

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ESDA 2021 SPECIAL BRIDGE AWARD

Schuttebusbrug *looking wavy elegant and light requires extraordinary engineering skills*

| | | |
|---------------------|---|---|
| Project owner | Municipality Zwolle | |
| Location | Central Station, Zwolle, NL | |
| Architect | ipv Delft | Gerhard Nijenhuis |
| Structural Engineer | BAM Infraconsult Setzpfandt Beratende Ingenieure | Tristan Wolvekamp Gerhard Setzpfandt |
| Steel Contractor | Victor Buyck Steel Construction | Shana De Waele |
| General Contractor | BAM Infra | John Regtop Tristan Wolvekamp |
| Date of Completion | February 2019 | |
| Steel Tonnage | 1,000 tons | |

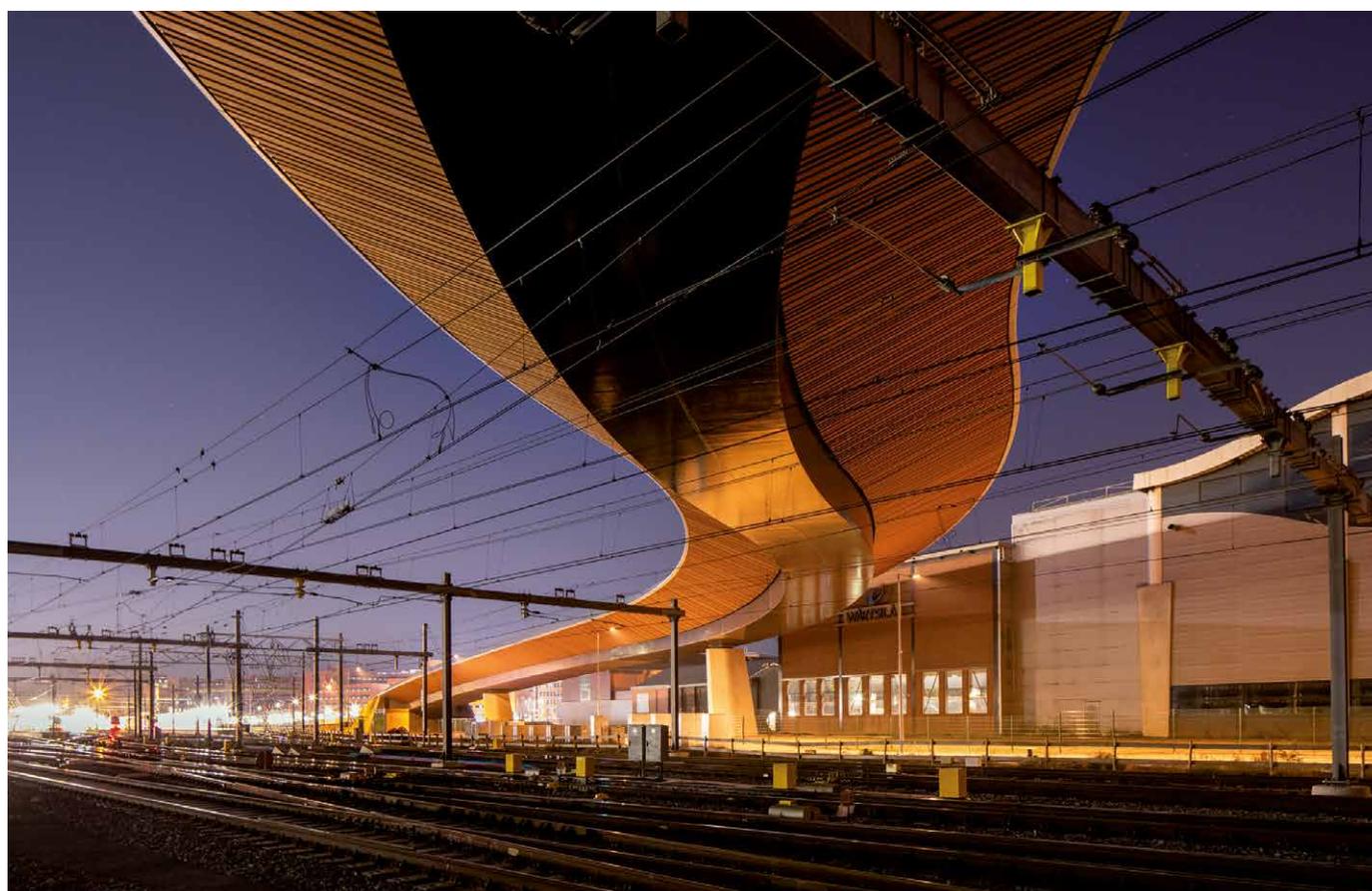


Photo: ipv Delft / Henk Smatense

ESDA 2021 SPECIAL BRIDGE AWARD

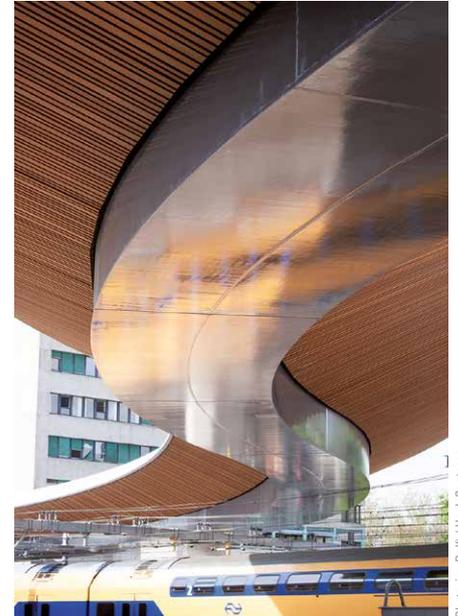
Schuttebusbrug looking wavy elegant and light requires extraordinary engineering skills

The finesse of this edgy steel bridge is captivating. The new traffic mark adds with an elegant S-shape, shiny metallic painting of the main beam and classy bamboo cladding of the deck a playful aspect to an otherwise busy urban space. What looks so wavy elegant and light requires extraordinary engineering skills to design for torsional strains and to build

for heavy traffic loads above the rail tracks.

With the bridge, named after the old Schutte Bus company, buses go over the tracks between the new bus stop and the train station. Passengers have a good view on the tracks whilst the bridge also contributes to the beauty of the public

space: It swings like a canopy over the track and the adjacent green zone. High-quality bamboo cladding on the underside of the bridge deck forms a wooden ceiling, which fits well with the city



park. Together with the S-shape, it gives the bridge its character.

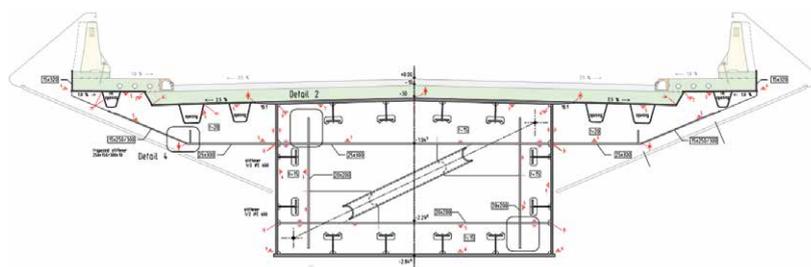
The structure is made of a box girder with cantilevers resulting in three lines: the dark gray steel girder, the wooden lamellae above it and the edge line. The columns are placed eccentrically on either side of the track. They seem to be inclined and surfaces are bevelled to fit the design of the bridge deck. All kinds of facilities are integrated in the edge of the bridge.

The torsion-resistant design makes the slender appearance of the 245-meter-long

bridge seem to float. The main S-shape span of about 80 m over the track is a steel box girder with cantilevered steel wings. On top is a concrete layer forming a composite deck. With a torsional rigid structure point supports are feasible and ensures a short span. The torsional moment is transferred at the abutments. The main span is also connected to the access bridges with prestressing strands requiring heavy steel anchors. Weight and length of the concrete access bridges reduce the field moment in the steel structure. As steel and concrete structure flow into each other, the bridge is continuous aesthetically and structurally.

Limited space and train traffic were the main challenges for erection. The steel structure was produced in segments, transported to the site and assembled next to the railroad. The steel span was driven overnight on self-propelled modular transporters to final position placed on an auxiliary structure and fixed. After the access bridges were ready the parts were tied together.

The bus bridge not only connects the new bus station and the public transport route, but also the urban and landscape fabric of Zwolle and enriches the busy traffic area with unique shape and shine.



EUROPEAN STEEL DESIGN AWARDS



FOREWORD

As steel is the most important and flexible construction material with further advantages such as 100% recyclability, it is produced and used in a wide range of products in different qualities. It is the extraordinary, persistent and innate ability of steel to be innovative that enables it to maintain its position as one of the most essential construction materials. Due to its huge potentials to develop products and technologies, steel can be implemented in new spheres of serviceability. Therefore, ECCS brings into focus the contemporary utilisation of these potentials and calls every other year for the European Steel Design Awards to encourage creative and outstanding use of steel in architecture and construction in Europe. Aim of ECCS is also to make these awards, given since 1997, internationally recognised competitions in the field of steel construction. Steel structures can be constructed to almost any shape or form. In other words, architects can accomplish whatever they imagine, by using steel. In this vademecum the best project of each of the ECCS member countries, chosen by the international expert jury, are presented as the European Steel Design Awards 2021. The jury nominated out of 23 submitted projects the European Steel Design Awards per country and finally determined amongst them the Norwegian nominee *Protective building for MIS Finnmarknes* as part of the Hurtigruten Museum in Stokmarknes as the European Steel Design Award 2021 Laureate. And the Dutch nominee *Schuttebusbrug* in Zwolle as the ESDA 2021 Special Bridge Award. Further, decided by public voting via Facebook, the ESDA 2021 Public Award went to the Danish *Camp Adventure Forest Tower* in Rønne.

Due to the special situation in 2021 all European Steel Design Awards 2021 have been celebrated in the respective countries and awarded by the national ECCS representatives. Nevertheless, the European Steel Design Award 2021 Laureate as well as the ESDA 2021 Special Bridge Award have been presented to the winning teams in a reception at 1 October 2021 in the Atomium in Brussels.

My special appreciation goes to all the project teams, which took part in the European Steel Design Awards 2021 for their excellent works. I further thank my fellow members of the international jury for their engagement and expertise and may not conceal here, that it was a great pleasure scrutinising all those phantastic projects made of steel. I also thank the ECCS Brussels office for organising the awards so industriously under the present restricted conditions. And last but not least I invite all of you to celebrate all participants, nominees and winners of the 13th European Steel Design Awards and the enduring beauty of steel in construction.

B. Hauke

Bernhard Hauke
Chairperson ECCS Promotional
Management Board



Photo: ECCS/Neenan De Sitter

Schuttebusbrug Zwolle

Design, Construction and Engineering

A striking part of the development of the Spoorzone in Zwolle is the new bus bridge. This bridge provides a completely free access route for buses only, without other traffic. It connects the new bus station on the south side of the railway yard with the intersection Rieteweg-Willemskade on the north side. Traveller comfort, optimisation of bus services and spatial qualities were decisive for the appearance of the bridge.

The bridge was festively opened on 9th of February 2019, when it was named the Schuttebus Bridge. The bridge is named after Herman Schutte, founder of the former bus transport and coach company Schutte Tours Zwolle. As per 17th of February, the bridge was included in the bus transport company's timetable. The bridge has six supports, an abutment on both sides and four intermediate piers (Fig. 1). At the northern abutment, the bridge changes into an embankment with a length of 129 m. On the southern side, there is also an embankment with a length of approximately 60 m, which will connect to the new built bus station. The length of the bridge including the embankments is therefore approximately 435 m.

1 Introduction

1.1 Architectural design

A tender design was made based on the requirements from the call for tender. The type of bridge and the choice of materials were free to choose, but had to meet the func-

tional and aspect requirements: a bus bridge with the smoothest possible line, which also offers optimum comfort to travellers.

A flowing line was achieved by minimising the number of supports and giving them a slender shape. The piers taper down from ground level to the top and have minimal dimensions at the top. The supports right next to the railway yard are placed eccentrically under the bridge to minimise the length of the main span. The piers underneath the approach bridges are also placed eccentric, but on the other side of the bridge axis.

By visually dividing the bridge into three horizontal layers, the construction height appears to be smaller than it actually is. The slenderness of the appearance is reinforced by the fact that the main supporting structure lies as far inward as possible. The steel main span and concrete approach bridges have been given a calm grey colour. The entire length of the superstructure is finished with edge elements made of curved aluminium panels fixed on top of concrete road barriers. Lane lighting has been integrated into the aluminium edge elements. The underside of the cantilever has been provided with bamboo panels attached to a steel substructure. This emphasises the landscape elements in the surroundings and connects the green embankments, giving the bridge a parklike appearance.



Source: ipv Deilt

Fig. 1 View of superstructure in direction south

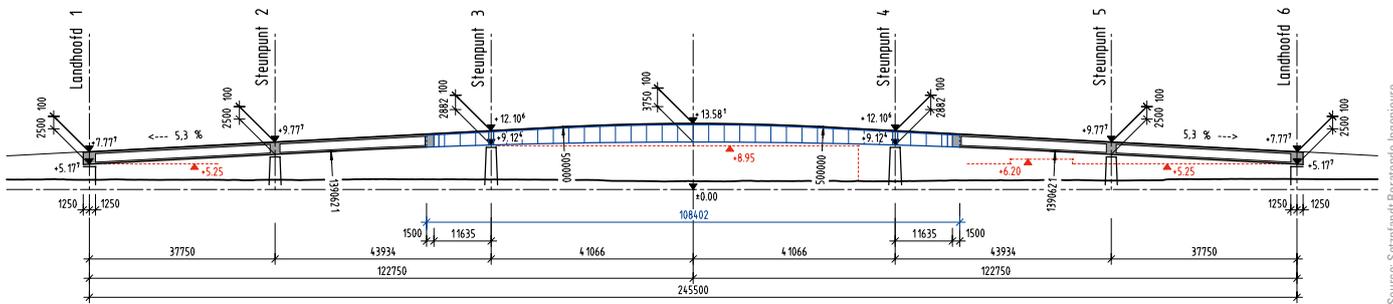


Fig. 3 Longitudinal section

perstructure. The steel superstructure lies almost entirely within the centrally symmetrical range of the centre span. Only the last 3.17 m up to the coupling joint with the northern approach bridge is already in the design curvature of the slope. The outer dimensions of the visible steel and concrete section at both coupling joints are identical, so that the material transition can only be recognised by the difference in colour and roughness of the materials.

2.1 Basic geometry of the cross sections

For reasons of driving comfort, the roadway width increases linearly from 7.60 m on the approach bridges from the middle between supports 2 and 3 and supports 4 and 5, respectively, to 9.00 m in the bridge section. The bituminous roadway structure including the seal has a thickness of 10 cm, below which there is a 20 cm thick concrete deck on top of the steel box girder. This deck which, also contributes in the composite section, essentially serves the drainage, to accommodate the conduits and the edge construction with barriers. The total external width of the bridge deck will thus increase from 10.23 m at the approach bridges to 12.23 m in the middle of the central span.

2.2 Steel cross section

The steel girder consists of an airtight welded box section. The plate thickness of the base plate is 65 mm in the centre and 70 mm at the supports, the plate thickness of the deck plate is 40 mm in the centre of the span and 50 mm

at the supports. In the area of the moment zero points, the plate thicknesses are reduced. The web plates have a continuous thickness of 35 mm. S 355 was used for the entire steel construction of the box girder.

The box section is stiffened by means of transverse frames with a distance of 3.16 m measured in the superstructure axis. The cross frames consist of a continuous T-sections. Every second cross frame is additionally stiffened by a diagonal. These diagonals consist of tubes 244.5×16 and are required for the shape stability of the cross-section due to the strong torsional buckling. Since the torsional load in the final stage is mainly caused by the carriageway curvature, the diagonals are arranged in such a way that they obtain tensile forces from this load. The slope of the diagonals therefore varies in the centre of the bridge and at the moment zero points for the supports 3 and 4.

The longitudinal stiffening of the web and flange plates is provided by T-profiles welded inside. These profiles follow the curvature in the top view and are adapted to the different box section widths and box section heights by changing their distance and number. Since the longitudinal stresses in the T-profiles on the bottom and top plates cause considerable secondary forces due to the horizontal curvature, the flanges of the stiffeners are welded to the bodies of the cross frames.

The cross-members of the cantilevers have a T-section and always connect to the top of the crossframes in the inner side of the box girder. The deck plate of the cantilevers has a continuous thickness of 20 mm in the area of the road-

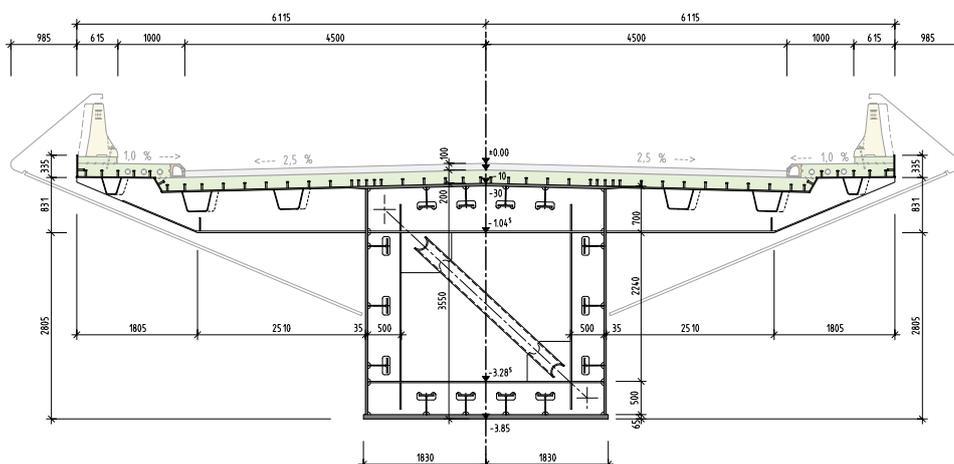


Fig. 4 Typical cross section

Tab. 1 Coating specifications

| Layers | Primer | 1 st layer | 2 nd layer | 3 rd layer |
|------------------------|---------------------------------------|-----------------------|---------------------------|------------------------------------|
| Coating specifications | Metallisation Zn Al 85/15 (150 µm) | Sigmacover (35 µm) | Sigmacover 280 (75 µm) | Sigmadur 1800 RAL 7004 (125 µm) |

way, in the area outside the roadway the thickness decreases to 15 mm.

Since the outer side of the cantilevers had to be protected against corrosion, by means of zinc spraying, T profiles stiffening could not be foreseen here. The stiffening of the cantilevers was therefore performed with the usual trapezoidal profiles, which were adapted to the bridge curvature in polygonal sections.

The 20 cm thick concrete deck on top of the cover plate (C 35/45) is connected to the deck plate with studs in such a way that it carries longitudinally. In the transverse direction, the reinforced concrete slab takes over the transverse distribution of the traffic loads on the longitudinal stiffeners and reduces the deformations in the roadway and in the stiffeners.

3 Coupling joints

The bending and torsion-resistant connection of the steel and concrete box sections is effected by means of welded studs on the inside of the steel box and by continuing the tensioning elements from the posttensioned bridges in the steel construction. The welded studs take over the torsional and shear forces and the post-tensioning elements the horizontal and vertical bending moments.

The coupling area has a total length of 5.00 m, of which a length of 1.50 m is a solid concrete section. On the steel side, a 1.00 m long steel anchoring cross member is connected, in which the post-tensioning anchors were installed. This crossbeam absorbs the compressive forces of the posttensioned concrete and the tensile forces from the tensioning elements and transfers the resulting sectional forces to the steel section.

During the construction of the tensioned concrete superstructure, a 3.50 m long “coupling section” for the connection to the steel superstructure was left open. This coupling section was cast in two concrete steps after the steel construction had been installed. This required temporary auxiliary support structures under the approaches.

4 Bearing schedule in the final – and construction stage

4.1 Bearing layout

The superstructure is supported on spherical bearings at all axis. A part of the torsional forces in the superstructure are already dissipated by the vertical bearing forces at

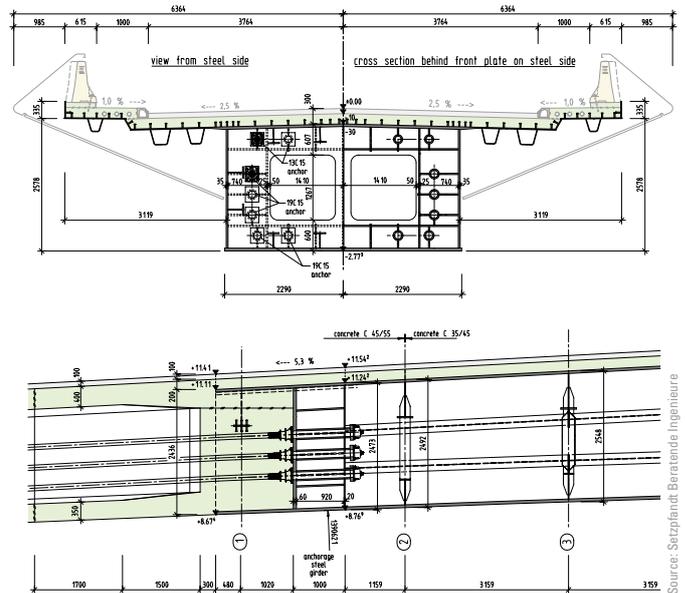


Fig. 5 Coupling joint

these points because of the existing layout of the bearings (they are not in a line and not central under the bridge axis). The torsional forces still present at abutments 1 and 6 are absorbed over the large spread of the bearings arranged there at both ends of the transverse girders, without any loosening of the bearings.

The longitudinal fixation for the entire superstructure is provided at abutment 6 by a centrally arranged bearing in the bridge axis. At this fixed point, the direction of movement of all other bearings in axes 1 to 6 is radially aligned. The transverse fixings of all the bearings are perpendicular to movement direction.

4.2 Supports during construction

In the construction stage after the steel superstructure has been installed, but before the connection to the post-tensioned concrete sections is made and before the bearings are connected to the steel superstructure, the steel box

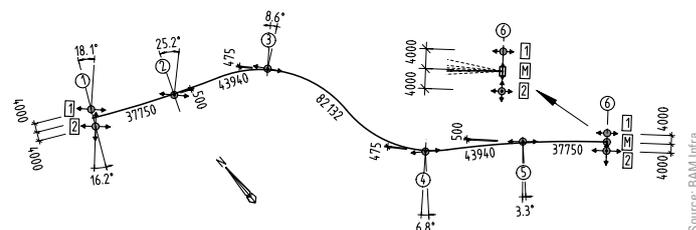


Fig. 6 Bearing schedule

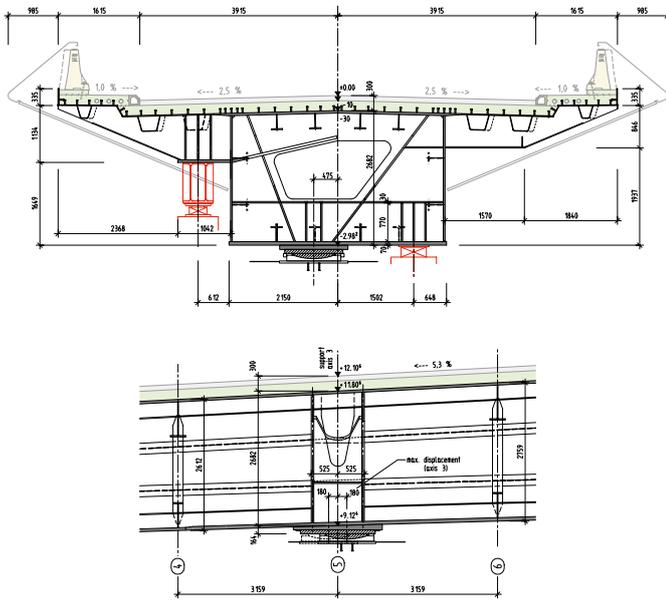


Fig. 7 Bearings and temporary supports in axis 3 and 4

girder is temporarily supported on an auxiliary support structure at the supports in axes 3 and 4. A transfer frame is fitted to transfer the loads from the spherical bearings into the box girder. This frame consists of two plates ($t = 50 \text{ mm}$) at a distance of 1.00 m with inclined stiffeners in between. Due to the eccentric arrangement of the supports the jacking points are located on the inside and outside of the box to prevent the superstructure from tilting. On the outside, therefore, an extra bracket had to be attached, so that it would not be visible on completion. These support points on the superstructure can be used in the final phase as jacking points for a possible exchange of the supports.

5 Installation and transportation

The 110 m long central box girder was transported to the construction site in Zwolle in 10 sections by axle and as-

sembled into a single girder at the preconstruction site. Because of the maximum width of 4.50 m , the transports took place at night. The maximum height of the box girder was 3.75 m , so a low-loader was needed to stay under the permitted height. The cantilevers were added 2×10 sections later. On small auxiliary supports with jacks, the sections were properly aligned and welded together.

5.1 Jacking up the box girder

The bridge was jacked up in steps of 25 cm to a height of approximately 7.0 m by means of jack towers under the jacking points of the bridge at the position of the future bearing points. This height was necessary to be able to manoeuvre the bridge above the overhead wires, so that these did not have to be removed. The suspension of the overhead wires ensured that the train free period could be kept as short as possible to minimise disruption to train traffic.

5.2 Transportation

Now that the bridge was at the right height, the Self-Propelled-Modular-Transporter (SPMTs) with auxiliary supports could be driven under the bridge. The first group with 4 SPMTs was located approx. 10 m from the centre of the bridge and the rear group was under the end of the bridge. Between the two groups 300 tonnes of ballast was then placed, which shifted the centre of gravity of the bridge approx. 10 m , allowing for a cantilever of 60 m at the front. On top of the rear group of SPMTs, 120 tonnes of ballast were placed, which significantly increased the safety of the tipping stability. The ballast consisted of crane ballast.

After applying the ballast, the northern jacking tower could be unloaded, which caused the cantilever to deflect about 1 m . This deformation was also predicted in the engineering calculations. This load situation was normative

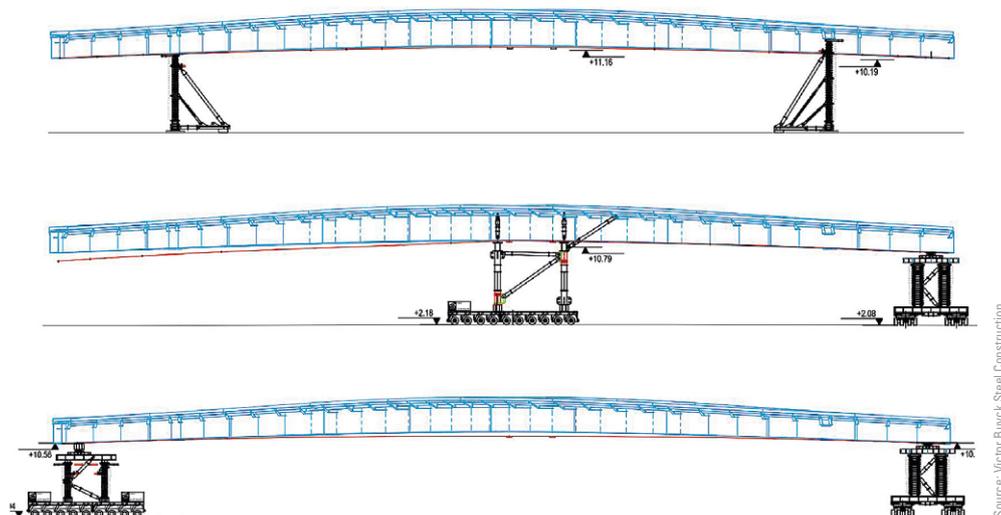


Fig. 8 Transportation stages – lifting and SPMT setup



Source: Stefan Verheik

Fig. 9 Cantilever ready for transportation

platform made of dragline mats. The cantilever reached so far that the railway was crossed.

A third set of SPMTs was waiting on the north side and was positioned under the cantilever. Two climbing towers with a turntable on top raised the cantilever. The turntable followed the angular rotation of the end of the cantilever as a result of the jacking. The 300 tonnes of counterweight were removed from the bridge and the middle group of SPMTs could be removed. The bridge was now supported at both ends, allowing the last 30 m to the auxiliary piers to be continued. Towards the end of the following day the bridge was placed on the two auxiliary pillars at axis 3 and 4, which temporarily fixed the bridge in the transverse and longitudinal direction.



Source: Satzpfandt Beratende Ingenieure

Fig. 10 Bridge crossed the railway lines

6 Design calculations

6.1 Global and local analyses

A global beam FE-model was used to determine the bearing reactions, deformations and global sectional forces. Later on the central steel girder was extended in the beam model with a FE-3D shell model, to analyse the deflections and force distribution due to torsion.

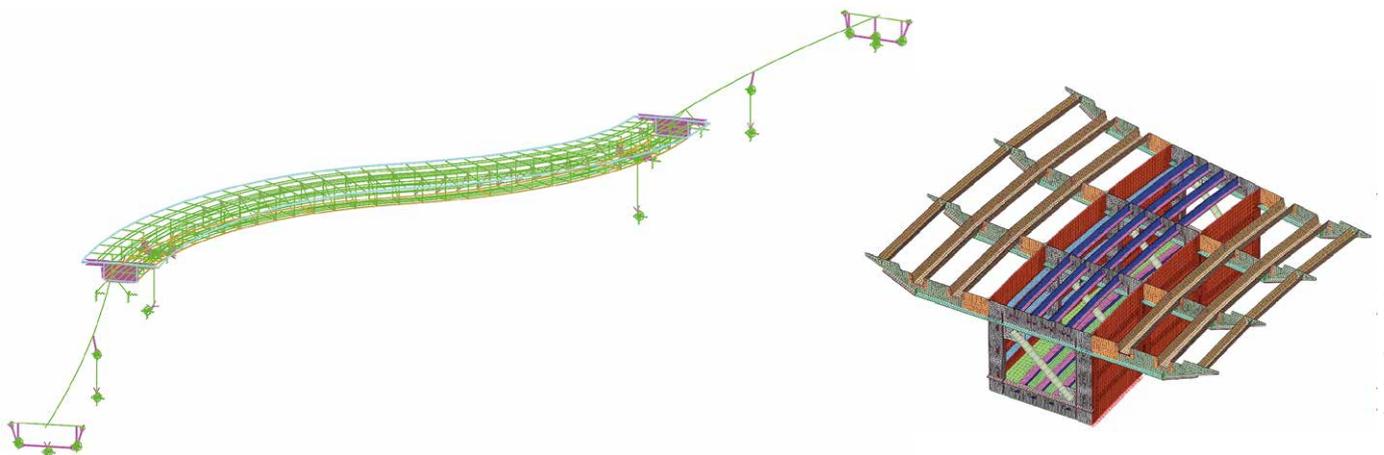
The crosssectional forces in the final phase were determined by also taking into account the construction stages from a previous phase with respect to the positions of auxiliary structures and temporary supports. Furthermore, 3D local models were used to study the transverse behaviour of the curved bridge sections, support sections and the connection joint with the concrete approaches.

for the steel box girder at the location of the central support.

The driving route across the construction site to the railway line was compacted with gravel and equipped with steel driving plates. The driving route was marked on the steel plates. During the night, the transport was driven to the railway line and parked on a specially constructed

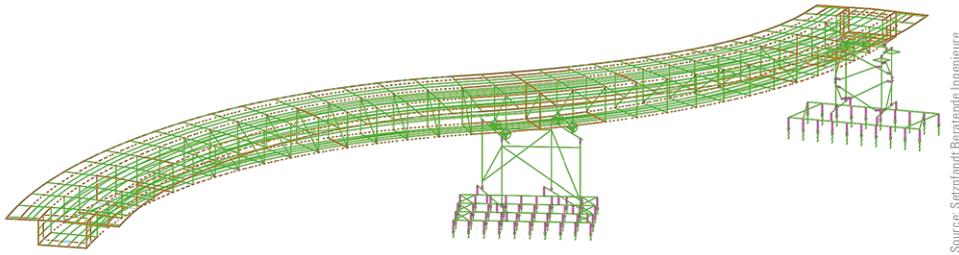
6.2 Analyses during transportation

A separate calculation model was made to study the transportation of the bridge. Apart from the loads of the ± 1.000 ton steel construction, the 420 tonnes of ballast special loads had to be taken into account



Source: Satzpfandt Beratende Ingenieure

Fig. 11 Integral beam with shell model and detailed FE-model



Source: Setzpfandt Beratende Ingenieure

Fig. 12 FE-model during transportation

- inertia forces from braking (emergency braking);
- forces due to steering errors (longitudinal and transverse direction);
- Inaccuracies in the application of ballast and distribution of dead weight;
- Wind loads during start-up and higher wind loads at standstill;
- Skew of support structure;
- Subsidence and unevenness of the ground.

Special attention had to be paid to the fact that cantilever changed the direction of the torsion moment. The stiffened diagonals in the box would then no longer be loaded on tension, but on pressure. Local stiffeners were also needed to transfer the bearing forces into the box girder.

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Data block

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 Engineering team: BAM Infraconsult bv, Gouda The Netherlands
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 Contractor: BAM Infra Regional bv, Gouda The Netherlands
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