

Zandhazen Railway Bridge, The Netherlands

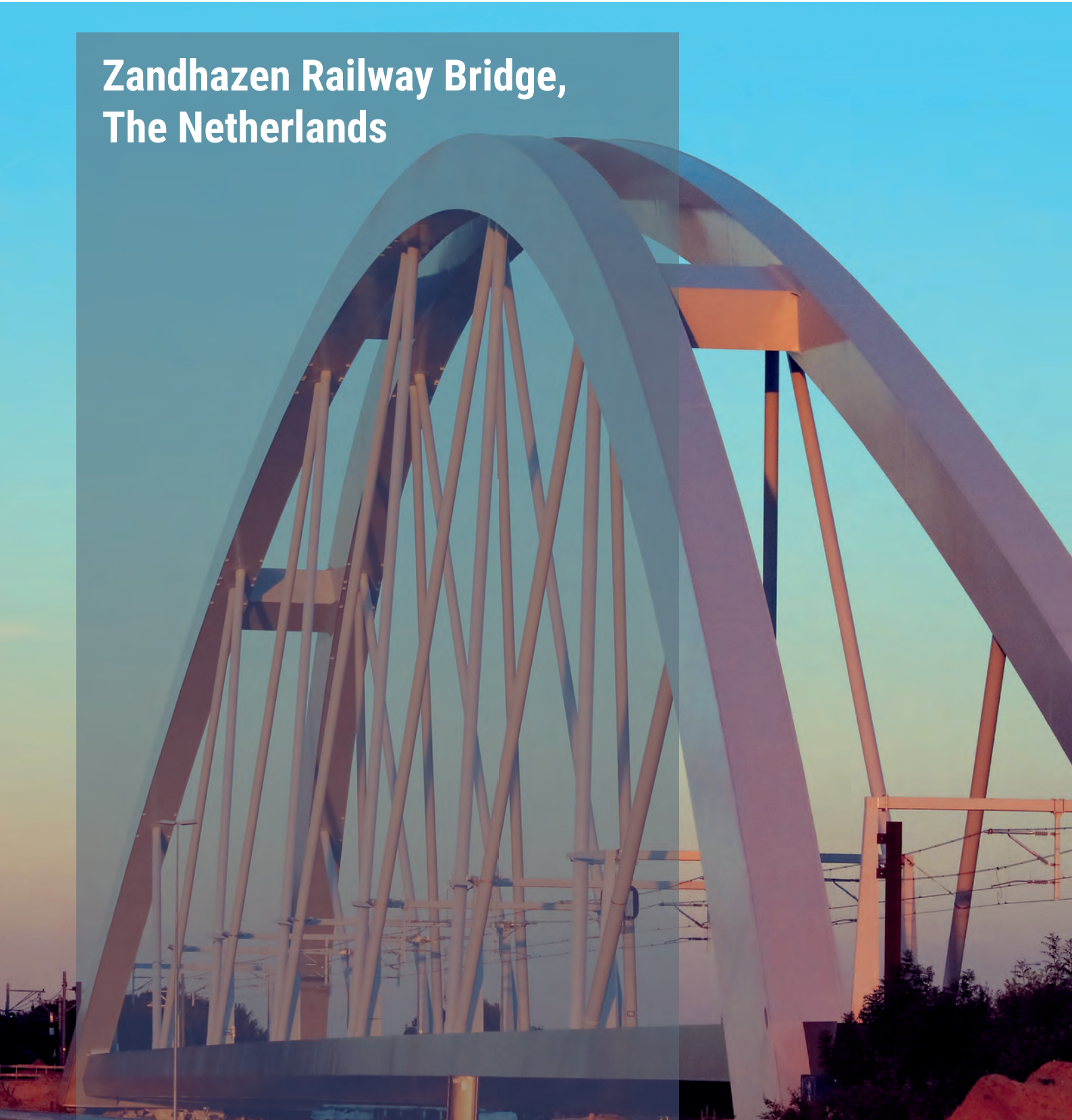




Figure 1 Zandhasen railway bridge – a tied arch bridge with inclined hangers
Courtesy: Iv-Infra b.v.

Summary

Spanning 255 m, the Zandhazen railway bridge is the longest railway arch bridge in Europe. It carries two railway tracks over the A1 motorway in Muiderberg, east of Amsterdam, and has a width of about 17 m and height of 55 m. The bridge was opened in August 2016.

Due to the need to minimise disruption to road and railway

traffic, the most critical aspect of the design was to ensure ease of transportation and installation. For this reason, steel grade S460 was chosen for the main girders and arch sections to limit the bridge self-weight.

The total cost of the railway bridge, including the substructure, was about € 40 Million.

Background

The Zandhasen railway bridge is part of the Schiphol-Amsterdam-Almere (SAA) project, a huge infrastructure development that aims to increase the road capacity of the Schiphol-Amsterdam-Almere corridor to alleviate the current traffic congestion. SAA will be the largest road construction project in the Netherlands in the period 2012-2024.

At the Muiderberg intersection, the A1 motorway will be widened from six to sixteen lanes and the existing prestressed concrete railway bridge over it will be dismantled and replaced by the new Zandhasen bridge with significantly larger span.



Figure 2 Zandhasen railway bridge
Courtesy: Ronald, licensed under CC BY-SA 4.0

Material selection

High strength steel with a yield strength of 460 MPa (S460) was selected for the main structural elements because of the need to minimise the self-weight of the structure for ease of transportation and installation. Furthermore, the use of lower strength 355 MPa (S355) steel was not possible because thicker plates would be needed, and this would not comply with the maximum permissible thickness values according to EN 1993-1-10. As neither fatigue strength nor stiffness governed the design of the main structural elements, the use of S460 was technically feasible and led to a total weight reduction of approximately 30%. In certain

places, the choice of S460 enabled a reduction in plate thickness from 160 mm down to 90 mm.

As the Dutch Railway Authority, ProRail, specified that the S460 steel be thermomechanically rolled in order to improve weldability, a niobium micro-alloyed steel alloy design was used. In addition, ProRail imposed tighter limits on carbon content, carbon equivalent, and yield to tensile strength ratio than that defined in the product standard EN 10025-4 and design standard Eurocode 3 (Table 1).

The S460 steel plate supplied by Dillinger was microalloyed with niobium (about 0.03 weight percent)

which gave improved toughness, strength, formability and weldability. Furthermore, it enabled the use of a lower carbon alloy composition which helped meet the carbon equivalent limitation and thus improved weldability.

S355K2+N was used for the crossbeams of the deck section, in order to expedite repair works in the event of vehicular impact.

In total, 8400 tonnes of steel were used in the bridge for the main girders, arch sections, hangers and cross beams, roughly equal to the quantity of steel used in the Eiffel Tower!

	Maximum Yield strength/ Tensile strength	Maximum Carbon composition % (ladle analysis)	Maximum Carbon equivalent value (ladle analysis)
EN 1993-1-1 requirement	0.909	-	-
EN 10025-4 requirement	-	0.16	0.45-0.48, depending on plate thickness
ProRail requirement	0.88	0.12	0.41

Table 1 Material properties for S460M/ML

	C	Mn	Si	S	P	Nb
Typical weight %	0.10	1.60	0.50	0	0.01	0.03
Maximum weight % (EN 10025-4)	0.16	1.70	0.60	0.025	0.03	0.05

Table 2 Typical steel chemical composition for S460M rolled steel

Design

The railway crosses the A1 motorway at a very oblique angle. The combination of this oblique angle and the requirement to span the entire motorway without intermediate supports, led to the exceptional design requirement to span 255 m. In addition, the bridge was required to be as slender and 'transparent' as possible. The final design involved two arches which slope towards each other, connected by four horizontal couplings. These 50 m high steel arches, with 25 diagonal hangers, make the long span possible without inducing excessive bending moments in the deck. This design concept ensures that the bridge behaves more like a lattice girder, and the greater stiffness leads to smaller deflections. The diagonal hangers, designed to carry axial compressive forces, are hollow steel tubes with a diameter of over 600 mm. The use of tube sections, as opposed to cables, obviates the need for continuous tightening during construction. In addition, the heavy bridge deck ensures reduced axial pressure forces in the hangers caused by unfavourable train positions. Hydraulic dampers were fitted to the relatively slender diagonals to suppress vortex-induced vibrations due to wind loading which might have led to fatigue problems.

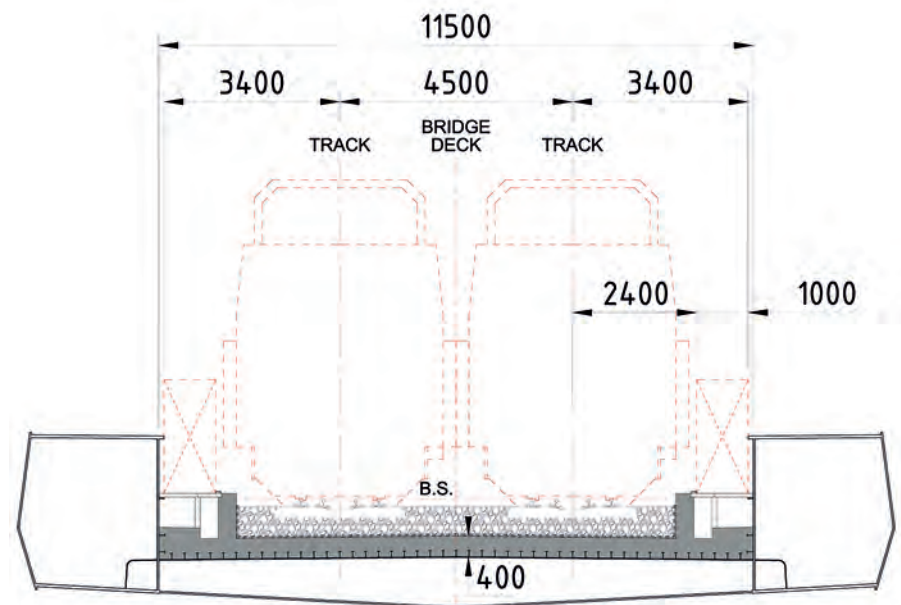


Figure 3 Bridge deck cross-section
Courtesy: Iv-Infra b.v.

The main girders and arches are box girders. The depth of the main girders is 3.05 m and the width varies from 2.38 to 2.74 m. The cross-section of the arch member is about 3.60 m by 2.50 m, with longitudinal trough stiffeners. To avoid expensive internal corrosion protection, the client did not require the girder to be accessible as internal inspections are not expected to take place during the lifetime of the bridge. In case of damage due to a truck collision, the main girders are easy to disassemble, with access

hatches. The complex welded connection details were optimised for strength and fatigue resistance.

Because the bridge is situated in a populated area, a deck design which minimised noise emission as a result of train passage was required (Figure 3). The deck consisted of steel cross beams acting compositely with a concrete deck, provided with a gravel bed. Other noise reducing elements included gravel mats on top of the concrete and sound barriers.

Fabrication and installation

Disruption for both road and train traffic had to be kept to an absolute minimum during construction and commissioning of the bridge. The structural steel bridge components were fabricated in two sites in Belgium. The pre-fabricated bridge sections had to fit into a virtual envelope of 3 x 4 x 20 m, weighing between 80 and 200 tonnes, in order to facilitate transportation to site by road during the night, to minimise disruption.

The bridge was first assembled next to the A1 motorway (Figures 4, 5 and 6). In a seven hour night-time operation, it was then moved over the A1 using self propelled modular trailers (with a total of 976 wheels) and positioned on temporary supports, parallel to the original bridge. This was the largest object ever to be moved across a roadway in the Netherlands. Construction of the new bridge was then completed with a concrete deck, the rails and the overhead line. The old railway bridge was subsequently demolished and the new railway bridge slid into place. During the entire project, there were only two brief closures of the track (52 hours and 120 hours) and only one closure of the roadway of up to 12 hours. The reduction in bridge weight which was possible due to the use of high strength steel made transportation and lifting easier, as well as reducing the overall project carbon footprint.



Figure 4 Assembly of the arch sections using strand jacks
Courtesy: Iv-Infra b.v.



Figure 5 Assembly of Zandhasen bridge by the side of the A1
Courtesy: Rijkswaterstaat



Figure 6 Assembly of Zandhasen bridge
Courtesy: Iv-Infra b.v.



Figure 7 Bridge being moved over A1 by self propelled modular trailers
Courtesy: Iv-Infra b.v.

References

- EN 1993-1-1 Eurocode 3: Design of steel structures. General rules and rules for buildings.
 EN 1993-1-10 Eurocode 3: Design of steel structures. Material toughness and through-thickness properties.
 EN 10025-4 Hot rolled products of structural steels – Part 4: Technical delivery conditions of thermomechanical rolled weldable fine grain structural steels.

Langedijk, Walter, van Lierop, Pieter and van Korten Hof, Britte (2016):
 Design and construction of a large railway bridge in a complex traffic junction. Presented at: *Challenges in Design and Construction of an Innovative and Sustainable Built Environment*, 19th IABSE Congress Stockholm, 21-23 September 2016, pp. 2543-2550.

Parties involved

Architect
Design and supervision of fabrication and construction
Owner
Client
General Contractor

Steel construction
Steel producer

Zwart & Jansma Architects
 Iv-Infra b.v.

ProRail
 Rijkswaterstaat
 SAAone (consortium VolkerWessels, Boskalis, Hochtief en DIF)
 Victor Buyck Steel Construction
 Dillinger

This [timelapse](#) video shows the hoisting of the middle arch and this [animation](#) shows the construction, transport and placement of the railway bridge.



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