Railway bridges / fly-over “Sporen in Den Bosch”

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Summary

The project “Sporen in Den Bosch” in it’s total is meant for the modernization and refurbishment of the railway area of Den Bosch. It is designed to solve several bottlenecks in the railway transport around Den Bosch. All the railway traffic around “Den Bosch” Station which is crossing the Dieze river, now has to pass on one double track steel bridge. During the process two new concrete trough bridges are to be built and the steel bridge is to be replaced while the railway traffic more or less has to continue. For these bridges a new concept of prefabricated concrete trough structures is used. The construction works started at the end of 2011 and will be finished in the spring of 2014. The client for the project is ProRail, the managing organisation of railway-infrastructure in the Netherlands.

Keywords: building in restricted areas, building within restricted time-periods, pre-tensioning post-tensioning, prefabrication, concrete railway bridges.

1. Introduction

The construction works of the project “Sporen in Den Bosch” consist of two concrete bridges and a concrete viaduct (fly-over) to cross the river “Dieze” and cross the railway, all to be built in a restricted area, full of railway tracks, switches and equipment, directly to the north of the railway station “Den Bosch”.
The building process should hinder the existing railway transport process as little as possible. Completely stopping the train traffic is only allowed during the so called “Train Free Periods”. They need to be planned long beforehand in consultation with “ProRail”. These periods of time (weekends) are the most important milestones in the planning of the complete project. Apart from these periods there are also the regular, shorter, train free periods during night-hours. For the replacement of the existing double track steel bridge by the concrete double track trough-bridge a train free period of 11days is available. During that time the existing bridge has to be removed, parts of the foundation have to be built and the new bridge has to be shifted to its final position.

The bridges are concrete trough bridges crossing the river Dieze with 3 spans of approximately 50-55m. The fly-over also is a concrete trough crossing the Dieze and crossing the tracks over the bridges, with a total length of 350m, which consists of 7 spans of approximately 50m.
The span of the trough-bridges / fly-over is the largest span in concrete trough railway bridges ever built in The Netherlands.
The bridges and viaducts are complex composite structures of high-strength concrete with pre- and post-tensioning combined. They are partly prefabricated and partly concrete cast on site.

2. Tender design

2.1 Preliminary design

On the basis of a preliminary design the client asked for contractor-bids. In the preliminary design the vertical and horizontal alignment (layout) of the tracks were a provided as a starting point. On this basis trough structures have been chosen.

The architectural appearance of the trough superstructure was also part of the preliminary design. Part of the architectural features is a “wicker-work” of aluminium surrounding the bridge and the train. Also part of the architectural appearance in the preliminary design was the use of “upside down” conical columns for the piers.

2.2 Trough bridges

Trough bridges can either be materialized as completely concrete structures, composite steel- and concrete structures or completely steel structures. The most cost effective design turned out to be a partly prefabricated concrete trough-bridge. In fact these can only be built as statically determinate structures. Finally the option chosen for the tender bid were the two bridges and the fly-over as a set of statically determinate concrete trough bridges, with as much prefabrication as possible in order to speed up the building process and to use as little as possible heavy temporary structures.

3. Substructure

The substructure can be divided in the those for the two bridges and the ones for the fly-over. For the fly-over there are 2 abutments and 6 piers. The piers are materialized as portal frames with 4 columns on a foundation, forming one pier supporting the superstructure. One of the abutments is build up of a row pipe-piles Ø1370mm filled with concrete and anchored at an anchor wall, with a large reinforced concrete girder on top. For railway projects this construction type has never been used in the Netherlands. The other abutment is made of reinforced soil on which a foundation slab is placed. This also is unique in the Netherlands.

One of the piers of the fly-over is made of a “portal-frame construction” which spans two tracks. This complete portal-frame, table 13m × 5.5m, about 6m high, is built next to the final location and has to be lifted in place as a complete unit over the overhead lines. The columns had to be connected to the foundation slab by pouring the concrete in the slab around the column after placing the portal-frame. Building this pier on the location itself is impossible because of train-traffic interruptions. Because of its dimensions and weight, 305 tons, enormous lifting equipment is needed.

The substructure of the two bridges consists of two abutments and two intermediate piers in the river Dieze.

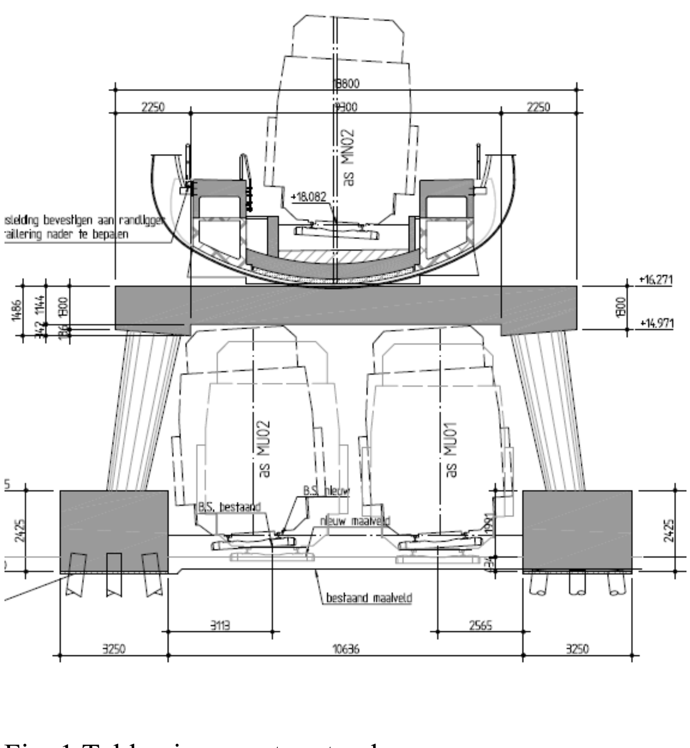

Fig. 1 Table pier over two tracks

The intermediate piers for the double- and single track bridge are a single continuous foundation slab, in line with the piers of the fly-over.

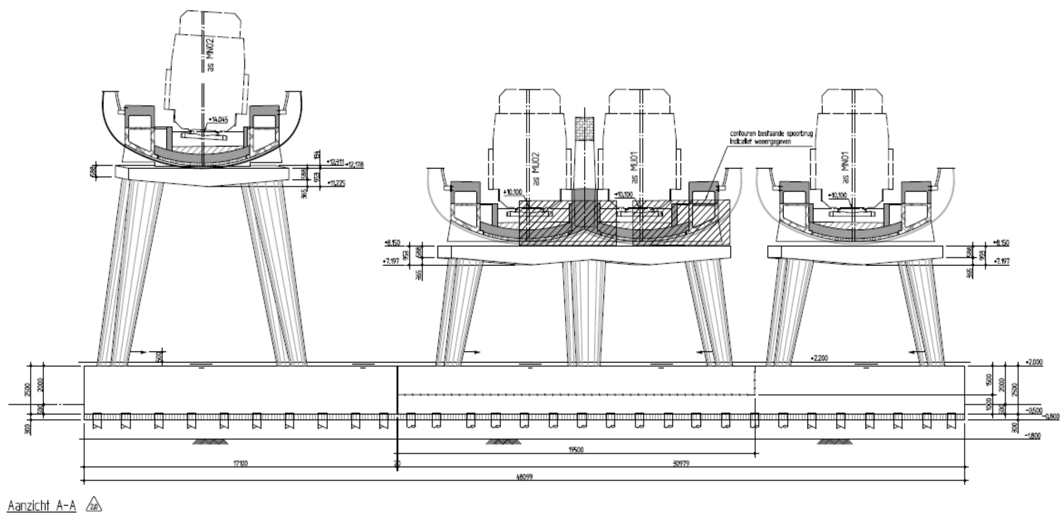

Fig. 2 Piers of the double- and single track bridge.

The substructure of the double track bridge is built below the existing steel bridge. In the first stage the lower half of the foundation slab has been built. The prefabricated columns are lifted- / shifted in from the side, then the table on top is poured, below the existing bridge. Next step is lifting the complete unit of columns and table and building the upper half of the foundation slab.

Fig. 3 The completed substructure barely fits underneath.

4. Superstructure

The superstructure of the bridges and the viaducts is a complex composite structure of high-strength concrete with pre- and post-tensioning combined. They are partly prefabricated and partly concrete cast on site.   The cross section of both consists of:

- High strength concrete box-girders, pre-tensioned C70/85;
- Onsite cast, upside down U-section, on top of these box girders, high-strength reinforced concrete C70/85, cast on top after partly jacking up the box-girders on site;
- In between the girders are prefabricated curved shell elements C53/65, spanning 5m;
- On top of the shell-elements onsite cast concrete C35/45 to compose the floor of the trough with post-tensioning in longitudinal- and cross-direction.

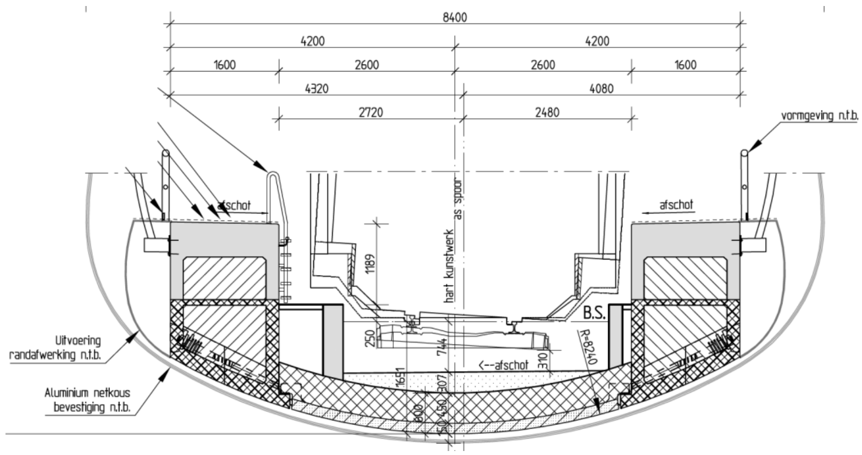

Fig. 4 Basic cross section of the fly-over and the single track bridge

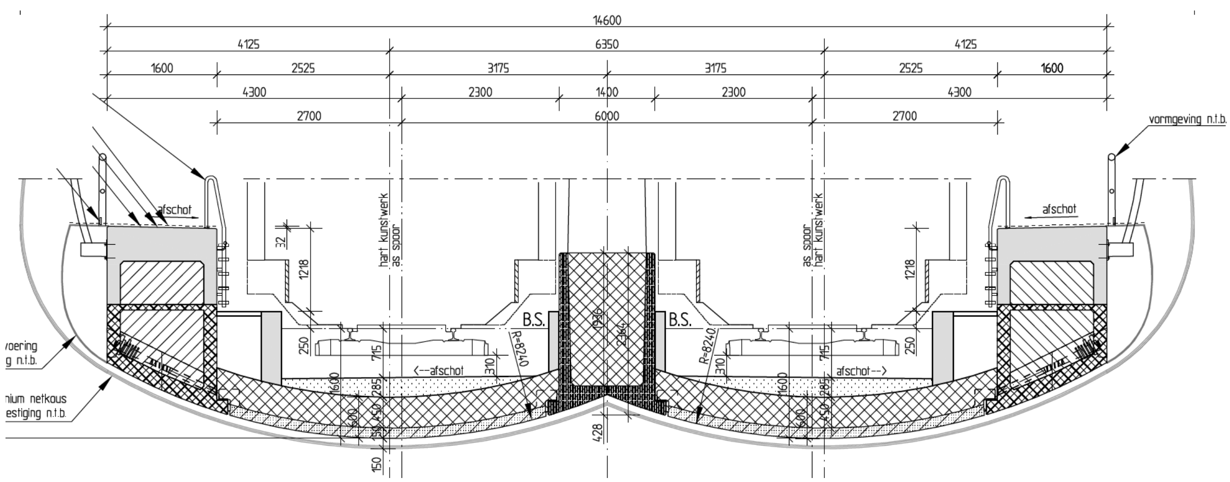

Fig. 5 Basic cross section of the double track bridge.

The double track bridge is built with an additional, heavily loaded, central-beam in between the two tracks, which supports 70 % of the double-track movable loads. The central-beam consists of a U-shaped prefabricated form (C70/85) filled with cast in-situ post tensioned concrete C53/65. On top of this lower beam there is a truss girder. This truss girder is composed of prefabricated reinforced elements C70/85. The lower beam and the truss together have a total height of 6m. The open structure formed by the truss girder was a required architectural feature.

Fig. 6 The central beam with the truss girder in its mounting frame

4.1 The building process

4.1.1 The fly-over

The concrete box girders, also with a curved shape at the lower side, are made by the prefab-contractor, at a distance of ±35 km from the site. The maximum length is 56m, the maximum weight 162 tons. The girders are heavily pretensioned, the weight is kept low by poly-styrene blocks in the girder. The box girders are transported by special heavy trucks to the site. On site the box-girders are positioned on temporary bearings. At the centre of the span the girders are jacked up to a calculated deformation at 3 positions. Then the concrete upside down U-cap is poured on top. This part also is with polystyrene blocks in it to reduce the weight.

In the box-girder on right the recesses for the post tensioning in cross direction can be seen.

This post tensioning consists of 10 strands 150mm^2 per cable each. At a centre to centre distance of 1.2m.

Fig. 7 A pretensioned box girder without the cap (right) and a completed girder (left)

The box girders themselves are pre-tensioned with at the maximum about 100 strands 150 mm^2. Pretension force 210 kN per strand.

The U-cap on top is only reinforced, there is no pre- or post tensioning in the cap.

Fig. 8 The process of building the U-cap on top

Fig. 9 Lifting the completed girder

After hardening of the concrete the complete girders of all the spans of the fly-over are lifted over the overhead lines onto its final bearings on top of the already built substructure. The maximum weight then is 344 tons.

With two girders in position on the substructure then the curved floor-elements can be put in-between. The two girders need to be stabilized by a frame to prevent rotation and horizontal displacements. After all the floor-elements of one span are laid out there is a closed trough bridge above the tracks. In this composed trough the rest of the reinforcement and post-tensioning can be built. Finally the floor can be cast.


Fig. 10 Curved floor elements


Fig. 11 Equipment for the tensioning of cross tensioning

After the floor is hardened the post tensioning in cross- and longitudinal direction can be activated.

The cross directional post-tensioning is put into place and tensioned from a carriage hanging on the outside of the trough.

In between two consecutive spans there is enough space for the jacks for tensioning the longitudinal post-tensioning.

4.1.2 The double track bridge

The double track bridge is built in basically the same way as the fly-over. The separate girders are all built on the north bank of the river. Once finished they are moved by SPMT- vehicles and a sheerleg to an "auxiliary structure" across the river Dieze adjacent the existing double track steel bridge. The maximum total weight of a competed middle beam with truss is 640 tons.

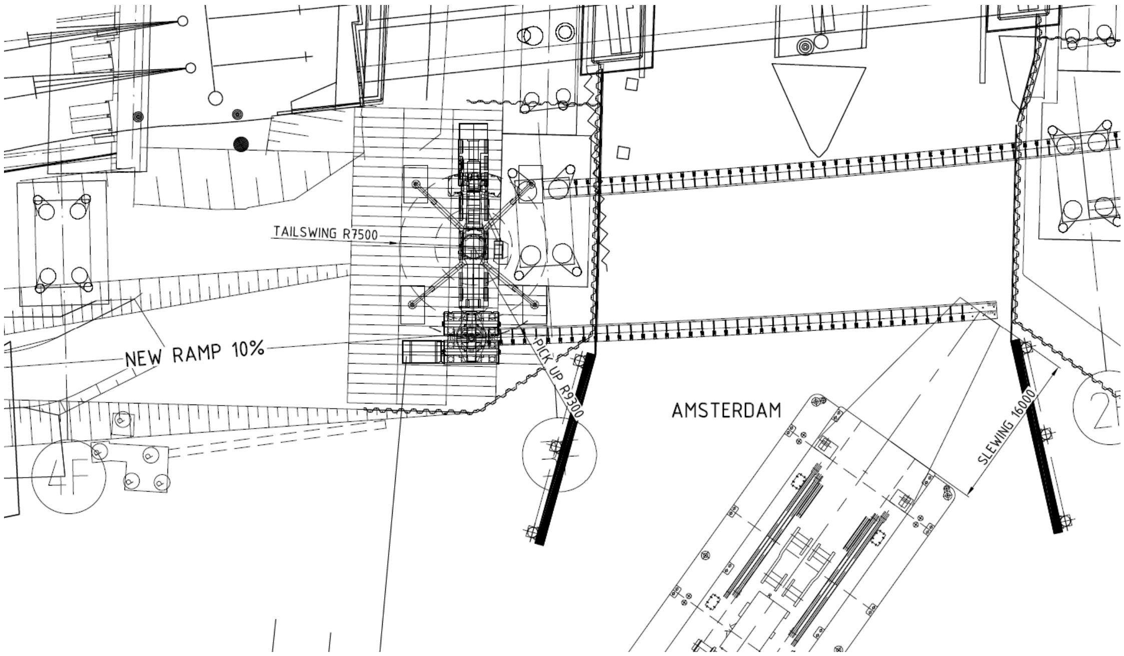

Fig. 12 Combined action of SPMT + Sheerleg

Fig. 13 The start of the auxiliary structure.

The auxiliary structure consists of the piers of the single track bridge as well as a temporary pier. On this position the double track deck is built together and afterwards as one complete deck-unit shifted in cross direction onto its final position on the already built substructure. This is one of the actions which has to take place in the train free period of 11 days.

5. Execution

In the meantime a lot has been explained about the execution on site. The main theme in the execution of this railway related project is that the building process should hinder the existing railway transport process as little as possible. In order to accomplish this first of all the superstructure was partly prefabricated. Besides this, also many parts of the substructure were prefabricated on site. This is extremely useful because most of the substructure has to be built directly next to the tracks with ongoing railway traffic. This means all of the columns and the tables on top were prefabricated on site. This prefabrication also helped to meet the required high quality finishing of the concrete surfaces. The prefabricated columns had to be placed in an auxiliary structure on the foundation slabs.

Fig. 14 Placing of prefabricated columns

All of the prefabrication and replacing bridges caused for a lot of auxiliary works, which is as usual in railway related projects. For this project there also are a lot of complicated and coordinated lifting and transportation actions needed. Herefore various equipment is used; mobile cranes, crawler cranes, SPMT's and a sheerleg.

6. Discussion, Conclusions

There certainly are many more details involved in the building of the bridges being discussed. However the timely finishing of the project has proven the adequacy of the choices made. As a conclusion the project demonstrates that the choice of prefabricated parts and their composition as a structure to a large extent has contributed to the progress of the project as scheduled.

7. Acknowledgements

The main contractor of the project is Heijmans Civiel, the prefab-contractor is BetonSon. Chief design engineer is Breijn, the incompany engineer of Heijmans, Movares and Wagemaker are the engineering partners. We want to express our thanks to the client (ProRail), the main contractor (Heijmans) and the engineer, (Breijn / Movares / Wagemaker) for the opportunity to write a paper about this project for the IABSE-conference.