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Barkarby Bridge

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Abstract. Barkarby Bridge is a bridge designed to take part of the Barkarby-Kallhäl section in the Sundbyberg-Kungsägen highway line project in Stockholm, Sweden. This bridge allows the road traffic to cross over the Sundbyberg-Kungsägen railway line and over the Västeras-Stockholm highway. This is a singular bridge because is intended to be used as a road bridge in a first phase, and as a combined pedestrian-road bridge in a second phase. In addition, it will provide access to the pedestrians to the new railway station. These factors have implied to design a non-usual trapezoidal and variable deck. The deck typology corresponds to a composite steel/concrete type.

1. Introduction
Barkarby Bridge is located in the Barkarby-Kallhäl section in the Sundbyberg-Kungsägen highway line project in Stockholm, Sweden. This bridge allows the road traffic to cross over the Sundbyberg-Kungsägen railway line and over the Västeras-Stockholm highway.

This bridge was intended to replace the old Barkarby Bridge which was unable to adequately make the traffic compatible with the new uses needed: the bridge had to be connected to the new railway station. In addition, the old bridge was affected by several typical pathologies of old concrete bridges in city environments. Hence, Trafikverket, the Swedish road authority decided to replace the old bridge and construct a new one adjacent to the old one which was finally demolished.

This is the first bridge that Acciona Infraestructuras Swedish Filial has constructed in Sweden as an EPC contractor. Acciona Ingeniería carried out the detailed engineering of the project and was in charge of the works assistance during its execution. Acciona Infraestructuras itself executed and delivered the project.

2. Description of the bridge
Barkarby Bridge presents a total length of 250.25 m developed in a straight line in plan view except for the last 17 m where follows a circular route with a radius of 500 m. The total length is distributed over 9 spans with a maximum clear span of 32.40 m. It is modulated in three different decks. The first deck is comprised by the first span only. The second deck is comprised by the following three spans and the third deck is comprised by the last 5 spans. See figure 1.

The first and the third deck are 8.00 m wide and are designed with the same deck typology: twin I-cross section steel girders of constant depth of 900 mm separated 3.46 m at the bearing level and are aligned in a parallel way to the centerline of the deck. See figure 2. The singularity of these girders is that their webs are inclined: the planes that contain them are not vertical. The second deck has a variable width from 11.10 m to 13.80 m, and it consists of three I-cross section steel girders of constant depth of 900 mm and inclined webs as well. See figure 3.

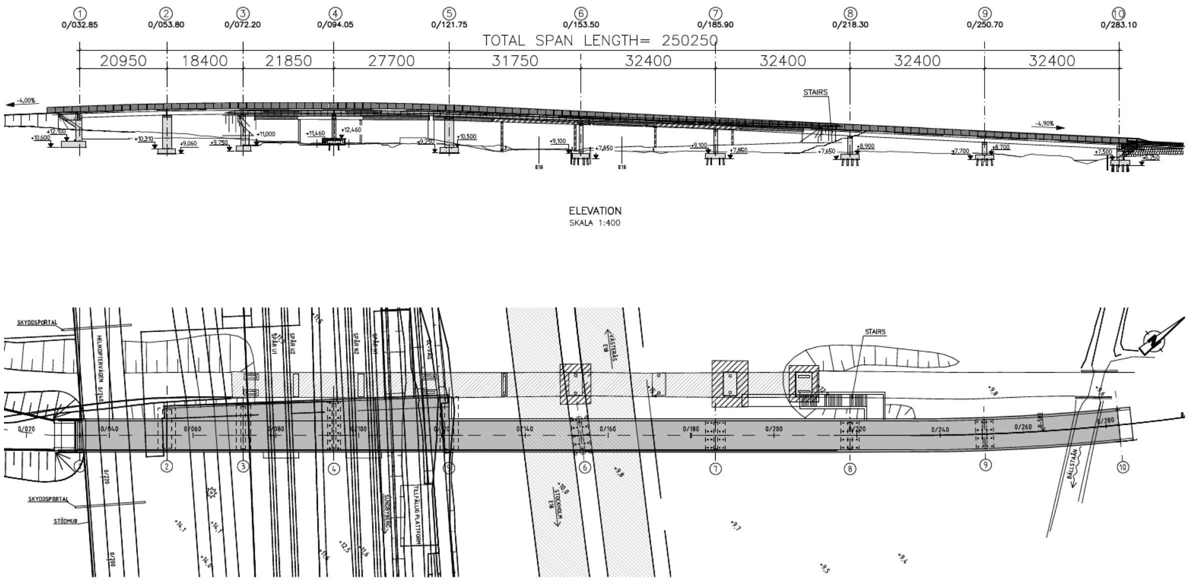

Figure 1. Plan and elevation view.

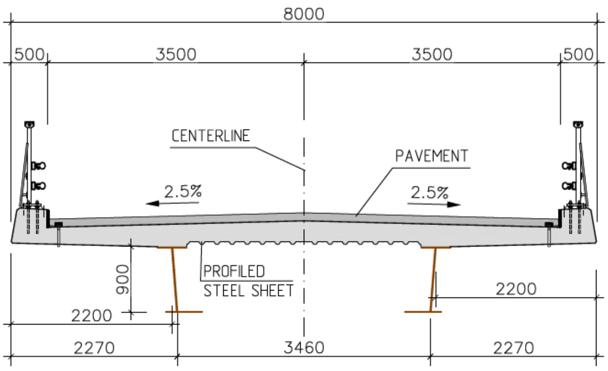

Figure 2. Twin-girder deck cross section.

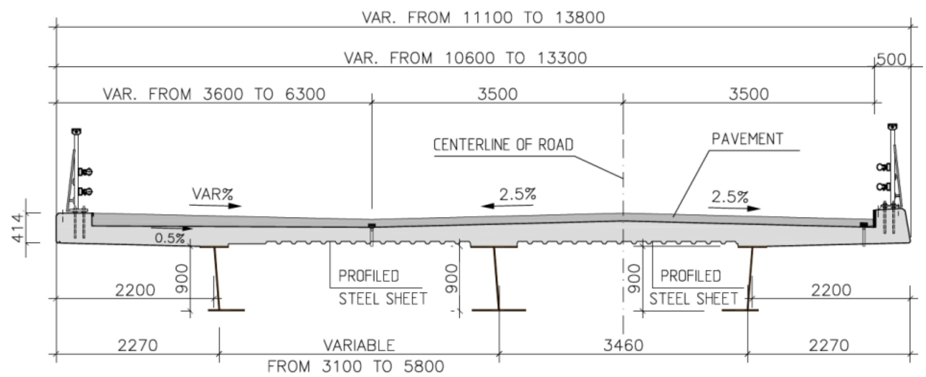

Figure 3. Three-girder deck cross section.

A diamond-type bracing was designed between the lower flanges of the steel girders to withstand the torsional forces that could act on the deck. K-bracing intermediate stiffeners have been located each 3.459 m to control de distortional effect of the eccentric loads that act on the deck. The diaphragms are located on the piers and the abutments. See figure 4.

Figure 4. Diaphragm, intermediate stiffeners and diamond-bracing.

On top of the steel girders a concrete slab of 28.2 cm maximum depth was casted by means of temporary hanging formworks in the cantilevered zones of the decks and permanent profiled steel sheets in the central zones. The top concrete slabs have a constant cross slope of 2.5% in the first and third decks, which implies a minimum depth of 21.6 cm at the edge of the deck, but varies in the second deck. Hence, the decks are composite steel/concrete decks. Each cantilever of the slab is 2.20 m long. The decks accommodate two road lanes of 3.50 m wide each one, and 0.50 m at both sides to locate the lateral barriers.

All of the exposed steel surfaces, including the profiled steel sheets, were applied an anticorrosion protective system C5M-H. The preparation grade of welds, edges and other areas with surface imperfections was P3 [1] according with the strict Swedish standards.

The pavement is 11 cm thick and is located between the inner sides of the lateral barriers.

At both ends two abutments have been designed. All of the intermediate supports are reinforced concrete wall piers and their mean height equals to 6.00 m, with maximum height of 7.90 m. The support 6 is designed parallel to the highway direction, so its axis is skew with an angle of 7.639g. The support 4 is located in the middle of the railway platform. As a result, due to the few hours available for the construction of this pier, the pier has been designed with three steel profiles columns in a first phase. On top of these three columns, a precast concrete pier cap is located. The dimensions of this pier cap are 1.00 m thick, 9.760 m wide and 1.00 m long. The pier was finally casted with the rest of the concrete in a second phase. See figure 5.

Figure 5. First stage of support 4 and unshored erection of deck.

The embankment behind abutment 10 is designed with cellplast (extruded polystyrene, or XPS) in order to reduce the weight transmitted to the soil due to the low bearing capacity of the latter. In addition, the foundation soil of this abutment needed to be treated to improve its bearing capacity by means of gravel cement columns. See figure 6.

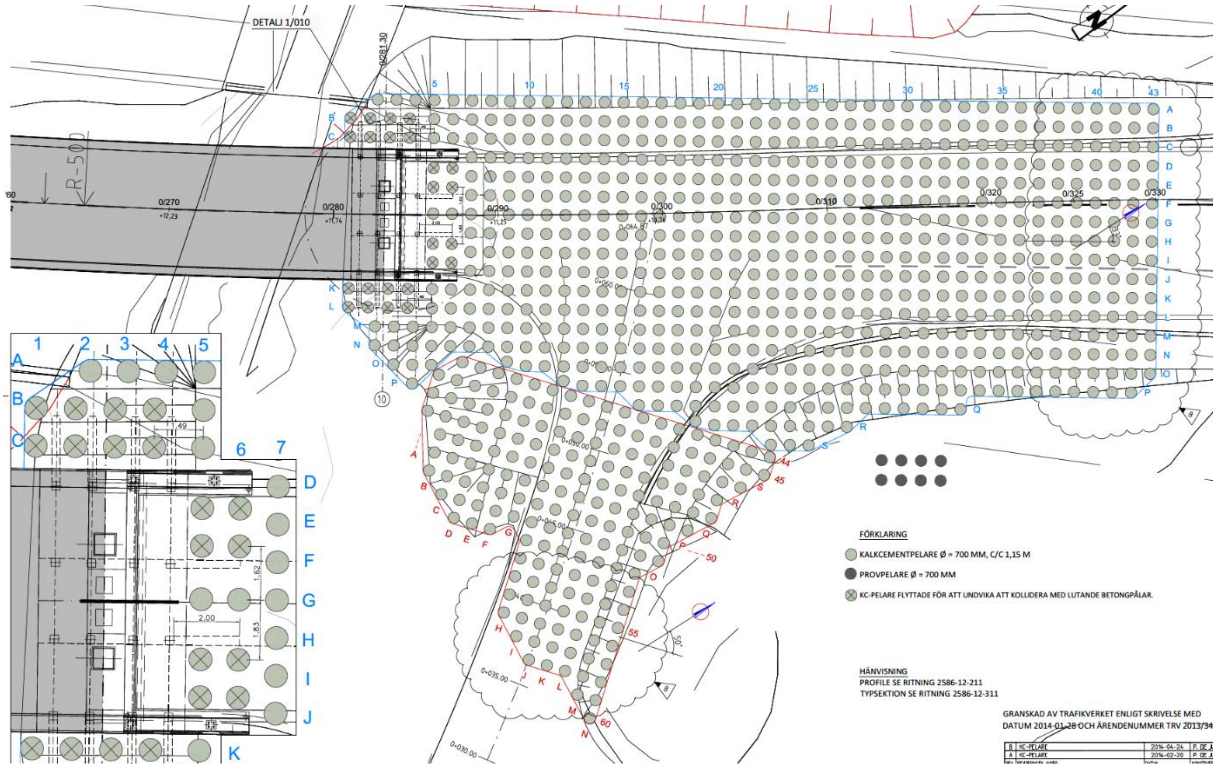

Figure 6. Treatment of embankment behind abutment 10.

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Supports 1, 2, 3, 5 are designed with spread foundations. The rest of supports are designed as deep foundations with precast square piles of 275×275 mm, except for support 4, where the piles are designed as steel pipe piles Ø220×10 mm.

The bearings are comprised by laminated elastomeric bearings which although widely spread in Europe, they are not of common use in Sweden.

3. Erection of the bridge

The foundation was constructed using classical construction methods for the spread foundations and for the deep foundations as well.

The piers and the abutments were carefully casted to account for the inner and surface temperature of the young concrete in order to limit the surface cracking of these elements. It is really common in Sweden, due to the low temperatures during the winter and the hydration heat of the concrete, to partially isolate the formwork to limit the temperature gradients.

Simultaneously, the steelwork of the deck was fabricated in Spain by the workshop of Acciona Infraestructuras. See figure 7. Then the steel components were transported from Spain to Sweden by road and sea. Due to transport dimensional limitations the steelwork of the deck was broken down but keeping in mind to minimize the need of field splices on site. These splices were executed on site by welding.

All of the construction stages of the bridge have been designed in order to avoid road and railway traffic disruption. As a result, the construction process is a relevant part of the bridge design. So, it was decided to erect the decks in an unshored way, just reducing the need of shores to the main welded girder splices only.

Once the steel girders and the diamond-type bracing were completely erected, the top concrete slab formwork was erected on the girders on site by means of conventional mobile cranes. See figures 8 and 9. The formwork was removed as soon as the top slab concrete strengthened and reused in other sections of the deck.

The final stages of the bridge erection consisted of the erection of the barrier, light poles, pavement, road signs, electric heating pipes and urban services, etc. See figure 10.

Figure 7. Fabrication at workshop.

Figure 8. Unshored formwork of the concrete slab.

Figure 9. Several erection stages, simultaneously.

Figure 10. General view of the bridge.

4. Design and calculations

In essence, the decks of the bridge act as a box girder deck: the lower diamond-type bracing simulates the lower plate of a box girder deck and the top concrete slab acts as the top plate of a box girder deck once the concrete strengths. However, detailed calculations were carried out to assess the risk of lateral-torsional buckling during the casting of the top concrete slab because in that very moment the box girder deck mechanism is not completely closed. See figure 11.

All of the construction stages have been taken into account in the calculations by means of the computer program RMBridge. This computer program allows to easily accumulate the tensional state of all of the most significant cross sections of the decks as the erection progress.

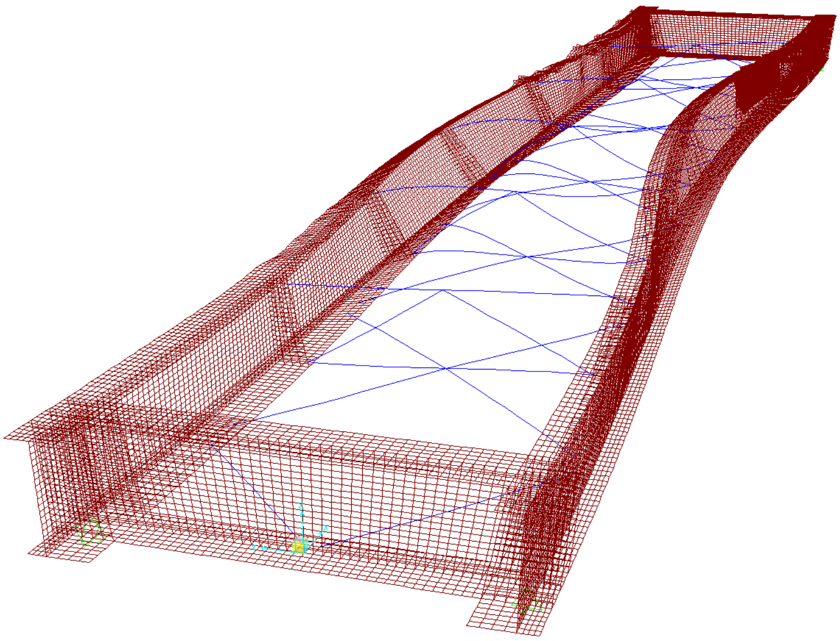

Figure 11. Lateral-torsional buckling assesment.

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References
[1] International Organization for Standardization (ISO) 2006 Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness. Part 3: Preparation of grades of welds, edges and other areas with surface imperfections *ISO 8501-3*