Extended summary section A

The Van Brienenoord bridges are a set of bridges in the province of South Holland, crossing the river New Meuse. The first bridge was opened in 1965, the second in 1990. Both bridges are still operational This case study focuses only on the first (Eastern) bridge.

The bridge carries the A16 motorway in northernly direction. At the location of the bridge, the A16 motorway consists of a main carriageway and a parallel carriageway in a local-express lane system. Both carriageways consists of three lanes.

The bridge consists of (starting from the north side) of a (concrete) approach bridge, a (steel) bascule movable bridge, the (steel) main arch and a (concrete) approach bridge. This case study focuses on the main arch only. The total length of the bridge is 1320 meters. The length of the main arch is 306 meters with a span of 287 meters. The width of the bridge is 33,5 meters.

The main span consists out of a tied double arch structure with diagonal hangers supporting the main girders. The arches and main girders are placed 24,9 meters center to center. The bridge has an orthotropic deck that spans on to cross-girders. The cross-girders then span between a central girder and the two outer main girders. To the outside of each arch, cantilevering from the main girders is a cycle path. The arch is mostly constructed out of S355 steel.

The arches are braced in plan with diagonals and cross members . The main girders are supported from the hangers connected to the arch. There are a variety of connections in the bridge. They can be welded, riveted or a combination of riveted and bolted (at the hanger connections). When the new West bridge was built in 1990, the West cycle path was no longer accessible. Instead of adding a new cycle path to the new West bridge, the existing East cycle path was widened.

The arch is formed from a box section. It has a constant cross section over the central section of the bridge of 2,5 by 1,25 meters. As the arch approaches each of the spring points, it increases to a maximum depth of 3,17 m. The web plates of the arches are internally braced with a longitudinal stiffener and diaphragms. The longitudinal stiffener is supported by a K-bracing which runs along the entire length of the arch at mid-height of the webs.

The diagonal and horizontal bracing members of the arch are box sections. In the middle of the span the bracing acts as a truss. At the spring points, the bracing members form a moment resisting portal frame to stabilize the arch while allowing traffic to pass through.

The main girders are box sections of 3,5 meters by 1,2 meters but increase to 5,1 meters in height near the arch spring point. Plate thicknesses vary of the span. At the centerline of bridge the central girder is placed. It consists of a continous I-beam spanning between major cross girders at 14,35 m centers. It has a height of approximately 2 meters. The top flange of the central girder is formed by the deck plate.

There are three main types of cross girders. All are I-sections where the top flange is formed by the deck plate. Firstly, there are the arch spring point cross girders, which are heavier since they are part of the moment resisting frame stabilizing the arch. Then there are major cross girders and minor cross girders. The major cross girders are spaced at 14,35 centers. These support the central girder as well as the orthotropic deck. The minor cross girders are shallowerer and span between the main girders and central girders. They are spaced every 2,05 meters and support the orhotropic steel deck.

The orthotropic deck consists of a 10 mm steel deckplate stiffened longitudinally by open stiffeners (bulbs) spaced at 300 mm.

Traffic across the bridge is heavy with approximately 2 million trucks passing per year (2020). About 3/4 of these are on the main carriage way, the other 1/4 on the parallel carriageway. The number of trucks is expected to grow to approximately 3 million in 2050.

Extended summary section B

The bridge owner (Rijkswaterstaat, the ministry of transport) has concluded, on the basis of an exploratory assessment, that various parts of the Van Brienenoordbridge may reach the end of their design life in the coming years. As a result, it has posted a request for proposal for a complete recalculation of the bridge (ULS and FLS) and the design of strengthening measures or control measures (such as inspection or monitoring). The scope of the analysis includes the main arch structure and excludes the movable bridge, approach spans and foundation.

The recalculation needs to be performed according to the relevant Eurocodes, their Dutch National Annexes, a supplementary Dutch code for existing structures (NEN8700) and a document of supplementary requirements by Rijkswaterstaat (RBK). All these documents follow the load and resistance factor design as used in Eurocode.

Before the analysis, the contractor is required to perform an extensive inspection of the bridge. The results of this inspection are to be incorporated in the subsequent analysis and/or strengthening report of the bridge.

To validate the calculation models that will be used for the recalculation of the bridge, Rijkswaterstaat requested a monitoring program of a minimum of 3 months. These measurements are performed on various parts of the bridge (main bearing structure, cross girders, deck). Besides measuring normal operation for 3 months, a controlled load test is to be performed where a truck of known weight and dimensions passes over an otherwise empty bridge. During the bridge closure for this load test, the forces in the hangers are to be measured as well while the bridge is empty.

The measurements during this controlled load test will be directly compared with a similar load configuration in the calculation model of the bridge. Significant differences between the measurements and model results are used to adjust the model to better replicate the real behavior. These adjustments are made based on engineering judgement. Examples of adjustments are: changing certain connections from fully fixed to a spring or fully hinged or changing the behavior of the supports.

The measurements during the three months in normal traffic will be used to determine the actual fatigue load spectrum (stress spectrum) at various locations in the bridge. This can be compared with the load spectrum that results from the normative spectrum imposed on the calculation model. Furthermore, the measurements in the three months in normal traffic will be used to predict the ULS stresses at the measurement locations. These can also be compared with the ULS stresses resulting from the normative loads imposed on the calculation model. The results from the measurement analysis are foreseen to either replace the model results, or be used for calibration of the model results on the basis of engineering judgement (e.g. scaling the model results based on the measurement results).

The results from the analysis either show that the bridge can safely fulfill its remaining design life, or that measures are required. Measures can be strengthening of the bridge, repair of existing cracks or monitoring certain locations where fatigue damage is expected. In case of critical situations, load restrictions and/or change or use can possibly be applied in the time period between the analysis and the subsequent strengthening or other measures.