Extended summary A

The Haringvlietbrug is a bridge in the province of South Holland, crossing the Haringvliet North Sea inlet. It was opened in 1964 and is currently still operational. The bridge carries the A29 motorway as well as a local road. The motorway consists of 2 lanes in southernly direction and 2 lanes in northerly direction. The parallel local road consists of one (relatively wide) lane which allows traffic to pass in both directions.

The bridge is constructed (starting from the north side) out of a 80 m side span, a 40 m long bascule movable bridge and an 1059.2 m long main bridge. The monitoring focuses only on the non-movable main bridge and side span.

The main bridge consists of a continuous steel box girder beam over 11 supports, with 10 spans of approximately 106 m. The side span consists of a single span box girder bridge. The box girder bridges consist of a 11,5 m wide, 5,4 m high steel box girder on which a 25,5 m wide deck is placed, carried by transverse steel girders. The deck is stiffened with open stiffeners (bulbs). The movable bridge consists of two plate girders, on which a similar deck is placed as on the box girders.

The motorway lanes in southernly direction are placed on the west cantilever of the deck. The motorway lanes in northerly directly are placed approximately central on the deck. The parallel local road is placed on the east cantilever of the deck.

The box is stiffened every 2,2 m with a ring frame consisting a bottom cross girder, stiffening of the side wall and a top cross girder cantilevering on two sides carrying the deck. The bottom, sides and top (deck) of the box are stiffened. In case of the 10 mm thick deck plate, these stiffeners are placed 300 mm center to center. Every fourth ring frame, diagonal struts are placed outside the box, supporting the cantilevering part of the deck. At these locations, further internal cross bracing is provided as well. Running underneath the cantilevers between the external diagonal struts, an approximately 600 mm high secondary beam is placed. The box is constructed out of separate pieces of approximately 12 m length. which are riveted together. The bridge is constructed out of S355 steel.

Traffic across the bridge is heavy with approximately 1,5 million truck passing in each direction, per year (2020). A remarkable increase in traffic was seen since the year 2014 due to the construction of the A4 motorway between Delft and Rotterdam, making the A29 motorway a more logical route for many trucks. The number of trucks per direction is expected to grow to approximately 2 million in 2050.

Extended summary B

The bridge owner (Rijkswaterstaat, the ministry of transport) has concluded, on the basis of an exploratory assessment, that various parts of the Haringvlietbridge will reach the end of their fatigue life in the coming years. As a results, 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 full steel structure of the main bridge and side span, but excludes the movable bridge and foundations.

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. The bridge needs to be recalculated assuming a residual design life of 30 years.

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 and 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 during 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.

The measurements during this controlled load test will directly be 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 supports from fully sliding to partially sliding.

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 traffic 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 of use can possibly be applied in the time period between the analysis and the subsequent strengthening or other measures.