Project related

5.22.4 Detail D - Bulkhead connection - horizontal flange longitudinal stiffener

Detail D is located at the bottom of the knee bulkhead, at the connection with the horizontal flange of the longitudinal stiffener. Measurements were taken in two places for this detail. In the measurement plan was originally indicated to measure in line with the end of the body of the transverse stiffener. However, it was mistakenly measured in line with the outside of the vertical flange of the longitudinal stiffener (D1) and 10 mm inwards, in line with the inside of the vertical flange of the longitudinal stiffener (D2).

D

Figure 228 - Detail photos DD-K24 detail D1 and D2 south and north.

Detail D - toe of the weld

The stress at the toe of the weld is determined in the model by the hot spot voltage at the peak of tension in line with the body of the transverse stiffener (see black line), by extrapolating the voltages to 0.4t and 1.0t. This therefore deviates from the location of the measurement (purple line).

E

D

F

Figure 229 - Voltage at the location of the bulkhead connection - horizontal flange longitudinal stiffener - transverse stiffener body (σ_{y+}) due to the unit load (2x50 kN)

Appendix G compares the calculated hotspot voltage and the measured hotspot voltages at D1 and D2, both for the north and south sides. Because the measurement on the wrong place, this comparison is not from the same location and probably therefore not the location with the maximum voltage. The comparison in this case is therefore only limited utility. The shape of the influence line does match. The highest voltage occurs at location D2_noord.

.

Figure 230 - Hotspot voltage DD-K24 detail D2-north

The stresses due to the unit load are not multiplied by one for the fatigue calculation model factor since the location of the strain gauges does not match the location where the maximum tensions occur. The fatigue test is therefore based on the calculated influence line. In the test is based on Detail category $\Delta\sigma_c$ = 90 N / mm², based on IIW report "Recommendations for Fatigue Design of Welded Joints and Components ", table 3.3, detail 6, comparable for detail A1.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	4.1	11.0	4.0	7.7	3.4	6.9	1.9	3.8
1.15	2.2	6.0	2.1	4.2	1.9	3.7	1.0	2.0
1	1.2	3.4	1.2	2.3	1.0	2.1	0.5	1.1

Table 98 - Damage figures for the end of 2018 and the end of 2050 for DD-K24 detail D North.

Detail D - Root of the weld

Because there is a strong voltage gradient at the tip of the bulkhead, the voltage change determined in accordance with "IIW Guideline for the Assessment of Weld Root Fatigue" [11] paragraph 3.3.2. The application of this method is described in chapter 5.20.3.

The mean voltage was determined using SCIA by averaging over the last 5 mm to request tension in the bulkhead with a thickness of 10 mm.

Figure 231 - Average stress in the last 5 mm of the plate (σ_{y-}) due to the unit load (2x50 kN) at detail D

The voltage change in the weld must be determined for testing. In accordance with the above method, the (maximum) normal voltage in the weld (a = 4 mm) as a result of the unit load (2x50 kN) can be determined as follows. Determining the stresses in the weld is described in chapter 5.20.3 therefore it is not discussed here again.

In accordance with TNO Note 100315818 / ALL, the connection may be calculated with detail category 40, taking into account the available compressive stress and the residual stresses due to the weld process. This is therefore slightly more favorable as a detail category 36 * in accordance with the Eurocode.

Contrary to the method in accordance with IIW, where a comparison voltage is used, must now a distinction is made between the normal stress and the shear stresses. The normal voltage perpendicular to the longitudinal axis of the weld ($\sigma_{\perp, w, loc}$) is tested for detail category 40, taking into account the (pressure) stress present, in accordance with the above TNO method, the shear stress is parallel the longitudinal axis of the weld ($\tau_{II, w, loc}$) is tested for detail category 80 with slope m = -5, in accordance with NEN-EN 1993-1-9. The damage from both calculations must be added together.

The tables below show the test results for the normal voltage, including testing is according to the method from the TNO memorandum, both for type 1 (contact between the plates) and type 2 2 (no contact between the plates). The normative of the two assessments must be adhered to and added to the shear stress damage parallel to the longitudinal axis of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	8.3	21.4	6.9	13.2	7.0	13.5	3.4	6.6
1.15	4.9	12.7	4.0	7.8	4.1	8.0	2.0	3.9
1	2.9	7.7	2.4	4.8	2.4	4.8	1.2	2.4

Table 99 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 1)

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	5.6	14.7	4.8	8.9	4.8	9.3	2.2	4.3
1.15	3.1	8.5	2.7	5.0	2.6	5.3	1.2	2.4
1	1.8	4.9	1.6	2.9	1.5	3.1	0.7	1.4

Table 100 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient. The damage caused by the shear stress actually has to be added to damage mentioned above

It is concluded that at location D both the toe and the root of the weld are not sufficient.

Project related

5.22.5 Detail E - Bulkhead connection - horizontal flange longitudinal stiffener

Detail E is located at the bottom of the bulkhead, at the junction with the horizontal flange of the longitudinal stiffener, on the side close to the main beam body. There is a welding gate here.

E

Figure 232 - Detail photo DD-K24 detail E

Relatively low voltages were found here in the model. During the measurement it appeared that the measured tensions were significantly higher. Appendix G gives the comparison between the measurements and the calculated hotspot voltages. The highest stresses were found on the south side, where the measurement ratio to calculated hotspot voltage change equals 203%.

Figure 233 - Hotspot voltage DD-K24 detail E, south side

Detail E - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-k24, detail E, south side) and equals 203%. The tensions for the fatigue calculation, the unit load has been multiplied by this model factor, after which a fatigue calculation of the toe of the weld has been performed. This is based on Detail category $C\sigma_c$ = 90 N / mm², based on IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”[10], table 3.3, detail 6.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.5	1.6	0.3	0.5	0.4	1.0	0.0	0.1
1.15	0.2	0.6	0.1	0.2	0.1	0.4	0.0	0.0
1	0.1	0.2	0.0	0.1	0.1	0.1	0.0	0.0

Table 101 - Damage figures for the end of 2018 and the end of 2050 for DD-K24 detail E

Detail E - Root of the weld

The root has been tested in the same way as for detail D. For this, the average voltage is in the latter t / 2 = 5 mm read and translated into a voltage in the weld.

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight (see detail E for the description of this method). There is no account with the higher measured voltage, because it is difficult for the root to unambiguously determine the reduction / surcharge.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.1	0.3	0.0	0.1	0.1	0.2	0.0	0.0
	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0

1.15								
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 102 - Damage figures for the end of 2018 and the end of 2050 for detail E - root of the weld (DC = 40, type 1)

Type 1	**HRB west**		**HRB east**		**PRB west**		**PRB east**	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 103 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 2)

The maximum damage is 0.3. The damage caused by the shear stress has to be added to this. However, the above damages are so small that it is plausible that the total damage does not exceed 1.0 will come out.

It is concluded that at location E only the toe of the weld at one location does not suffice. Because location D is also not sufficient, it is recommended to replace the entire weld between D and E.

5.22.6 Detail F - Connection horizontal flange longitudinal stiffener - transverse stiffener

Detail F is located on the body of the transverse stiffener, just below the horizontal flange of the longitudinal stiffener, on the side close to the vertical flange of the longitudinal stiffener.

Figure 234 - Detail photo DD-K24 detail F

Appendix G provides the comparison between the measurements and the calculated hotspot voltages. The highest tensions including reduction occur on the north side. The relationship between the measurement and the calculated hotspot voltage change is 86%.

Figure 235 - Hotspot voltage DD-K24 detail F, south side

Detail F - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-k24, detail F, south side). This is based on a type a extrapolation. The stresses due to the unit load have been multiplied for the fatigue calculation with this model factor, after which a fatigue calculation of the toe of the weld was performed. Hereby is based on Detail category $\Delta\sigma_c$ = 90 N / mm², based on IIW report "Recommendations for Fatigue Design of Welded Joints and Components "[10], Table 3.3, Detail 6.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	61.7	158.2	49.6	90.9	52.2	100.5	22.1	42.8
1.15	37.6	96.9	30.1	55.3	31.8	61.4	13.3	25.9
1	24.2	62.5	19.3	35.5	20.4	39.6	8.5	16.6

Table 104 - Damage figures for the end of 2018 and the end of 2050 for DD-K24 detail F

Detail F - Root of the weld

The square root of detail F has been tested in the same way as for detail D. The average is for this tension in the last t / 2 = 4.35 mm read and translated into a tension in the weld.

Figure 236 - Average stress in the last 5 mm of the plate (σ y-) due to the unit load (2x50 kN) at detail F

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight (see detail D for the description of this method). There is no account account for the lower measured voltage, because it is difficult for the root to clearly determine the reduction to determine and any size violations have already been found for the toe of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	15.8	38.5	13.7	28.0	12.6	23.9	7.7	14.8
1.15	9.6	23.4	8.2	16.7	7.6	14.5	4.5	8.8
1	5.9	14.6	5.0	10.3	4.7	9.0	2.8	5.4

Table 105 - Damage figures for the end of 2018 and the end of 2050 for detail F - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	20.6	52.4	16.7	31.4	17.2	33.1	7.8	15.1
1.15	12.3	31.6	10.0	18.8	10.3	19.9	4.6	9.1
1	7.8	20.1	6.3	11.9	6.5	12.7	2.9	5.7

Table 106 - Damage figures for the end of 2018 and the end of 2050 for detail F - root of the weld (DC = 40, type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient. The damage caused by the shear stress actually has to be added to damage mentioned above.

It is concluded that at location F both the toe and the root of the weld are not sufficient.

Project related

5.23 Type DD-STPA: Main girder - crossbeam portal A connection

In addition to the local effect of an axle load above the cross beam, the portals also have global effects as the transfer of the load on the main beam to the support point. This allows the tensions in the different details deviate from the normal cross bars. The geometry of the connection between the crossbeam at portal A and the main beam is broadly comparable to the normal one crossbars with k-bandages. However, there is an extra horizontal top rail that connects to the shot, making the shot a bit wider than with the other cross bars.

Figure 237 - Overview of the connection Type STPA

5.23.1 Location of tested crossbeam

The tested and measured cross beam corresponds to the 1st cross beam of the main bridge on the north side. The voltage fluctuations in the connection are determined with the hybrid model A, in which about a length of the cross beam 1 to 3, the calculation model is constructed with plate elements. On the spot of this cross beam the body of the main beam is reinforced with ½ INP30 in the cross direction. In addition, both knee bulkheads are connected by a horizontal top rail, consisting of a composite t-profile.

Figure 238 - Location of tested cross beam portal A, DD-STPA

5.23.2 Tested details

In the connection between cross beam and main beam there are various details that are critical regarding fatigue. For each part it will be explained how the test voltage is determined, where the normative cut and which detail category applies.

G1

AB

I

G2

J

C →

I

A2

A1-B

G3

D

G4

E D

F

H

Figure 239 - Tested details of crossbeam connection (Type STPA)

Project related

The following table describes the details that have been tested and / or where a measurement is executed.

Detail	Description	Fatigue test	Measured
A1	Fillet weld bulkhead - bottom flange (type a)	X	X
A1	Fillet weld bulkhead - bottom flange (type a)	X	
B	Fillet weld bulkhead - bottom flange (type b)		X
C	Nominal voltage lower flange	X	X
D	Fillet weld bulkhead - horizontal flange longitudinal stiffener	X	X
E	Fillet weld bulkhead - horizontal flange longitudinal stiffener	X	X
F	Fillet weld transverse stiffener - horizontal flange longitudinal stiffener	X	X
G1 / G2	Fillet weld transverse stiffener - headboard	X	X
G3 / G4	Fillet weld bulkhead	X	X
H	Weld web transverse stiffener - vertical flange longitudinal stiffener		
I	Lower flange crossbeam - headboard	X	
J	Lower flange crossbeam at bulkhead	X	

Table 107 - Overview of test and measurement locations for crossbeam with K bandage (DD-K24)

For the connection in the top flange of the cross beam it applies that it is driven directly by a wheel print. From the voltage fluctuations from the local model it follows that local bending of the deck / top flange main beam in the direction perpendicular to the body of the main beam determines the voltage change and so the fatigue calculation. However, testing the deck construction falls outside the scope of the assignment and is therefore not tested further here. The fatigue calculations are shown in Appendix E21.

It is further noted that the weld between the vertical flange of the longitudinal stiffener and the body of the transverse stiffener was found not to be present. This creates virtually no stress at the location H and this location has therefore not been tested, see also section 5.23.5. The tensions at location F will on the other hand are higher. In the model, the connection between vertical flange is longitudinal stiffener and web the transverse stiffener is therefore adapted and not connected.

5.23.3 Detail A1 / B - Bulkhead connection - crossbeam bottom flange

At the end of the bulkhead, at the connection to the bottom flange of the crossbeam of portal B is a voltage concentration present. Measurements were taken at the front and rear (detail A1) and at the short side (detail B).

A1 / B

A1 / B

Figure 240 - Tensions σ y- at the detail of the A / B bulkhead - lower flange crossbeam

In Appendix G the comparison of the measured voltages and the calculated voltages is given for detail A1 (north and south side) and detail B. The highest average hotspot voltage change measured occurs in detail A1 (north).

Figure 241 - Voltage change hotspot voltages DD-STPA detail A1 north

Project related

Influence of the dynamic effects of measurement results

The measurements showed that there is a significant dynamic effect at detail A1 / B. The actual dynamic impact factor is therefore higher than what is calculated in the fatigue tests. TNO has derived an impact factor of approx. 1.54 for location A1 / B from the measurement results of detail A1 / B. The standard prescribes for existing construction with good quality road surfaces factor of 1.1 * 1.15 = 1.27 for. The difference for this location is caused by the defect joint transition. For the other details, this dynamic effect is less great and suffices the magnification factor in accordance with the standard.

In accordance with TNO's derivation, detail A1 / B has been calculated with an increased dynamic magnification factor of 1.54. For a possible amplification, you can count with the normal enlargement factor, because the joint construction will be replaced during the renovation.

Detail A1 / B - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor (45%). This is based on the largest measured voltage change at 20 km / h (detail A (north)). The voltages due to the unit load are for the fatigue calculation of the toe of the weld multiplied by this model factor, after which one fatigue calculation has been performed. This is based on a hotspot analysis with a detail category DC = 90, in accordance with table 3.3, detail 6 of IIW report “Recommendations for Fatigue Design or Welded Joints and Components ”.

The table below shows the damage figures for three different safety factors. The welded joint does not meet the damage requirement D ≤ 1.0.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	44.9	101.1	44.0	97.5	30.1	58.2	28.3	55.1
1.15	27.5	62.0	27.0	59.9	18.4	35.6	17.4	33.8
1.00	17.9	40.4	17.6	39.0	12.0	23.3	11.2	21.9

Table 108 - Damage figures for late 2018 and late 2050 for detail A - toe of the weld

Project related

Detail A1 / B - root of the weld

The root of the weld has been tested in accordance with the IIW Guideline for the Assessment of Weld Root Fatigue "section 3.3.2, where the force in the last t / 2 mm is at the end of the plate distributed over the surrounding weld. The mean voltage has been determined using SCIA by over the last 5 mm request the average voltage in the plate.

Figure 242 - Average stress in the last 5 mm of the plate (σ y-) due to the unit load (2x50 kN)

The voltage change in the weld must be determined for testing. In accordance with the above method, the (maximum) normal voltage in the weld (a = 4 mm) as a result of the unit load (2x50 kN) can be determined as follows.

$$_{\perp,,} = \frac{}{2 \cdot + {}_2} = \frac{\cdot 5 \cdot 10}{2 \cdot 4 \cdot 10 + (4)_2} = 0.52 \cdot$$

The (maximum) shear stress parallel to the weld can be determined in a similar way and is the same On:

$$_{\parallel,,} = \frac{}{2 \cdot + {}_2} = \frac{\cdot 5 \cdot 10}{2 \cdot 4 \cdot 10 + (4)_2} = 0.52 \cdot$$

Contrary to the method in accordance with IIW, where a comparison voltage is used, must now a distinction is made between the normal stress and the shear stresses. The normal voltage perpendicular to the longitudinal axis of the weld ($\sigma_{\perp, w, loc}$) is tested for detail category 40, taking into account

the (pressure) stress present, in accordance with TNO Note 100315818 / ALL, the shear stress parallel to the
longitudinal axis of the weld ($\tau_{ll, w, loc}$) is tested for detail category 80, in accordance with NEN-1993-1-9. The damage of both calculations must be added together.

The tables below show the test results for the normal voltage, including testing is according to the method from the TNO memorandum, both for type 1 (contact between the plates) and type 2 2 (no contact between the plates). The normative of the two assessments must be adhered to and added to the shear stress damage parallel to the longitudinal axis of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	44.9	101.1	44.0	97.5	30.1	58.2	28.3	55.1
1.15	27.5	62.0	27.0	59.9	18.4	35.6	17.4	33.8
1.00	17.9	40.4	17.6	39.0	12.0	23.3	11.2	21.9

Table 109 - Damage figures for the end of 2018 and the end of 2050 for detail A - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	74.6	175.7	70.0	150.1	53.6	104.1	42.1	82.2
1.15	45.7	107.8	42.8	91.8	32.9	63.9	25.6	50.2
1.00	29.5	69.9	27.6	59.3	21.2	41.4	16.5	32.3

Table 110 - Damage figures for the end of 2018 and the end of 2050 for detail A - root of the weld (DC = 40, type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient.

It is concluded that at location A1 both the toe and the root are not sufficient.

5.23.4 Detail C - Bottom flange cross member (nominal)

A measurement was carried out at location C to compare the nominal voltages
to be able to perform the calculation model and measurements. This was measured at 1.75 m from the edge of the shot.

1750

Figure 243 - Overview DD-STPA location C

Figure 244 - Voltage change (nominal) DD-STPA location C.

The shape of the stresses correspond well between model and measurement. However, the measured stresses somewhat lower as calculated (68%), probably because the joint construction is part of the will absorb tensions. Because location C is a nominal voltage and not one fatigue sensitive detail, no fatigue calculation has been performed for this location.

5.23.5 Detail D - Bulkhead connection - horizontal flange longitudinal stiffener

Detail D is located at the bottom of the knee bulkhead, at the connection with the horizontal flange of the longitudinal stiffener. For this detail measurements were taken in two places, D1 as an extension of the inside of the welding port under the longitudinal stiffener, D2 at 10 mm inwards. There is not on the corner, measured in line with the vertical flange of the longitudinal stiffener, because there is during the inspection it has been found that there is no connection between the vertical flange of the longitudinal stiffener and the body of the transverse stiffener.

Do not read
present

D2 D1

Figure 245 - Detail photo DD-STPA location D1 North and D2 North

Detail D - toe of the weld

The tension at the toe of the weld is determined by determining the hot spot voltage location of the stress peak at the end of the bulkhead, by extrapolating the stresses at 0.4t and 1.0t.

D

F

Figure 246 - Tension at the location of the bulkhead connection - horizontal flange longitudinal stiffener - transverse stiffener body (σ_{y+}) due to the unit load (2x50 kN)

Project related

Appendix G compares the calculated hotspot voltage and the measured hotspot voltages at D1 and D2, both for the north and south sides.

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPB detail D2, south side) and equals 39%.

D2 South

D1 South

Figure 247 - Hotspot voltage DD-STPA detail D, south side

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	19.2	51.3	14.9	26.8	16.4	32.4	5.7	11.7
1.15	10.8	29.4	8.3	14.9	9.2	18.5	3.0	6.3
1	6.3	17.5	4.8	8.6	5.4	10.9	1.7	3.6

Table 111 - Damage figures for the end of 2018 and the end of 2050 for detail DD-STPA-D2.

Project related

Detail D - Root of the weld

The root has been tested in the same way as for detail A. For this, the mean voltage in the last t is 2 = 5 mm read and translated into a tension in the weld.

Figure 248 - Average stress in the last 5 mm of the plate (σ_{y-}) due to the unit load (2x50 kN) at detail E

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight. The measured voltage has not been taken into account, because for the carrot is difficult to unambiguously determine the reduction and size overshoots have already been found for the toe of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	11.2	24.1	11.0	27.9	6.9	13.4	8.5	16.9
1.15	5.9	13.0	6.0	15.7	3.4	6.9	4.8	9.6
1	3.1	6.6	3.3	9.2	1.6	3.3	2.8	5.7

Table 112 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	13.0	32.9	10.7	21.3	10.3	20.2	5.2	10.5
1.15	7.4	19.0	6.0	12.1	5.8	11.6	2.8	5.9

1	4.4	11.4	3.5	7.1	3.4	6.9	1.6	3.4

Table 113 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient.

It is concluded that at location D both the toe and the root of the weld are not sufficient.

5.23.6 Detail E - Bulkhead connection - horizontal flange longitudinal stiffener

Detail E is located at the bottom of the bulkhead, at the junction with the horizontal flange of the longitudinal stiffener, on the side close to the main beam body. There is a welding gate here.

E

Figure 249 - Detail photo DD-STPA detail E North

Appendix G provides the comparison between the measurements and the calculated hotspot voltages. The highest voltages were found on the south side, where the ratio measurement to computed hot spot voltage change equals 187%.

Figure 250 - Hotspot voltage DD-STPA detail E, south side

Detail E - Toe of the weld

Figure 251 - Tension at the location of the bulkhead connection - horizontal flange longitudinal stiffener - transverse stiffener body (σ y-) due to the unit load (2x50 kN)

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPA, detail E, south side) and is equal to 187%. The tensions for the fatigue calculation, the unit load has been multiplied by this model factor, after which a fatigue calculation of the toe of the weld has been performed. This is based on Detail category $C\sigma_c$ = 90 N / mm², based on IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”, table 3.3, detail 6.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	40.7	113.9	28.1	41.7	38.4	75.1	6.9	13.7
1.15	24.0	67.8	16.4	24.1	22.7	44.6	3.8	7.7
1	15.0	42.6	10.0	14.6	14.2	28.1	2.2	4.5

Table 114 - Damage figures for the end of 2018 and the end of 2050 for DD-STPA detail E

Detail E - Root of the weld

Figure 252 - Average stress in the last 5 mm of the plate (σ_{y}) due to the unit load (2x50 kN) at detail E

The square root at detail E has been tested in the same way as for detail D. The average is for this voltage in the last t / 2 = 5 mm read and translated into a voltage in the weld.

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight. The lower measured voltage is not taken into account, because it is for the root is difficult to unambiguously determine the reduction.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 115 - Damage figures for the end of 2018 and the end of 2050 for detail E - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	3.0	8.9	1.8	2.4	2.9	5.9	0.3	0.6
1.15	1.6	4.9	0.9	1.2	1.6	3.2	0.1	0.2
1	0.9	2.7	0.5	0.6	0.9	1.8	0.0	0.1

Table 116 - Damage figures for the end of 2018 and the end of 2050 for detail E - root of the weld (DC = 40, type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient.

It is concluded that at location E both the toe and the root of the weld are not sufficient.

5.23.7 Detail F - Connection horizontal flange longitudinal stiffener - transverse stiffener

Detail F is located on the body of the transverse stiffener, just below the horizontal flange of the longitudinal stiffener, on the side close to the vertical flange of the longitudinal stiffener. Here is one welding gate.

F

Figure 253 - Detail photo DD-STPA detail F

Appendix G provides the comparison between the measurements and the calculated hotspot voltages. The highest voltages were found on the north side, where the ratio measurement to computed hot spot voltage change equals 44%.

Figure 254 - Hotspot voltage DD-STPA detail F, north side

Detail F - Toe of the weld

Figure 255 - Voltage at the location of the bulkhead connection - horizontal flange longitudinal stiffener - transverse stiffener body (σ_{y+}) due to the unit load (2x50 kN)

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPA, detail F, north side). This is based on a type a extrapolation. The stresses due to the unit load have been multiplied for the fatigue calculation with this model factor, after which a fatigue calculation of the toe of the weld was performed. Hereby is based on Detail category $\Delta\sigma_c$ = 90 N / mm², based on IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”, table 3.3, detail 6.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	21.1	59.2	14.5	22.4	19.7	38.8	3.9	7.9
1.15	12.2	34.7	8.2	12.5	11.4	22.7	2.1	4.2
1	7.3	21.1	4.8	7.1	6.9	13.8	1.1	2.3

Table 117 - Damage figures for the end of 2018 and the end of 2050 for DD-STPA detail F

Detail F - Root of the weld

The square root of detail F has been tested in the same way as for detail D. The average is for this voltage in the last t / 2 = 5.4 mm read and translated into a voltage in the weld.

Figure 256 - Average stress in the last 5 mm of the plate (σ_{y+}) due to the unit load (2x50 kN) at detail F

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight (see detail A1 for the description of this method). There is no account

account for the lower measured voltage, because it is difficult for the root to clearly determine the reduction
to determine and any size violations have already been found for the toe of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 118 - Damage figures for the end of 2018 and the end of 2050 for detail F - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	51.6	140.3	37.2	60.7	47.2	91.5	12.2	23.9
1.15	31.3	85.7	22.5	36.5	28.7	55.9	7.2	14.2
1	20.0	55.2	14.4	23.1	18.4	35.9	4.5	8.9

Table 119 - Damage figures for the end of 2018 and the end of 2050 for detail F - root of the weld (DC = 40, type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient.

It is concluded that at location F both the toe and the root of the weld are not sufficient.

5.23.8 Detail G - Connection body / bulkhead cross beam - headboard on main beam body

The stresses at the location of the welded connection between the body of the cross beam and the headboard and between the bulkhead under the cross beam and the head bulkhead is shown in the figures below. It the headboard, in turn, is connected to the body of the main beam with rivets. Especially with the welding gates occur voltage concentrations.

G2

G4

G1

G3

Figure 257 - Tensions at the location of crossbeam / bulkhead connection - headboard on main beam body, DD-STPA, Detail G

During the measurement it emerged that the welding gate appears to be absent at G2. There is therefore decided to perform measurements at G1 and G3. Measurements were only taken on the south side. Appendix G gives the comparison between the measurements and the calculated hotspot voltages.

It was not possible to determine one factor for location G1 for the ratio between measurement and calculation. The calculated tensions show an overall tax effect that is not apparent in the measurements, perhaps due to deformation of the T-connection with the rivets on tension. This deviation is also observed at location G1 of DD-K30 and DD-zK. Because the measured voltage change is very small (ca 2 to 3 MPa) it is likely that both the toe and the root of the weld will meet fatigue.

Figure 258 - Hotspot voltage DD-STPA detail G1, south side

The calculated and measured stresses at location G3 are also very low. The maximum measured hot spot voltage is only 1.8 MPa. It is plausible that the toe and root of the weld are at location G3 meets fatigue. The fatigue test has therefore been omitted.

Figure 259 - Hotspot voltage DD-STPA detail G3, south side

The calculated stresses at location G4 are very low. The maximum calculated hotspot voltage is only 0.3 MPa. It is plausible that the toe and root of the weld at location G4 is satisfactory fatigue. The fatigue test has therefore been omitted.

Figure 260 - Hotspot voltage DD-STPA detail G4, south side

5.23.9 Detail I - Crossbase bottom flange connection - headboard

The bottom flange has a narrowing at the connection to the head plate from 250 mm to 200 mm. Voltage peaks also occur here, although they are considerably lower than the previous peaks.

Xlast = 0.4m

I1 I2

Xlast = 2.2m I2

I1

Figure 261 - Tension σ_{x+} in the bottom flange (longitudinal tension) at details I1 and I2.

Based on the hot spot voltage, the toe of the fillet weld is tested for fatigue, based on detail category 90, similar to detail A1. The following results follow from this.

Detail I1

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.2	0.8	0.1	0.1	0.2	0.5	0.0	0.0
1.15	0.1	0.3	0.0	0.0	0.1	0.2	0.0	0.0
1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0

Table 120 - Damage figures for late 2018 and late 2050 for location I1 - toe of the weld (DC = 90)

Detail I2

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	1.9	5.7	0.9	1.5	1.9	3.8	0.3	0.6
1.15	1.0	3.0	0.4	0.6	0.9	2.0	0.1	0.3
1	0.5	1.5	0.2	0.3	0.5	1.0	0.0	0.1

Table 121 - Damage figures for the end of 2018 and the end of 2050 for location I2 - toe of the weld (DC = 90)

Project related

Detail I - Root of the weld

Detail I2 is decisive for the assessment. The root has been tested in a similar way as for detail A1. The tension in the weld is determined by determining the force in the outer 12/2 = 6 mm of the bottom flange and divide it over the cross section of the fillet weld, including the end face. The test was performed on detail category 40, with the break point at 10 $_7$. Given the tensile stress present by permanent loads will cause type 1 and type 2 the same damage. The tensile stress due to permanent loads arises because the cross beam will want to rotate, because there is only one field on one side the end crossbeam. This results from bending in the bottom flange perpendicular to the crossbeam, with the side of I2 pull when clamped in the main beam.

Detail I1

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 122 - Damage figures for the end of 2018 and the end of 2050 for location I1 - root of the weld (DC = 40 type 1)

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.3	0.9	0.1	0.1	0.2	0.6	0.0	0.0
1.15	0.1	0.3	0.0	0.0	0.1	0.2	0.0	0.0
1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0

Table 123 - Damage figures for the end of 2018 and the end of 2050 for location I1 - root of the weld (DC = 40 type 2)

Detail I2

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	6.5	18.7	3.6	5.8	6.4	12.5	1.1	2.2
1.15	3.8	11.1	1.9	3.2	3.7	7.4	0.6	1.2
1	2.3	6.8	1.1	1.8	2.3	4.5	0.3	0.7

Table 124 - Damage figures for the end of 2018 and the end of 2050 for location I2 - root of the weld (DC = 40 type 1)

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	6.5	18.7	3.6	5.8	6.4	12.5	1.1	2.2
1.15	3.8	11.1	1.9	3.2	3.7	7.4	0.6	1.2
1	2.3	6.8	1.1	1.8	2.3	4.5	0.3	0.7

Table 125 - Damage figures for the end of 2018 and the end of 2050 for location I2 - root of the weld (DC = 40 type 2)

In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient.
It is concluded that at location I, both the toe and the root of the weld are not sufficient.

5.23.10 Detail J - Lower flange crossbeam at the end of the bulkhead

For the bottom flange of the cross beam, it must be tested for detail category 56,
in accordance with NEN -EN 1993-1-9 Table 8.4 Detail 1 (L> 100 mm), based on the nominal voltage in the bottom flange.

Figure 262 - Detail category for the fatigue calculation of the DD-STPA compound, detail J

It follows from the calculation that the nominal longitudinal voltages in the lower flange at the location of the connection be approximately -3 N / mm². The voltage change is so low that no damage will occur here. This cut has therefore not been tested further.

Lower flange at the end of the bulkhead (J)

Figure 263 -. Stress in lower flange due to unit load on the intermediate cross member

5.24 Type DD-STPB: Main girder - crossbeam portal connection B

Similar to portal A, the crossbeam at portal B has also been investigated. Portal B has no horizontal top edge, such as portal A. The geometry of the connection between the cross beam is comparable to the normal crossbars with k-bandages. However, due to the imposition there will also be global tensions must be borne, making tensions in different details may deviate.

Figure 264 - Overview of the connection type DD-STPB (portal B)

5.24.1 Location of tested crossbeam

The tested and measured cross beam corresponds to the cross beam at Pillar G. De
voltage fluctuations in the critical points are determined with the hybrid model B which is also used for the fatigue test of the intermediate crossbeam DD-zK. In this model, over a length of two K-relationships before and after portal B the calculation model built up with plate elements, the rest of the bridge is modeled as a plate with eccentric beam elements.

Figure 265 - Location of tested cross beam portal B, DD-STPB

5.24.2 Tested details

In the connection between cross beam and main beam there are various details that are critical regarding fatigue. For each part it will be explained how the test voltage is determined, where the normative cut and which detail category applies. The details tested are otherwise the same to those for the crossbars with K-bandage.

Figure 266 - Detail of the FEM model of connection type DD-STPB (portal B)

G1
G2
J
J
A1 B
C →
G3
A2
G4
E D
F
H

Figure 267 - Tested cuts of crossbeam connection DD-STPB at portal B.

The following table describes the details that have been tested and / or where a measurement is executed.

Detail	Description	Fatigue test	Measured
A1	Fillet weld bulkhead - bottom flange (type a)	X	X
A2	Fillet weld bulkhead - bottom flange (type a)	X	
B	Fillet weld bulkhead - bottom flange (type b)	X	X
C	Nominal voltage lower flange		X
D	Fillet weld bulkhead - horizontal flange longitudinal stiffener	X	X
E	Fillet weld bulkhead - horizontal flange longitudinal stiffener	X	X
F	Fillet weld transverse stiffener - horizontal flange longitudinal stiffener	X	X
G1 / G2	Fillet weld transverse stiffener - headboard	X	
G3 / G4	Fillet weld bulkhead	X	
H	Weld web transverse stiffener - vertical flange longitudinal stiffener	X	
I	Lower flange crossbeam - headboard	X	
J	Lower flange crossbeam at bulkhead	X	

Table 126 - Overview of test and measurement locations for cross bars with K-bandages (DD-STPB)

The fatigue calculations are shown in Appendix E22.

5.24.3 Detail A1 / B - Bulkhead connection - crossbar bottom flange

Detail A1 / B concerns the connection at the top, at the end of the bulkhead with the bottom flange of the crossbeam. A voltage concentration is present at this location. Measurements were taken at the front and back (detail A1) and on the front side (detail B).

A1 / B

A1 / B

Figure 268 - Tensions at the location of detail A1 / B bulkhead - lower flange crossbeam

In Appendix G the comparison of the measured voltages and the calculated voltages is given for detail A1 (north and south side) and detail B. The highest average hotspot voltage change measured occurs in detail A1 (north).

Figure 269 - Voltage change hotspot voltages DD-STPB detail A1 north

Detail A1 / B - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor (74%). This is based on the largest measured voltage change at 20 km / h (detail A1 (north)). The voltages due to the unit load are for the

fatigue calculation of the toe of the weld multiplied by this model factor, after which one
fatigue calculation has been performed. This is based on a hotspot analysis with a
detail category DC = 90, in accordance with table 3.3, detail 6 of IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”[10].

The table below shows the damage figures for three different safety factors. The welded joint does not meet the damage requirement D ≤ 1.0.

	HRB west		**HRB east**		**PRB west**		**PRB east**	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	22.4	56.3	21.7	44.8	17.7	34.7	12.2	23.8
1.15	13.3	33.8	12.9	26.8	10.5	20.7	7.2	14.2
1.00	8.3	21.2	8.1	16.9	6.6	13.0	4.6	8.9

Table 127 - Damage figures for the end of 2018 and the end of 2050 for detail A1 - toe of the weld

Detail A1 / B - root of the weld

The root of the weld has been tested in accordance with the IIW Guideline for the Assessment of Weld Root Fatigue ”[11] section 3.3.2, where the force in the last t / 2 mm is at the end of the plate distributed over the surrounding weld. The mean voltage has been determined using SCIA by over the last 5 mm request the average voltage in the plate.

Figure 270 - Average stress in the last 5 mm of the plate (σ y-) due to the unit load (2x50 kN)

The voltage change in the weld must be determined for testing. In accordance with the above method, the (maximum) normal voltage in the weld (a = 4 mm) as a result of the unit load (2x50 kN) can be determined as follows.

$$\perp,, = \frac{}{2 \cdot + 2} = \frac{\cdot 5 \cdot 10}{2 \cdot 4 \cdot 10 + (4)^2} = 0.52 \cdot$$

The (maximum) shear stress parallel to the weld can be determined in a similar way and is the same On:

$$\parallel,, = \frac{}{2 \cdot + 2} = \frac{\cdot 5 \cdot 10}{2 \cdot 4 \cdot 10 + (4)^2} = 0.52 \cdot$$

Contrary to the method in accordance with IIW, where a comparison voltage is used, must now a distinction is made between the normal stress and the shear stresses. The normal voltage perpendicular to the longitudinal axis of the weld ($\sigma_{\perp, w, loc}$) is tested for detail category 40, taking into account the present (pressure) stress, in accordance with TNO Note 100315818 / ALL [2], the shear stress parallel to the longitudinal axis of the weld ($\tau_{II, w, loc}$) is tested for detail category 80, in accordance with NEN-1993-1-9. The damage of the two calculations must be added together.

The tables below show the test results for the normal voltage, including testing is according to the method from the TNO memorandum, both for type 1 (contact between the plates) and type 2 2 (no contact between the plates). The normative of the two assessments must be adhered to and added to the shear stress damage parallel to the longitudinal axis of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	2.5	5.8	2.7	6.8	1.5	3.1	2.0	4.0
1.15	1.2	2.8	1.3	3.5	0.7	1.5	1.0	2.1
1.00	0.5	1.2	0.6	1.7	0.2	0.6	0.4	1.0

Table 128 - Damage figures for the end of 2018 and the end of 2050 for detail A1 - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	15.2	37.8	14.2	29.6	11.8	23.1	8.0	15.7
1.15	9.1	22.8	8.5	17.7	7.1	13.9	4.8	9.4
1.00	5.7	14.4	5.4	11.3	4.4	8.8	3.1	6.0

Table 129 - Damage figures for the end of 2018 and the end of 2050 for detail A1 - root of the weld (DC = 40, type 2)

The shear stress change is so low that it does not cause any damage. The review of the root of the weld does not meet the damage requirement D ≤ 1.0.

5.24.4 Detail A2 - Bulkhead connection - crossbeam bottom flange

Detail A2 is located at the welding gate close to the main beam, in the connection bulkhead with the bottom flange of the cross beam. This detail is comparable to detail A1 and has been tested in a similar manner.

Detail A2 - toe of the weld

For detail A2, the calculated hotspot voltage is lower than for detail A1. Because A1 is not sufficient the damage calculation for location A2 was also performed.

A2

A2

Figure 271 - Tensions at location A2, bulkhead-to-flange crossbeam connection

The damage category is equal to location A1, if DC = 90, based on a hotspot analysis.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 130 - Damage figures for the end of 2018 and the end of 2050 for location A2

Location A2 - root of the weld

The damage calculation of the root of the weld was performed in the same way as for location A1. Also here the shear stress change is so low that it will not cause any damage.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 131 - Damage figures for the end of 2018 and the end of 2050 for location A2 - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 132 - Damage numbers for the end of 2018 and the end of 2050 for location A2 - root of the weld (DC = 40, type 2)

5.24.5 Detail C - Bottom flange cross member (nominal)

A measurement was carried out at location C to compare the nominal voltages
to be able to perform the calculation model and measurements. This was measured at 1.75 m from the edge of the shot.

1750

Figure 272 - Overview DD-STPB location C

Figure 273 - Voltage change (nominal) DD-STPB location C.

The voltages correspond well between model and measurement. Because location C has a nominal voltage and not a fatigue-sensitive detail, there is no fatigue calculation for this location executed.

5.24.6 Detail D - Bulkhead connection - horizontal flange longitudinal stiffener

The weld at position D has no noticeable edge indentation or other imperfections. The plate is 10.0 mm thick. For this detail measurements were taken in two places, D1 is used up as much as possible the corner, D2 at 10 mm inwards.

D1 D2

Figure 274 - Detail photo DD-STPB location D1 North and D2 North

Detail D - toe of the weld

The tension at the toe of the weld is determined by determining the hot spot voltage location of the stress peak at the end of the bulkhead, by extrapolating the stresses at 0.4t and 1.0t.

E

F D

Figure 275 - Voltage at the location of the bulkhead connection - horizontal flange longitudinal stiffener - transverse stiffener body (σ_{y+}) due to the unit load (2x50 kN)

Appendix G compares the calculated hotspot voltage and the measured hotspot voltages at D1 and D2, both for the north and south sides.

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPB detail D2, south side) and equals 39%.

Figure 276 - Hotspot voltage DD-STPB detail D, south side

Weld toe fatigue analysis was performed for three partial safety factors, where
the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		**HRB east**		**PRB west**		**PRB east**	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	9.5	25.2	7.1	13.2	8.1	16.0	3.0	6.0
1.15	5.5	14.7	4.1	7.5	4.7	9.4	1.7	3.4
1	3.3	9.0	2.4	4.4	2.8	5.7	0.9	1.9

Table 133 - Damage figures for the end of 2018 and the end of 2050 for detail DD-STPB-D.

Detail D - Root of the weld

The root has been tested in the same way as for details A1 and A2. For this, the average voltage in the last t / 2 = 5 mm read and translated into a tension in the weld.

Figure 277 - Average stress in the last 5 mm of the plate (σ_{y-}) due to the unit load (2x50 kN) at detail D

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight. The lower measured voltage is not taken into account, because it is for the root is difficult to unambiguously determine the reduction and there are already size overruns found for the toe of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 134 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	24.7	63.5	18.6	35.3	20.5	39.9	8.6	16.9
1.15	15.0	38.5	11.2	21.3	12.5	24.2	5.1	10.2
1	9.6	24.8	7.2	13.6	8.0	15.6	3.3	6.5

Table 135 - Damage figures for the end of 2018 and the end of 2050 for detail D - root of the weld (DC = 40, type 2)

It can be seen that in type 1, where contact between the plates is assumed, no damage occurs. This is because there is a relatively high voltage due to the permanent load, which the self-tensions largely offsets. This means that virtually the entire change in pressure is included method 1 must be multiplied by α = 0.00. With type 2 there is a (size) damage found, because here the voltage change in pressure must be included with α = 0.63.
In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient. The damage caused by the shear stress actually has to be added to damage mentioned above.

It is concluded that at location D both the toe and the root of the weld are not sufficient.

5.24.7 Detail E - Bulkhead connection - horizontal flange longitudinal stiffener

Detail E is located at the bottom of the bulkhead, at the junction with the horizontal flange of the longitudinal stiffener, on the side close to the main beam body. There is a welding gate here.

E

Figure 278 - Detail photo DD-STPB detail E

Appendix G provides the comparison between the measurements and the calculated hotspot voltages. The highest voltages were found on the south side, where the ratio measurement to computed hot spot voltage change equals 63%.

Figure 279 - Hotspot voltage DD-STPB detail E, south side

Detail E - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPB, detail E, south side) and equals 63%. The tensions for the fatigue calculation, the unit load has been multiplied by this model factor, after which a fatigue calculation of the toe of the weld has been performed. This is based on Detail category $C\sigma_c$ = 90 N / mm², based on IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”[10], table 3.3, detail 6.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

γ_{Mf}	HRB west		HRB east		PRB west		PRB east	
	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.3	1.0	0.2	0.4	0.3	0.6	0.1	0.1
1.15	0.1	0.4	0.1	0.1	0.1	0.3	0.0	0.0
1	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.0

Table 136 - Damage figures for the end of 2018 and the end of 2050 for DD-STPB detail E

Detail E - Root of the weld

The square root at detail E has been tested in the same way as for detail D. The average is for this voltage in the last t / 2 = 5 mm read and translated into a voltage in the weld.

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight. The lower measured voltage is not taken into account, because it is for the root is difficult to unambiguously determine the reduction.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	1.0	2.7	0.9	2.1	0.7	1.6	0.5	1.1
1.15	0.4	1.1	0.4	0.9	0.3	0.7	0.2	0.5
1	0.2	0.5	0.1	0.3	0.1	0.3	0.1	0.2

Table 137 - Damage figures for the end of 2018 and the end of 2050 for detail E - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.4	1.1	0.3	0.5	0.3	0.7	0.1	0.2
1.15	0.1	0.5	0.1	0.2	0.1	0.3	0.0	0.1
1	0.1	0.2	0.0	0.1	0.1	0.1	0.0	0.0

Table 138 - Damage figures for the end of 2018 and the end of 2050 for detail E - root of the weld (DC = 40, type 2)

The calculation is type 1, which assumes contact between the plates. The shear stress is so low that it will not lead to additional damage.

It is concluded that at location E the root of the weld is not sufficient. It is noted that it it is plausible that the actual voltage is lower, as is apparent from the measurement of the hotspot voltages turned out.

Project related

5.24.8 Detail F - Connection horizontal flange longitudinal stiffener - transverse stiffener

Detail F is located on the body of the transverse stiffener, just below the horizontal flange of the longitudinal stiffener, on the side close to the vertical flange of the longitudinal stiffener. Here is one welding gate.

Figure 280 - Detail photo DD-STPB detail F

Appendix G provides the comparison between the measurements and the calculated hotspot voltages. The highest voltages were found on the north side, where the ratio measurement to computed hot spot voltage change equals 60%.

Figure 281 - Hotspot voltage DD-STPB detail F, south side

Project related

Detail F - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPB, detail F, south side). This is based on a type a extrapolation. The stresses due to the unit load have been multiplied for the fatigue calculation with this model factor, after which a fatigue calculation of the toe of the weld was performed. Hereby is based on Detail category $\Delta\sigma_c$ = 90 N / mm², based on IIW report "Recommendations for Fatigue Design of Welded Joints and Components "[10], Table 3.3, Detail 6.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	6.4	17.1	5.5	10.5	5.4	10.8	2.5	5.1
1.15	3.6	9.8	3.0	5.9	3.0	6.1	1.4	2.8
1	2.1	5.8	1.8	3.4	1.8	3.6	0.8	1.6

Table 139 - Damage figures for the end of 2018 and the end of 2050 for DD-STPB detail F

Detail F - Root of the weld

The square root of detail F has been tested in the same way as for detail D. The average is for this voltage in the last t / 2 = 5.4 mm read and translated into a voltage in the weld.

The result of the damage calculation for the normal voltage in the weld is shown below ($\sigma_{\perp, w, loc}$), where testing is done on detail category 40, taking into account the (pressure) stress present by its own weight (see detail A1 for the description of this method). There is no account account for the lower measured voltage, because it is difficult for the root to clearly determine the reduction to determine and any size violations have already been found for the toe of the weld.

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 140 - Damage figures for the end of 2018 and the end of 2050 for detail F - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	19.6	50.9	16.1	30.7	16.4	32.1	7.5	14.8
1.15	11.9	30.8	9.7	18.5	9.9	19.4	4.5	8.9
1	7.6	19.8	6.2	11.8	6.3	12.4	2.9	5.8

Table 141 - Damage figures for the end of 2018 and the end of 2050 for detail F - root of the weld (DC = 40, type 2)

The calculation is based on type 2, which assumes no contact between the plates.
In view of the exceedance, the damage due to the shear stress is no longer determined, since the connection is already insufficient. The damage caused by the shear stress actually has to be added to damage mentioned above.

It is concluded that at location F both the toe and the root of the weld are not sufficient.

5.24.9 Detail G - Connection body / bulkhead crossbeam - headboard on main beam body

The stresses at the location of the welded connection between the body of the cross beam and the headboard and between the bulkhead under the cross beam and the head bulkhead is shown in the figures below. It the headboard, in turn, is connected to the body of the main beam with rivets. Especially with the welding gates occur voltage concentrations. No measurements were taken for this location. In front of the comparable DD-K30 follows from the measurements that the occurring voltages were lower than the measured voltages.

G1

G2

G4

G3

Figure 282 - Tensions at the point of connection of crossbeam body / bulkhead - bulkhead on main beam body, DD-zK, Detail G

Detail G - Toe of the weld

The highest voltage fluctuations occur at detail G1 and G2. The testing of the toe of the weld has therefore been carried out for detail G1 and G2 on the basis of a hotspot analysis based on the calculated tensions. Tested for detail category DC = 90, comparable to detail A1.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 142 - Damage figures for the end of 2018 and the end of 2050 for location G1 - toe of the weld

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 143 - Damage figures for the end of 2018 and the end of 2050 for location G2 - toe of the weld

Detail G - Root of the weld

It is not possible to say beforehand which detail is decisive for testing the root. Detail G2 has the largest change, but is completely under pressure. Detail G1 has a smaller change, but is partial loaded on tension. The review was therefore carried out for both details. Tested against detail category DC = 40, based on the TNO method, as described in detail A1.

Detail G1

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 144 - Damage figures for the end of 2018 and the end of 2050 for location G1 - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 145 - Damage figures for the end of 2018 and the end of 2050 for location G1 - root of the weld (DC = 40, type 2)

Detail G2

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 146 - Damage figures for the end of 2018 and the end of 2050 for location G2 - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 147 - Damage figures for the end of 2018 and the end of 2050 for location G2 - root of the weld (DC = 40, type 2)

The shear stresses are very low in both cases and will not result in additional damage.

5.24.10 Detail H - Connection transverse stiffener body - vertical flange longitudinal stiffener

Detail H is located at the connection between the body of the transverse stiffener and the vertical flange of the longitudinal stiffener. At the end of the welded joint between the vertical flange of the longitudinal stiffener and the body of the transverse stiffener a stress concentration occurs. There are no measurements performed at this location.

H

Figure 283 - Tensions at the location of transverse stiffener body connection - vertical flange longitudinal stiffener, DD-STPB, Detail H

The testing of the toe of the weld of this detail has been carried out on the basis of the hot spot voltage is determined by a non-linear extrapolation of the results at 4 mm, 8 mm and 12 mm from the toe of the weld (type b extrapolation in accordance with IIW). This is based on a detail category DC = 100, in accordance with table 3.3, detail 6 of IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”[10].

Figure 284 - Detail category for detail H - toe of the weld [10]

The following damage figures follow from the fatigue analysis

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	54.8	144.6	44.1	79.9	47.1	92.0	18.7	36.6
1.15	33.2	88.2	26.7	48.6	28.5	56.0	11.3	22.2
1	21.4	56.9	17.1	31.2	18.4	36.1	7.2	14.2

Table 148 - Damage figures for the end of 2018 and the end of 2050 for location H - toe of the weld (DC = 100)

Project related

5.24.11 Detail I - Connection bottom flange crossbeam - headboard

Detail I - Toe of the weld

The bottom flange has a narrowing at the connection to the head plate from 250 mm to 200 mm. Voltage peaks also occur here, although they are considerably lower than the previous peaks.

I1

I2

Figure 285 - Tension σ x- in the bottom flange (longitudinal tension) at details I1 and I2.

Detail I2 is decisive for the assessment. The toe of the fillet weld is based on the hot spot voltage tested for fatigue, based on detail category 90, comparable to detail A1. Follow from this the following results.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 149 - Damage figures for the end of 2018 and the end of 2050 for location I2 - toe of the weld (DC = 90)

Detail I - Root of the weld

The root has been tested in a similar way as for detail A1. The voltage in the weld is determined by the determine the force in the outer 12/2 = 6 mm of the bottom flange and distribute it over the cross-section of the fillet weld, including end face. The test was performed conservatively on class 40, with the break point at 10^7, without taking into account the available compressive stress. It follows from the calculation that the weld connection is sufficient.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 150 - Damage figures for the end of 2018 and the end of 2050 for location I2 - root of the weld (DC = 40)

5.24.12 Detail J - Lower flange crossbeam at the end of the bulkhead

For the bottom flange of the cross beam, it must be tested for detail category 56,
in accordance with NEN -EN 1993-1-9 Table 8.4 Detail 1 (L> 100 mm), based on the nominal voltage in the bottom flange.

Figure 286 - Detail category for the fatigue calculation of the DD-zK compound, detail J

It follows from the calculation that the nominal longitudinal voltages in the lower flange at the location of the connection be approximately -3 N / mm².

Lower flange at the end of the bulkhead (J)

Figure 287 -. Stress in lower flange due to unit load on the intermediate cross member

The voltage change is so low that no damage will occur here. This cut is therefore not further tested.

5.25 Type DD-STPC: Main girder - crossbeam portal connection C

Similar to portal A and B, the crossbeam at portal C has also been investigated. Portal C is something else performed as the other portals and K-bandages. So is the transverse stiffener, the bulkhead, the diagonals and the top edge is doubled. The cross beam itself is the same as the other cross beams.
In addition, the portal is considerably higher than with portal A and B, so that the diagonals have a different, have a steeper angle. In addition, the connection at the bottom of the knee bulkheads is different without welding gates.

Figure 288 - Overview of the connection type DD-STPC (portal C)

5.25.1 Location of tested crossbeam

The tested and measured cross beam corresponds to the cross beam at Pillar H. De
voltage fluctuations in the critical points have been determined with the hybrid model. In this model is about one
length of one K-connection before and after portal C the calculation model built up with plate elements, the

the rest of the bridge is modeled as a plate with eccentric beam elements.

Figure 289 - Location of tested cross beam portal B, DD-STPC

5.25.2 Tested details

In the connection between cross beam and main beam there are various details that are critical regarding fatigue. For each part it will be explained how the test voltage is determined, where the normative cut and which detail category applies. The details tested are otherwise the same to those for the crossbars with K-bandage.

Figure 290 - Detail of the FEM model of connection type DD-STPC (portal C)

G1

I

E

F

C →

AB

G3

D

H

Figure 291 - Tested cuts crossbeam connection DD-STPC at portal C.

Project related

It is noted that there is a thickness jump in the horizontal plate under the cross beam between the bulkheads because here below the bottom flange of the cross beam a filling plate and a (wider) sloping plate present. In the plate model you get a thickness jump and eccentric plates that have a disrupt the (local) tensions, especially at location A, B and F. It is expected that the The results of the FEM model will not lead to meaningful results here. Here are also measurements executed.

E-south E-north

F-south F-north

uid uid
-z -z
B a

-north -north
a B

E

AB

F

Figure 292 - Tested cuts crossbeam connection DD-STPC at portal C (detail shot - horizontal plate - bottom flange crossbeam)

The following table describes the details that have been tested and / or where a measurement is executed.

Detail	Description	Fatigue key	Measured
a	Fillet weld knee bulkhead - horizontal plate under bottom flange crossbeam (type a)	X	X
B	Fillet weld knee bulkhead - horizontal plate under bottom flange crossbeam (type b)	X	X
C	Nominal voltage lower flange		X
D	Weld bulkhead - end of vertical flange transverse stiffener	X	X
E	Weld bottom flange cross beam - cross beam web (tension cross direction)	X	X
F	Weld plate under bottom flange cross beam - bulkhead (tension cross direction)	X	X
G1	Fillet weld transverse stiffener - headboard	X	
G3	Fillet weld bulkhead	X	
H	Weld bottom sides - horizontal flange longitudinal stiffener - body transverse stiffener	X	
I	Lower flange crossbeam - headboard	X	

Table 151 - Overview of test and measurement locations for cross bars with K-bandages (DD-STPC)

The fatigue calculations are shown in Appendix E23.

5.25.3 Detail A / B - Bulkhead connection - horizontal plate under bottom flange crossbeam

Detail A / B concerns the connection at the top of the bulkheads with the horizontal plate underneath the bottom flange of the cross beam is present. A voltage concentration is present at this location. Because there is a thickness jump in the horizontal plate, local are created in the plate model stress disturbances likely to affect the bulkhead at detail A / B. There is therefore decided to also perform measurements at this location. During the pre - inspection inspection the application of the strain gauges showed that it was not possible to place the inside of the plates to place strain gauges, therefore they are only on the outside (Detail A) and on the front side (Detail B) pasted.

AB

AB

Figure 293 - Tensions at the location of detail A / B bulkhead - horizontal plate under bottom flange crossbeam

In Appendix G the comparison of the measured voltages and the calculated voltages is given for detail A (north side of the north plate and south side of the south plate) and detail B (front side, north and south plate). The highest average measured hotspot voltage change occurs in detail A (north).

Figure 294 - Voltage change hotspot voltages DD-STPC detail A north

For location A it is not quite possible to determine a ratio between measurements and calculation. This is because there is a disturbance in the calculation model due to a thickness jump in the horizontal plate between the bulkheads. This results in incorrect results locally, which will have an effect on the shot on site of location A. In order to be able to make a scaling, the following approach was used for the scaling the influence line:

An influence line has been determined manually, based on a unit load, when passing a truck gives the same line of influence. The calculated voltage change with this corrected influence line is in it shown in yellow in the figure above. The ratio between measurement and (corrected) calculation is therefore by definition equal to 100%, because this already contains the correction.

Project related

Detail A1 / B - Toe of the weld

The fatigue calculation was performed based on the adjusted influence line. This is based on a hotspot analysis with a detail category DC = 90, in accordance with table 3.3, detail 6 of the IIW report Recommendations for Fatigue Design of Welded Joints and Components [10].

The table below shows the damage figures for three different safety factors. The welded joint does not meet the damage requirement D ≤ 1.0 at most locations.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
1.35	3.3	9.4	2.2	4.0	3.0	6.1	0.8	1.7
1.15	1.8	5.1	1.1	1.9	1.6	3.3	0.4	0.8
1.00	1.0	3.0	0.6	1.0	0.9	1.9	0.2	0.4

Table 152 - Damage figures for late 2018 and late 2050 for detail A north toe of the weld

Detail A / B - root of the weld

Normally the force in the last t / 2 mm was determined for testing the root of the weld converted to a voltage in the weld. Because the model gives unreliable results, this is the case portal C not possible. Also the measurements are not suitable for the average voltage in the last t / 2 mm, because this is a measurement of the hotspot voltage. It is therefore not possible to perform a root test.

Given the size of the hot spot voltage, it can be assumed that the root of the weld will not either meet the fatigue assessment.

Because the toe already has large overruns, a reinforcement will have to be performed. It is believed that the weld will need to be replaced. The starting point is that with a possible reinforcement no more k-weld will be applied and the testing of the root therefore will no longer be relevant. The testing of the root is therefore no longer further executed.

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Project related

5.25.4 Detail C - Bottom flange cross member (nominal)

A measurement was carried out at location C to compare the nominal voltages to be able to perform the calculation model and measurements. This was measured at 1,446 m from the edge of the shot.

1446

Figure 295 - Overview DD-STPC location C

Figure 296 - Voltage change (nominal) DD-STPC location C

The voltages correspond well between model and measurement. Because location C has a nominal voltage and not a fatigue-sensitive detail, there is no fatigue calculation for this location executed.

5.25.5 Detail D - Bulkhead connection - transverse stiffener vertical flange

Location D is at the end of the rounding of the bulkhead, at the end of the weld between flange and body of the transverse stiffener. It was not possible to stick a strain gauge on the end face through the bumps. It was therefore decided to perform the strain measurement on the flat side of the plate. This is done on both the northern and southern plates, in both cases on the outside measured (south side of the south plate, north side of the north plate. The plate is 10.0 mm thick. Detailed photos of the location are given in the figures below.

D

D

Figure 297 - Detail photo DD-STPC location D North and D South

On the north side, the rounding is not nicely rounded, but a jump is visible at the second strain gauge. The rounding is neatly completed on the south side.

Figure 298 - Detail photo strain gauges DD-STPC location D North + D South

Detail D - toe of the weld

The tension at the toe of the weld is determined by determining the hot spot voltage location of the stress peak at the end of the vertical flange of the cross stiffener. The maximum tensions occur on the outer sides, i.e. on the north side of the north plate and on the southern side of the southern plate. Because measurements are taken on the flat side of the plate, a type a extrapolation, by extrapolating the voltages at 0.4t and 1.0t. This is also for the calculation done

rd
oo
-n
D

id
-zu
D

Figure 299 - Voltage at the location of the bulkhead connection - end of flange transverse stiffener (σ y +) due to the unit load (2x50 kN)

Appendix G compares the calculated hotspot voltage and the measured hotspot stresses at detail D for both the north side of the north plate and the south side of the southern plate. The largest (measured) voltage change occurs on the south side.

Figure 300 - DD-STPC hotspot voltage detail D, north and south side

It is striking that the local effects in the hotspot influence lines are limited, while the global effect is correct is relatively large. In addition, a tensile load is found in the measurement when the vehicle is in it field before (south side) or after (north side). Further analysis of the different strain gauges shows that the local effect is suppressed by the hotspot extrapolation. The further away from the lasteen, the the more emphatically the local effect becomes visible again and the smaller the global effect becomes.

NB. North side measurement at 10 mm is an extrapolated value

Figure 301 - Measured voltages DD-STPC detail D, north and south side

On the south side it can be seen that over a length of 12 mm the sign of the voltage change through the global behavior switch sign. There is no clear explanation as to why there is so much variance in it tensions occur over a relatively short distance, precisely when the truck is relatively far away from the measured crossbeam. It is possible that a disturbance may occur here by local deviations in the construction.

Because the results of the measurement deviate from the expectations, it cannot simply be done assuming the measurement is representative of the other portals. It can be assumed that the calculated voltage change, despite the deviating shape compared to the measurement, is conservative for the fatigue analysis. It was therefore decided, in consultation with Rijkswaterstaat, for the fatigue analysis based on the calculated voltage change. The normative calculated voltage change occurs on the north side, see Figure 300 . The fatigue analysis is assumed of detail category DC = 90, in accordance with table 3.3, detail 9 of IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”[10]. Deviating from this table, a type a is assumed extrapolation instead of a type b extrapolation, because there is also bending in the plane. The tensions are therefore determined on the corner of the plate, and not on the front side.

The table below shows the damage figures for three different safety factors. The welded joint does not meet the damage requirement D ≤ 1.0 at most locations.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	5.5	16.7	3.3	4.1	5.5	11.1	0.3	0.7
1.15	3.1	9.6	1.9	2.3	3.1	6.4	0.1	0.3
1	1.8	5.8	1.1	1.3	1.8	3.8	0.1	0.1

Table 153 - Damage figures for the end of 2018 and the end of 2050 for detail DD-STPC-D.

5.25.6 Detail E - Bottom flange cross beam at line cross beam

Detail E is located at the top of the bottom flange of the cross beam, perpendicular to the span direction of the cross beam, exactly on the line of the end of the connecting plate at the bottom the cross beam between the bulkheads. There are no photos available of the measurement location.

E-south E-north

E

Figure 302 - Location detail DD-STPC detail E

Appendix G provides the comparison between the measurements and the calculated hotspot voltages. The highest voltages were found on the south side, where the ratio measurement to computed hot spot voltage change equals 128%.

Figure 303 - Hotspot voltage DD-STPC detail E, south side

Detail E - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPC, detail E, south side) and equals 128%. The tensions for the fatigue calculation, the unit load has been multiplied by this model factor, after which a fatigue calculation of the toe of the weld has been performed. This is based on Detail category $C\sigma_c$ = 100 N / mm², based on IIW report "Recommendations for Fatigue Design of Welded Joints and Components "[10], table 3.3, detail 3.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	3.0	8.4	2.2	3.8	2.7	5.5	0.7	1.5
1.15	1.6	4.6	1.1	1.8	1.4	3.0	0.3	0.7
1	0.9	2.6	0.6	0.9	0.8	1.6	0.2	0.3

Table 154 - Damage figures for the end of 2018 and the end of 2050 for DD-STPC detail E

Project related

5.25.7 Detail F - Horizontal plate under cross beam for vertical partitions

Detail F is located on the underside of the horizontal plate under the bottom flange of the cross beam, in the transverse direction of the cross beam, at the location of the end of the partitions.

F-south F-north

Figure 304 - Detail photo DD-STPC location F

Project related

Appendix G gives the comparison between the measurements and the calculated hotspot voltages and the voltage at 1.0t. The highest stresses were found on the south side, where the ratio measurement was over compared to calculated hotspot voltage change equals 106%. In the measurement some unexpected results were found, for example, a tensile stress was found at 10 mm (1.0t), while ter a pressure stress is found at the location of the hotspot.

Figure 305 - Voltage at 1.0 t and hot spot voltage DD-STPC detail F, south side

Detail F - Toe of the weld

Based on the ratio of the voltage range from the measurements and from the model when passing the heaviest axis is a model factor determined. This is based on the largest measured voltage change at 20 km / h (from DD-STPC, detail F, south side). This is based on a type a extrapolation. The stresses due to the unit load have been multiplied for the fatigue calculation with this model factor, after which a fatigue calculation of the toe of the weld was performed. Hereby is based on Detail category $\Delta\sigma_c$ = 100 N / mm², based on IIW report “Recommendations for Fatigue Design of Welded Joints and Components ”[10], Table 3.3, Detail 3.

Weld toe fatigue analysis was performed for three partial safety factors, where the damage was determined at the end of 2018 and at the end of 2050. The results are summarized in the table below.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 155 - Damage figures for the end of 2018 and the end of 2050 for DD-STPC detail F

It is concluded that at location F the toe of the weld is sufficient.

5.25.8 Detail G - Connection body / bulkhead crossbeam - headboard on main beam body

The stresses at the location of the welded connection between the body of the cross beam and the headboard and between the bulkheads under the cross beam and the top plate on the body of the main beam is in figures below. The headboard and cover plate are in turn connected to the main beam body with rivets. Voltage concentrations occur particularly with the welding gates. No measurements were taken for this location.

G1

G2

G3

Figure 306 - Tensions at the location of crossbeam / bulkhead connection - bulkhead on main beam body, DD-STPC, Detail G

Some higher tensile stresses are found on the inside of the bulkheads at G3, by bending the bulkheads. This occurs particularly in traffic in lane 2, in traffic in lane 1 this is compensated by the pressure from the wheel load that is directly above the relevant detail. The highest damages are therefore found in the eastern beams.

Detail G - Toe of the weld

The highest voltage fluctuations occur at detail G1 and G3. The testing of the toe of the weld was therefore carried out for detail G1 and G3 on the basis of a hotspot analysis based on the calculated tensions. Tested for detail category DC = 90, comparable to detail A.

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 156 - Damage figures for late 2018 and late 2050 for location G1 - toe of the weld

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.3	0.6	0.5	1.5	0.1	0.3	0.4	0.9
1.15	0.1	0.2	0.2	0.6	0.0	0.1	0.2	0.4
1	0.0	0.1	0.1	0.3	0.0	0.0	0.1	0.2

Table 157 - Damage figures for the end of 2018 and the end of 2050 for location G3 (northern plate) - toe of the weld

	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.4	0.9	0.7	1.9	0.2	0.5	0.5	1.1
1.15	0.2	0.4	0.3	0.8	0.1	0.2	0.2	0.5
1	0.1	0.2	0.1	0.3	0.0	0.1	0.1	0.2

Table 158 - Damage figures for the end of 2018 and the end of 2050 for location G3 (south plate) - toe of the weld

Detail G - Root of the weld

Details G1 and G3 were tested for testing the root. Tested for detail category DC = 40, op based on the TNO method, as described in detail A1. Given the low voltage, none occur of the details damage on.

Detail G1

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 159 - Damage figures for the end of 2018 and the end of 2050 for location G1 - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 160 - Damage figures for the end of 2018 and the end of 2050 for location G1 - root of the weld (DC = 40, type 2)

Detail G2

Type 1	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 161 - Damage figures for the end of 2018 and the end of 2050 for location G3 - root of the weld (DC = 40, type 1)

Type 2	HRB west		HRB east		PRB west		PRB east	
γ_{Mf}	2018	2050	2018	2050	2018	2050	2018	2050
1.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 162 - Damage figures for the end of 2018 and the end of 2050 for location G3 - root of the weld (DC = 40, type 2)

The shear stresses are very low in both cases and will not result in additional damage.

It is concluded that a small exceedance has been found at the location of location G3 based on of the calculated stresses. The measurements at locations G3 with cross beam DD-zK, DD-K30 and DD-STPA however, all indicated that the actual voltage change is considerably lower, approximately 2 to 3 N / mm². It can be assumed that this will also be the case here. Given the limited excess and the fact that significantly lower voltages have been measured as calculated at other comparable locations it is assumed that detail G3 is sufficient.

5.25.9 Detail H - Connection at the bottom of the knee bulkhead - cross stiffeners

The knee bulkheads are welded to the cross beam body with a 10 mm X-weld. In addition, there is something higher also a shot welded to the knee shot.

H

Figure 307 - Detail DD-STPC location H

For these locations, this plate must be tested for fatigue on the basis of the stresses in the vertical direction. It follows from the calculation that the stresses at these locations are very small and there are also no large voltage concentrations are present. Therefore, there are no further details for these fatigue calculations performed. These details can be assumed to be sufficient.

Figure 308 - Tensions at the location of the knee joint connection - transverse stiffener body, DD-STPC, Detail H

5.25.10 Detail I - Connecting the lower flange crossbeam - headboard

Location I concerns the connection of the bottom flange of the crossbeam with the headboard. At portal C, different from the other portals, a widening plate is placed under the bottom flange, so that the voltages across a significantly wider plate are transferred to the main beam, via the bulkhead.

I1

I2

Figure 309 - Detail DD-STPC location I

Given the magnitude of the voltages, it can be assumed without calculation that it complies with fatigue. Therefore, no further calculations have been made.

I2

I1

Figure 310 - Tensions at the location of the horizontal plate connection under the lower flange - bulkhead on main beam body, DD-STPC, Detail I

5.26 Type DD-Of: Longitudinal weld bottom flange-body crossbeam

A longitudinal weld is present in the cross beam between the body and the flanges. The weld connection between the body and the bottom flange has been tested in this section. This applies to the connection in the top flange is part of the deck construction and that it is driven directly by a wheel print. Review of the deck construction falls outside the scope of the assignment and has therefore not been tested further.

Figure 311 - Weld connection body and flange crossbeam [Source: A.85378]

The detail category for the fatigue calculation of this compound is used as $\Delta\sigma_c$ = 100 N / mm ^{2} in accordance with NEN-EN 1993-1-9 Table 8.2 Detail 7.

Figure 312 - Detail category for the fatigue calculation of the connection type DD-Of (main bridge).

The voltage change at the location of the body-bottom flange connection was determined using the local fashion model. This is based on the cut with the maximum tension due to an axle load in lane 1, when the axle is exactly above the cross beam. The cross beam on axle 13 gave the largest tension, although the differences are small. This cross beam is used for the determination of the fatigue damage.

Tested cut

Figure 313 - Location of the stress determination for crossbearing fatigue testing (type DD-Of) (main bridge)

The calculation was performed for 3 different safety factors γ_{Mf} = 1.35, 1.15 and 1.00. Hereby is based on the tension at the top of the bottom flange, at the connection to the body. Because the lane 1 position for the main carriageway has changed, the damage is both just on the western side determined from the center as just on the eastern side. According to the previous calculations wort referred to as main carriageway west (HRB west), main carriageway east (HRB east), parallel carriageway west (PRB west) and parallel carriageway east (PRB east).

Table 163 shows the results for γ_{Mf} = 1.35. The test results with the other safety factors are shown in Appendix E17.

γ_{Mf} = 1.35	**HRB west**		**HRB east**		**PRB west**		**PRB east**	
	2018	**2050**	**2018**	**2050**	**2018**	**2050**	**2018**	**2050**
DD-Or	0.1	0.4	0.1	0.1	0.1	0.3	0.0	0.0

Table 163 - Damage numbers of connection type DD-Of for the end of 2018 and the end of 2050 (γ_{Mf} = 1.35)

The weld joint meets the damage requirement. Given the margin between the damage numbers and the damage requirement, it is not necessary to account for any small variations in the moments between the different cross beams further investigate. It can be concluded that the connection is adequate for all cross bars.

6 Distortions

6.1 Joint deformations

The joint movements are determined on the basis of the requirements for joint transitions in accordance with ROK v1.4 Appendix A. The joint movements are determined on the basis of the characteristic load combinations, as shown in Table 164 are displayed.

Characteristic load combinations of joint transitions

	1a / c	1b / d	1st / f	2a / c	2b / c	2nd / f	3a / c	3b / d
TS (LM1)	0.8	0.64	0	0.8	0.64	0	1	0.8
UDL (LM1)	0.8	0.64	0	0.8	0.64	0	1	0.8
Single axis (LM2)	0.8	0.64	0	0.8	0.64	0	1	0.8
Horizontal load	0.64	0.8	0	0.64	0.8	0	0.8	1
Wind [b] F_{wk}	0	0	0.8 [b]	0	0	1 [b]	0	0
F^*_w	0.8	0.8	0	1	1	0	0.8	0.8
Temperature [a]	1	1	1	0.8	0.8	0.8	0.8	0.8

[a] The higher temperature range for joint transitions has been taken into account by multiplying the load factor by 45 ° C / 35 ° C = 1.29.

[b] Where traffic load is present on (parts of) the bridge, F^*_w may be used instead of F_{wk}. For the combinations with $\psi_0 * F_{wk}$ is based on the wind load F^*_w with a load factor $1.0 * \psi_0 * F_{wk} / F^*_w = 1.0 * 0.8 * 1.056 = 0.85$ and 1.0 * 1, 0 * 1.056 = 1.06.

Table 164 - Load combinations for deformation of joint transitions [ROK 1.4]

Figure 314 shows the minimum and maximum joint transition movement in x-direction (longitudinal direction of the bridge). The other maximum joint movements and rotations are shown in Table 165 . For a full overview of the joint deformations can be found in Appendix F1.

Fixed imposition

Figure 314 - Minimum and maximum deformation of the joint transition in the x direction.

	U_x [mm]	U_y [mm]	U_z [mm]	φ_x [mrad]	φ_y [mrad]	φ_z [mrad]

Minimum (Pillar F)	-78.8	-4.5	-10.7	-4.3	--4.3	-1.1
Maximum (Pillar F)	87.8	4.1	6.3	4.4	13.2	2.3
Minimum (abutment south))	-137.8	-4.5	-1.9	-0.8	-9.0	-1.6
Maximum (abutment south)	165.0	4.1	2.1	0.9	3.5	0.7

Table 165 - Total deformations at the beginning and end of the main bridge (SLS)

z

zu
φ

Figure 315 - Axle system model

The displacements found differ per side, because the fixed support is not in the middle.
It should be noted that the tandem systems are placed only on the left part of the bridge in the model.
Rotations at pillar F should therefore be used for the joint transition at the location of
abutment south.

At Pillar F and the southern abutment, MAURER D-180 joint transitions were applied with a joint range of 180 mm (+90 mm / -90 mm), see drawing [A.105058]. The calculated joint movement of the southern abutment joint transition is -138 mm / +165 mm, which makes it available joint range is insufficient. At Pillar F the joint movement of the main bridge is -79 mm / +88 mm, the joint movement of the bridge is -71 mm / +51 mm (see calculation bridge), with which the total joint movement is -150 mm / +139 mm. This is also more than the available joint range (+90 mm / -90 mm).

The joint deformations are further broken down by type of load in the table below. Like too expect the greatest contribution to the deformation is the temperature load. The deformations due to temperature are displayed for + 45 ° C / -46 ° C, which corresponds to the temperature range in accordance with RTD 1007-2. This is +/- 10 ° C higher if the temperature range conforms to the Eurocode.

		U_x [mm]	U_y [mm]	U_z [mm]	φ_x [mrad]	φ_y [mrad]	φ_z [mrad]
Wind load	Minimum (Pillar F)	-4.9	-0.8	-0.5	-0.3	-1.2	-0.4
	Maximum (Pillar F)	4.9	0.8	0.6	0.3	1.2	0.4
	Minimum (abutment south))	-6.3	-0.9	-0.7	-0.3	-1.3	-0.5
	Maximum (abutment south)	6.3	0.9	0.7	0.3	1.3	0.5
Temperature tax	Minimum (Pillar F)	-61.7	-3.3	-1.3	-0.5	-1.5	-0.2
	Maximum (Pillar F)	56.3	3.3	1.2	0.5	0.5	0.2
	Minimum (abutment south))	-117.8	-3.3	-1.3	-0.5	-0.5	-0.2
	Maximum (abutment south)	129.4	3.3	1.2	0.5	1.5	0.2
Traffic tax Vertical	Minimum (Pillar F)	-7.8	-0.5	-4.9	-2.1	-1.1	-0.4
	Maximum (Pillar F)	17.6	0.3	2.5	2.0	5.6	0.8
	Minimum (abutment south))	-8.8	-0.3	-0.1	-0.1	-3.6	-0.5
	Maximum (abutment south)	19.5	0.1	0.5	0.2	0.7	0.1
Traffic tax Horizontal	Minimum (Pillar F)	-1.6	0.0	0.0	0.0	0.0	0.0
	Maximum (Pillar F)	1.6	0.0	0.0	0.0	0.0	0.0
	Minimum (abutment south))	-2.3	0.0	0.0	0.0	0.0	0.0
	Maximum (abutment south)	2.3	0.0	0.0	0.0	0.0	0.0

Table 166 - Deformation of joint transition per load type

6.2 Deformations of bearings

For the deformations at the support points of pillar F, G, H, J, K and abutment south, use is made from the same approach as for the joint deformations; see Chapter 6.1. In the tables below the main results per imposition are presented. For a complete overview and the breakdown for each tax group reference is made to Appendix F2. It is noted that use has been made of the combinations for joint deformations, so including surcharge on the temperature load.

	U_x [mm]	U_y [mm]	U_z [mm]	φ_x [mrad]	φ_y [mrad]	φ_z [mrad]
Pillar F min.	-75.6	0	0	0	-3.7	-1.5
Pillar F max.	78.5	0	0	0	10.6	0.5
Pillar G min.	-54.6	0	0	0	-8.7	-0.6
Pillar G max.	68	0	0	0	5.8	0.9
Pillar H min.	0	0	0	-4.0	-4.4	-0.1
Pillar H max.	0	0	0	4.1	8.3	0.1

Pillar J min.	-89.4	-0.9	0	-1.3	-9.5	-1.4
Pillar J max.	130.3	0.9	0	1.4	3.5	3.2
Pillar K min.	-110.6	0	0	0	-3.9	-1.0
Pillar K max.	132.7	0	0	0	7.7	0.6
abutment south min.	-136.9	0	0	0	-7.3	-0.6
abutment south max.	171.0	0	0	0	3.0	1.3

Table 167 - Maximum knot displacements for supports (SLS)

7 Collision with the construction

The bridge can be crossed at the location of the river span. In the strength calculations in Chapters 5 and 6 do not take into account the acceptance tax. Because of it obtained by law level, it is not mandatory to have an existing construction meet a special one

tax (combination) if it did not apply when the original was issued
building permit. Nevertheless, Rijkswaterstaat has asked to see to what extent the bridge is capable of
include an acceptance tax in accordance with current standards.

7.1 Approach

For the calculation it is assumed that the acceptance tax is applied to the lower edge of the main beam. The load will be transferred to the K-bandages and then via the lower flange to the deck. Because in the global model with eccentric beams under the deck, there is no coupling the lower flange with the K-bandages was chosen to perform the analysis on the local plate model. Although this modeled part is not actually in the river span, a acceptance tax on this model does give a reasonable picture of the tax payment via the lower flange to the K-relationships and the tensions that arise.

The collision load, 1MN, is distributed as a line load over 3 m on the bottom flange of the main beam. To visualize all possible scenarios, the acceptance tax will be at 4 different locations applied both at the k-bandages and exactly in between (see Figure 316) .

Figure 316 - The locations of the acceptance load (note: load has been entered as line load over 3 m)

7.2 Deformations

Based on the deformation of the construction, it was checked w t should is expected in a collision. It can be seen in Figure 317 and Figu bend the bottom flange in the transverse direction and rotate the bridge as a whole. This corresponds to the expectation.

Figure 317 - 3D deformation of the structure due to the acceptance load

Figure 318 - 3D deformation of the structure due to the acceptance load (cross-section)

Project related

Figure 319 - 3D deformation of the structure due to the collision load (bottom flange of main beam)

7.3 Tensions

The greatest stresses will arise in the parts that are directly loaded, such as the bottom flange and the diagonals and bottom edge of the K-bandages. Figure 320 shows the maximum voltage in the lower flange of the main beam and the lower edges of K connections due to the collision load (NB. This is so without the other taxes). In the lower flange there is a collision between the K-bandages a bending stress of approximately 650 N / mm², far above the permissible tension of 350 N / mm². This means that large plastic deformations of the bottom flange will occur.

Figure 320 - Stress in the bottom flange of the main girder and K-bandages due to a collision load in the first field

In the event of a collision with the lower flange in line with the K-connection, a compressive stress occurs locally of 839 MPa (see Figure 321) . The maximum compressive stress is created at the joint of the bottom edge with the bottom flange of the main beam. The connection will therefore collapse here

Figure 321 - Tension in the bottom flange of the main beam and K-bandages due to an acceptance load on the second K-bandage

For the other two locations, comparable high voltages apply, which, certainly in combination with the other variable loads will result in the flow of the bottom flange and bottom edge of the K-bandage.

Figure 322 - Tension in the bottom flange of the main beam and K-bandages due to an acceptance load in the second field

Figure 323 - Tension in the bottom flange of the main beam and K-bandages due to an acceptance load on the third K-band

7.4 Conclusion

As mentioned earlier, an existing construction does not have to be due to the legally obtained level meet current requirements for acceptance taxes. Strengthening the bridge to meeting the current requirements will be very expensive and does not seem to outweigh the risks involved is taken away.

In addition, the clearance of the nearby bridges is considerably lower than the IJssel Bridge.
For example, according to Rijkswaterstaat, the underpass height (ODVH) of the IJssel Bridge is decisively high water (MHW) 8.22 m. The Doesburg road bridge has an ODVH of 6.27 m at MHW, in the railway bridge Westervoort has an ODVH of 6.41 m at MHW. This makes the chance of collision very small.

8 Conclusions

In this report, the results of the structural recalculation of main bridges of the IJssel Bridge. The bridges were tested for structural strength and stability of the main supporting structure and the connections, as well as fatigue of the main supporting structure.

8.1 Strength and stability

The strength of the longitudinal stiffeners appears to be insufficient in the area between the river pier and the first next section in the river span. It is recommended to replace it, or the reduce tension by reinforcing the bottom flange of the main beam.

The verticals of portal B are not strong enough. It has been demonstrated using a plate model only the cut at the bottom of the bulkhead between the cross beam and the cross stiffener does not meet strength.

The other parts comply with strength and stability.

8.2 Connections

The connection of the lower edge of portal C at the location of the river pillars is not satisfactory. The rivet connection is not sufficient for both fixed and roller bearings, the net
The cross section of the connecting plate is not sufficient for fixed supports only. This is recommended connection by replacing the rivets for a bolted connection and the flanges connect to the connecting plate. In addition, a number of connections of the longitudinal stiffeners suffice not at the site of section divisions and portal C. In addition, these connections have creaking noises noted. In consultation with Rijkswaterstaat, it has been decided that all connecting pieces of the longitudinal stiffeners replace at section divisions and lower couplers at portal C.
must become.

The joints of the inspection path consoles show considerable corrosion. For this is referred to the inspection report. It is recommended to determine or have determined the degree of corrosion see to what extent these can still be preserved.

8.3 Fatigue

Most fatigue details of the main beams and crossbars do not meet the requirement D <1.0 at γ_{Mf} = 1.35. Even now (at the end of 2018), a large number of connections do not meet the set requirement.
It is recommended that the current inspection regime, which was introduced in response to the results of update previous (preliminary) analyzes of the fatigue problem by TNO, based on the maintain new results and inspection regime until remedial action is taken.

The damage caused by fatigue is so high that besides “simple” remedial measures such as civil grinding or drilling out rivet holes will also require tension relief. This one voltage drop will be needed over great lengths. The remedial measures will be elaborated in a separate report.

8.4 Deformations

The occurring joint deformations are calculated to be greater than the joint range of the current one add. In practice, however, there does not appear to be any damage to the joint transitions related to excessive deformation or adjacent joints. However, there are significant corrosion of the joint transitions, dirt in the joint transitions and cracked rubbers found during the inspection. When replacing the joint transitions it is recommended to take into account the in this one report calculated joint deformations and not with the joint capacity of the current joint transitions.

8.5 Collision

In addition to the strength and fatigue calculations, the consequences of a possible assessment were also examined collision against the bridge. The analysis shows that in the event of a collision, the voltage is well over the permissible strength. Due to the legally obtained level, an existing bridge does not have to comply with the current requirements for acceptance taxes. Reinforcing the bridge to meet the current requirements will be very costly and does not seem to outweigh the risk that this removes is going to be. Moreover, the vertical clearance of the nearby bridges in the IJssel (Spoorbrug in Westervoort and the Doesburg road bridge) are considerably lower than the IJssel bridge, which reduces the risk of collision is very small.

Project related

Appendix A

Taxes

IJssel Bridge

Project related

Appendix A1

Permanent taxes

IJssel Bridge

Appendix A2

Traffic taxes

IJssel Bridge

Appendix A3

Wind load

IJssel Bridge

Appendix A4

Temperature load

IJssel Bridge

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Project related

Appendix A5

Other taxes

IJssel Bridge

Appendix B

Modeling

IJssel Bridge

Annex B1

Tax input SCIA Engineer - global model

IJssel Bridge

Appendix B2

Tax input SCIA Engineer - local model

IJssel Bridge

Appendix B3

Tax Import Validation - Global fashion model

IJssel Bridge

Project related

Appendix B4

Tax Import Validation - Local fashion model

IJssel Bridge

Appendix C

Test strength and stability

IJssel Bridge

Appendix C1

Main beam assessment

IJssel Bridge

Appendix C2

Assessment of crossbars

IJssel Bridge

Appendix C3

Assessment K-relationships and portals

IJssel Bridge

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Appendix C4

Driving deck assessment

IJssel Bridge

Appendix C5

Inspection path assessment

IJssel Bridge

Appendix D

Assessment of connections

IJssel Bridge

Appendix D1

Detail type A - Weld end on plate

IJssel Bridge

Project related

Appendix D2

Detail type B and C - Riveted connections bridge sections

IJssel Bridge

Project related

Appendix D3

Detail type K - Rivet connection flange package

IJssel Bridge

Appendix D4

Detail Type DD-zK - Connection between main beam and console / cross beam

IJssel Bridge

Appendix D5

Detail type P - Connections diagonals

IJssel Bridge

Project related

Appendix D6

Detail type Q - Connections horizontals bottom and top edge K-bandages

IJssel Bridge

Project related

Appendix D7

Appendix H3 Detail type R - Connections deck construction

Detail type S - Connection longitudinal stiffeners in section division

IJssel Bridge

Appendix E

Fatigue assessment

IJssel Bridge

Appendix E1

Detail type A - Weld end on plate

IJssel Bridge

Appendix E2

Detail type B - Flange wideners ter height of rivet at section division

IJssel Bridge

Appendix E3

Detail type C - Riveted connections bridge sections

IJssel Bridge

Project related

Appendix E4

Detail type D - Vertical pleat stiffeners inside - weld with bottom flange

IJssel Bridge

Project related

Appendix E5

Detail type E - Vertical pleat stiffeners inside - weld with body main beam

IJssel Bridge

Appendix E6

Detail type F - Vertical outside crease stiffener - weld with bottom flange

IJssel Bridge

Appendix E7

Detail type G - X-seam in bottom flange main beam

IJssel Bridge

Appendix E8

Detail type H - Flange widener ter height of supports

IJssel Bridge

Project related

Appendix E9

Detail type I - Vertical pleat stiffener outside - weld with cross beam body

IJssel Bridge

Appendix E10

Detail type J - Long welded body

IJssel Bridge

Appendix E11

Detail type K - Rivet connection flange package

IJssel Bridge

Appendix E12

Detail Type DD-K30 - Connections between main girder and cross beam

IJssel Bridge

Appendix E13

Detail Type DD-K24 - Connections between main girder and crossbeam with K bandage ½ INP30

IJssel Bridge

Project related

Appendix E14

Detail type N - Longitudinal weld between cover plate and bottom flange

IJssel Bridge

Appendix E15

Detail type O - X-weld ½ DIN profiles

IJssel Bridge

Appendix E16

Detail type P - X-weld in body plate main beam

IJssel Bridge

Appendix E17

Detail type DD-Of - Longitudinal weld-lower flange crossbeam

IJssel Bridge

Project related

Appendix E18

Detail type S - Coupling longitudinal stiffeners at the site of

portal C

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Appendix E19

Detail type T - Weld connection jack points

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Appendix E20

Detail Type DD-zK - Connections between main girder and intermediate crossbars

IJssel Bridge

Appendix E21

Detail Type DD-STPA - Connections between main girder and cross beam portal A

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Project related

Appendix E22

Detail Type DD-STPB - Connections between main girder and cross beam portal B

IJssel Bridge

Project related

Appendix E23

Detail Type DD-STPC - Connections

between main girder and cross beam portal C

IJssel Bridge

Project related

Appendix F

Distortions

IJssel Bridge

Annex F1

Joint deformation SCIA output

IJssel Bridge

Appendix F2

Deformation for the support of SCIA output

IJssel Bridge

Appendix G

Rack measurement comparison - FEM crossbars main bridge

IJssel Bridge

Project related

Appendix G1

Rack measurement comparison - FEM crossbars main bridge

IJssel Bridge

Project related

Appendix H

Analysis undercut

IJssel Bridge

Appendix H1

DIANA Analysis undercut weld

IJssel Bridge