Concept development, floating bridge
E39 Bjørnafjorden

Appendix K – Enclosure 8

10205546-13-NOT-194
Shear lag and buckling effects of Bridge Girder concept K12

MEMO

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CLIENT	Statens vegvesen	ACCESSIBILITY	Restricted
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SUMMARY

When designing the bridge girder, effects of shear lag and plate buckling must be taken into account at the ultimate, serviceability and fatigue limit state. This memo presents the design requirements and the applied design approach accounting for these effects.

Sufficient capacity of the bridge girder subject to compression and biaxial bending is verified based on equation (4.15) in NS-EN 1993-1-5:2006 + NA 2009. Equation (4.15) is a linear summation of the utilization that each force component utilizes the capacity corresponding to the respective type of force. Due to the bridge girders shape with an inclined bottom plate, the capacity check will give conservative utilization results for biaxial bending when the utilization about each axis is large at the same time.

Since the Eurocode does not account for conservative utilizations due to geometric shapes, a second way of performing the capacity check has been introduced. In the second method, the geometric shape is considered in the capacity check by calculating the utilization at all the 7 extremity points of the girder based on the effective elastic section modulus for the specific point.

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1 Introduction

When designing the bridge girder, effects of shear lag and plate buckling must be taken into account at the ultimate, serviceability and fatigue limit state. This memo will present the design requirements and the applied design approach.

Calculation examples will be given, but the final results of the bridge girder capacity verification can be found in a closure to Appendix G: Global Analyses – Response, as it is a part of the post-processing routine of the global analyses results.

1.1 Design method

NS-EN 1993-1-5:2006 + NA:2009 provides two different design methods for plated steel structures; effective width method and reduced stress method. The applied method for the design of the bridge girder will be the effective width method, where all requirements are given in chapters 3 – 9 of the NS-EN 1993-1-5. The effective width method is efficient because it accounts for post-critical reserve in single plate elements and load shedding between cross-sectional elements.

Similar to the Eurocode, the following designation of three types of effective cross-section and effective width will be used in this memo:

- Effective^{s} – includes effects of shear lag
- Effective^{p} – includes effects of plate buckling
- Effective – includes effects of both shear lag and plate buckling

1.2 Bridge girder

Figure 1 to Figure 3 shows the longitudinal steel in the typical bridge girder sections at mid span and by columns. Transverse bulkheads and trusses are not shown in the figures, as their design is not within the scope of this memo.

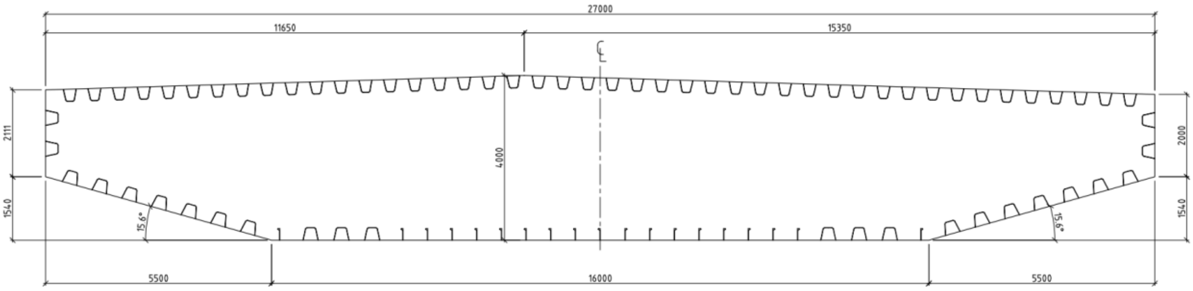


Figure 1 Bridge girder section at mid span

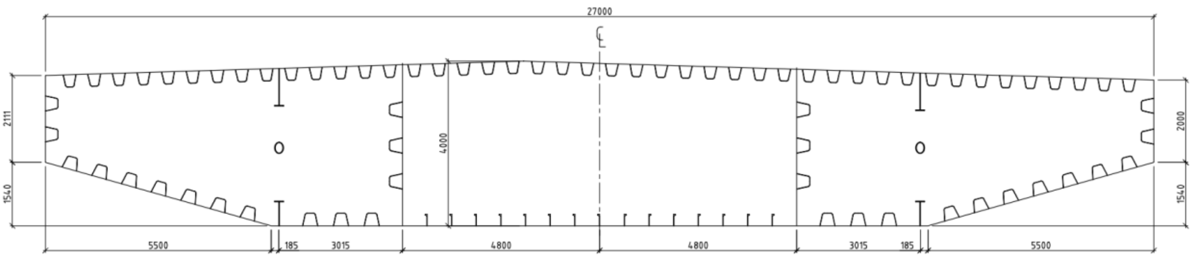


Figure 2 Bridge girder section by column axis 3 - 8

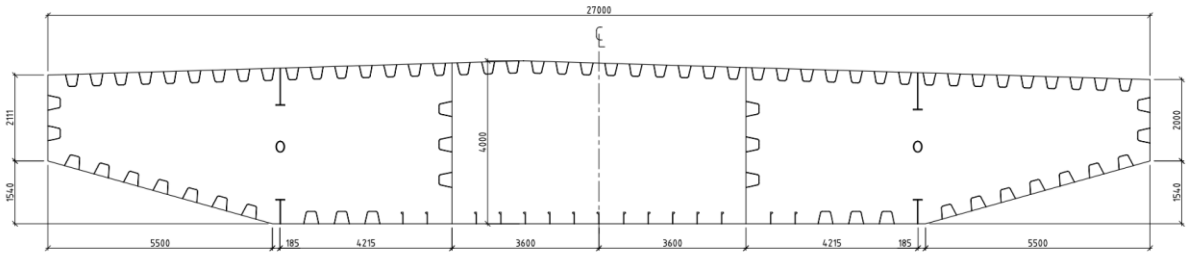


Figure 3 Bridge girder section by column axis 9 – 38

Figure 4 shows the positive direction of the v – vertical axis, h – horizontal axis and l – longitudinal axis as they are in the model for the global analysis of each bridge concept. The positive direction for the axial force, N_{Ed}, moment about the weak axis (horizontal), M_{weak}, and moment about the strong axis (vertical), M_{strong}, are also shown in the figure.

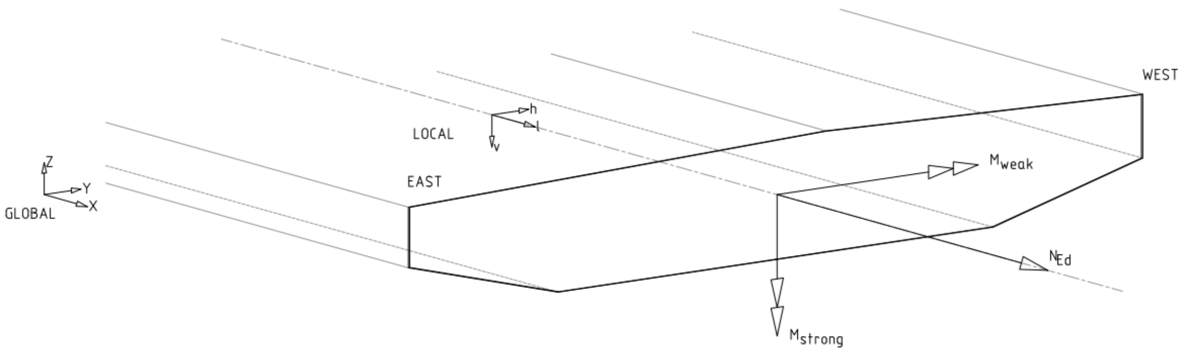


Figure 4 Local axis system in bridge girder and positive force direction

2 Design requirements

NS-EN 1993-1-5:2006 + NA:2009 (later referred to as EC3-5) gives design requirements of stiffened (and unstiffened) plates which are subject to in-plane forces.

2.1 Global analysis

According to clause 2.2(1)P in EC3-5, the effects of shear lag and of plate buckling on the stiffness of members shall be taken into account in the global analysis. Further on, in clause 2.2(5), it is stated that the effects of plate buckling on the stiffness can be ignored if the effective^{p} cross-sectional area of the girder in compression is larger than ρ_{lim} times the gross cross-sectional area of the girder. Clause NA.2.2(5) of the National Annex to EC3-5 gives the value of ρ_{lim} as 0.5.

2.2 Shear lag in member design

Shear lag effects are dependent on the span of the bridge, as well as the width of the internal elements in the flanges of the girder. With the typical span of Bjørnafjorden being 125 m, the distance L_e determined from Figure 3.1 in EC3-5 is 87,5 m for sagging bending, and 62,5 m for hogging bending.

According to clause 3.1(1) in EC3-5, the effects of shear lag may be neglected if half the width of the internal elements in the flanges of the girder is less than $L_e/50$. This is never the case for the bridge girder of Bjørnafjorden, hence shear lag effects should be considered at serviceability and fatigue limit state according to clause 3.2.1, and at ultimate limit state according to clause 3.3 of EC3-5.

2.3 Plate buckling effects due to direct stresses at the ultimate limit state

Sufficient capacity of the bridge girder due to direct stresses is verified based on equation (4.15) given in clause 4.6(1) in EC3-5:

$$\eta_1 = \frac{N_{Ed}}{\frac{f_y A_{eff}}{\gamma_{M0}}} + \frac{M_{y,Ed} + N_{Ed} e_{y,N}}{\frac{f_y W_{y,eff}}{\gamma_{M0}}} + \frac{M_{z,Ed} + N_{Ed} e_{z,N}}{\frac{f_y W_{z,eff}}{\gamma_{M0}}} \quad (4.15)$$

The effective cross-sectional properties of the girder are based on the effective areas of the compression elements and on the effective^s area of the tension elements due to shear lag, in accordance with clause 4.3(2).

According to clause 4.3(3) and 4.3.(4), the effective^p area A_{eff} should be determined assuming that the cross-section is subject only to stresses due to uniform axial compression. The shift, $e_{y,N}$ and $e_{z,N,}$ of the centroid of the effective^p area A_{eff} relative to the center of gravity of the gross cross-section, gives and additional moment which should be taken into account in the cross-section verification. The effective section modulus W_{eff} should be determined assuming the cross-section is subject only to bending stresses about the respective axis.

2.4 Further requirements

In addition to the requirements for checking effects of shear lag and plate buckling effects due to direct stresses, NS-EN 1993-1-5:2006 + NA:2009 also gives requirements and resistance models for shear buckling and buckling due to transverse loads.

Experience show that buckling effects due to shear loads for a heavily stiffened plated structure are very low (often neglectable), thus at this stage of design, the shear resistance is considered as full. A check of the von mises stress in the girder at ULS is performed in order to verify the capacity. Results of this check can be found in a closure to 90-RE-107 Appendix G: Global Analyses – Response_0

3 Shear lag effects

At serviceability and fatigue limit state, an effective^s width for elastic shear lag is used in accordance with clause 3.2 of EC3-5. The effective^s width is $b_{eff} = \beta\ b_0$, where the effective^s width factor β is calculated based on formulas given in table 3.1 of the Eurocode.

In the global analysis, the stiffness of the bridge girder about the weak axis is based on the effective^s cross-section attained by using the effective^s flange widths $b_{eff} = \beta\ b_{0.}$

Refer to memo 13-NOT-099 – FEM analysis of bridge girder and column for verification of shear lag factors calculated according to clause 3.2 of the Eurocode compared to the shear lag experienced in the local FE-model of the bridge girder.

At ultimate limit state, elastic-plastic shear lag effects are taken into account as given in clause 3.3(1)c). As the National Annex does not specify a preferred method, the recommended method in NOTE 3 is adapted. The effective^s width is $b_{eff} = \beta^{\kappa}\ b_0$, where the factors β and κ are calculated according to table 3.1 of NS-EN 1993-1-5.

The elastic-plastic shear lag effects are combined with the effects of plate buckling due to direct stresses at the ultimate limit state. This is further explained in section 4.2.4 of this memo.

An additional check of the von mises stresses at 7 extremity points of the bridge girder is performed at the ultimate limit state. For these calculations, the effective^s flange width applied when calculating the second moment of area about the weak axis is taken as $b_{eff} = b_0\ \beta^{\kappa}$.

3.1 Calculation example

On the following pages, examples of calculations of β and β^{κ} factors at sagging and hogging bending are shown.

Figure 5 shows the girder section at sagging bending. Top and bottom flanges are internal flanges, and the width b_0 is half of their width. The calculations below give the β and β^{κ} for the top and the bottom flange.

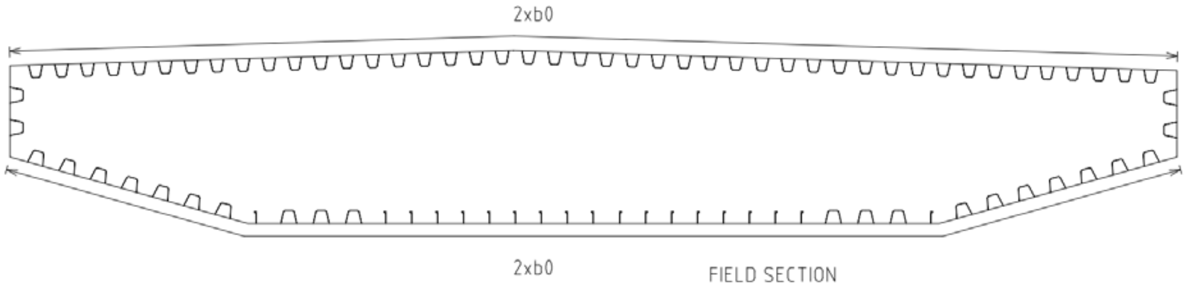


Figure 5 Section at sagging bending

NS-EN 1993-1-5 chapter 3.2 Effectives width for shear lag and 3.3 Shear lag at the ultimate limit state

$kNm := kN \cdot m$

Input

Top flange at sagging bending:

$b_0 := 13506 \cdot mm$	Half width of flange
$A_s := 5923mm^2$	Area of one stiffener
$n_s := 22$	Number of stiffeners within width b_o
$t := 16mm$	Plate thickness
$L_s := 125m$	Distance between supports

Calculations

$L_e := 0.7 \cdot L_s = 87500 \cdot mm$ Distance between adjacent points of zero bending

$$A_{sl} := n_s \cdot A_s = 0.1303\, m^2$$

$$\alpha_0 := \sqrt{1 + \frac{A_{sl}}{b_0 \cdot t}} = 1.27$$

$$\kappa := \frac{\alpha_0 \cdot b_0}{L_e} = 0.20$$

$$\beta := \begin{cases} 1 & \text{if } \kappa < 0.02 \\ \dfrac{1}{1 + 6.4 \cdot \kappa^2} & \text{if } 0.02 < \kappa \le 0.7 \end{cases} = 0.804$$

Effectives width factor β for shear lag under elastic conditions. Relevant for serviceability and fatigue limit state

$$\beta_{ULS} := \beta^{\kappa} = 0.958$$

Effectives width factor β for shear lag under elastic-plastic conditions. Relevant for ultimate limit state

Input

Bottom flange at sagging bending:

$b_0 := 13712 \cdot mm$	Half width of flange
$A_{s\_t} := 4997 mm^2$	Area of one trapezoidal stiffener
$A_{s\_b} := 4127 mm^2$	Area of one bulb stiffener
$n_{s\_t} := 10$	Number of trapezoidal stiffeners within width b_o
$n_{s\_b} := 9.5$	Number of bulb stiffeners within width b_o
$t := 12mm$	Plate thickness
$L_s := 125m$	Distance between supports

Calculations

$L_e := 0.7 \cdot L_s = 87500 \cdot mm$ Distance between adjacent points of zero bending

$$A_{sl} := n_{s\_t} \cdot A_{s\_t} + n_{s\_b} \cdot A_{s\_b} = 0.0892\,m^2$$

$$\alpha_0 := \sqrt{1 + \frac{A_{sl}}{b_0 \cdot t}} = 1.24$$

$$\kappa := \frac{\alpha_0 \cdot b_0}{L_e} = 0.19$$

$$\beta := \begin{cases} 1 & \text{if } \kappa < 0.02 \\ \dfrac{1}{1 + 6.4 \cdot \kappa^2} & \text{if } 0.02 < \kappa \le 0.7 \end{cases} = 0.805$$

Effective^s width factor β for shear lag under elastic conditions. Relevant for serviceability and fatigue limit state

$$\beta_{ULS} := \beta^{\kappa} = 0.959$$

Effective^s width factor β for shear lag under elastic-plastic conditions. Relevant for ultimate limit state

Figure 6 shows the girder section at hogging bending. The flanges are supported by longitudinal girders, causing each flange to be separated into five widths where each width b_0 is half of the internal widths. Due to symmetry, some widths are identical. The calculations below give the β and β^{κ} factors for the top flange only.

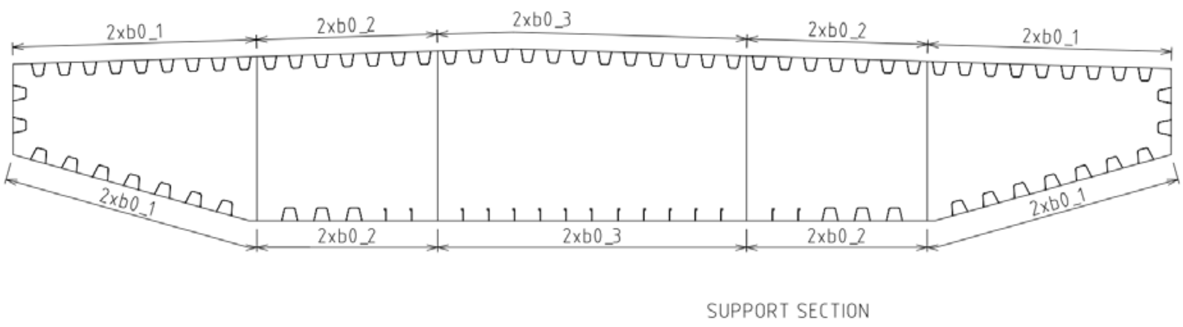


Figure 6 Section at hogging bending

NS-EN 1993-1-5 chapter 3.2 Effectives width for shear lag and 3.3 Shear lag at the ultimate limit state

$kNm := kN \cdot m$

Input

Top flange at hogging bending:

$b_{0\_1} := 2844 \cdot mm$	Half width of internal flange part 1
$b_{0\_2} := 2095 \cdot mm$	Half width of internal flange part 2
$b_{0\_3} := 3595 \cdot mm$	Half width of internal flange part 3
$A_s := 5923 mm^2$	Area of one stiffener
$n_{s\_1} := 4.5$	Number of stiffeners within width b_{o_1}
$n_{s\_2} := 3.5$	Number of stiffeners within width b_{o_2}
$n_{s\_3} := 6$	Number of stiffeners within width b_{o_3}
$t := 16mm$	Plate thickness
$L_s := 125m$	Distance between supports

Calculations

$L_e := 0.25(L_s + L_s) = 62500 \cdot mm$ Distance between adjacent points of zero bending at

Internal flange part 1

$A_{sl\_1} := n_{s\_1} \cdot A_s = 0.0267\, m^2$

$\alpha_{0\_1} := \sqrt{1 + \frac{A_{sl\_1}}{b_{0\_1} \cdot t}} = 1.26$

$\kappa_1 := \frac{\alpha_{0\_1} \cdot b_{0\_1}}{L_e} = 0.06$

Internal flange part 2

$A_{sl\_2} := n_{s\_2} \cdot A_s = 0.0207\, m^2$

$\alpha_{0\_2} := \sqrt{1 + \frac{A_{sl\_2}}{b_{0\_2} \cdot t}} = 1.27$

$\kappa_2 := \frac{\alpha_{0\_2} \cdot b_{0\_2}}{L_e} = 0.04$

Internal flange part 3

$A_{sl\_3} := n_{s\_3} \cdot A_s = 0.0355\, m^2$

$\alpha_{0\_3} := \sqrt{1 + \frac{A_{sl\_3}}{b_{0\_3} \cdot t}} = 1.27$

$\kappa_3 := \frac{\alpha_{0\_3} \cdot b_{0\_3}}{L_e} = 0.07$

$$\beta_1 := \begin{cases} 1 & \text{if } \kappa_1 < 0.02 \\ \dfrac{1}{1 + 6.0\left(\kappa_1 - \dfrac{1}{2500 \cdot \kappa_1}\right) + 1.6 \cdot \kappa_1^2} & \text{if } 0.02 < \kappa_1 \le 0.7 \end{cases} = 0.765$$

Effectives width factor β for shear lag under elastic conditions. Relevant for serviceability and fatigue limit state

$\beta_{ULS\_1} := \beta_1^{\kappa_1} = 0.985$

Effectives width factor β for shear lag under elastic-plastic conditions. Relevant for ultimate limit state

$$\beta_2 := \begin{cases} 1 & \text{if } \kappa_2 < 0.02 \\ \dfrac{1}{1 + 6.0\left(\kappa_2 - \dfrac{1}{2500\cdot\kappa_2}\right) + 1.6\cdot\kappa_2^{\,2}} & \text{if } 0.02 < \kappa_2 \le 0.7 \end{cases} = 0.832$$

Effective[s] width factor β for shear lag under elastic conditions. Relevant for serviceability and fatigue limit state

$$\beta_{ULS\ 2} := \beta_2^{\,\kappa_2} = 0.992$$

Effective[s] width factor β for shear lag under elastic-plastic conditions. Relevant for ultimate limit state

$$\beta_3 := \begin{cases} 1 & \text{if } \kappa_3 < 0.02 \\ \dfrac{1}{1 + 6.0\left(\kappa_3 - \dfrac{1}{2500\cdot\kappa_3}\right) + 1.6\cdot\kappa_3^{\,2}} & \text{if } 0.02 < \kappa_3 \le 0.7 \end{cases} = 0.707$$

Effective[s] width factor β for shear lag under elastic conditions. Relevant for serviceability and fatigue limit state

$$\beta_{ULS\ 3} := \beta_3^{\,\kappa_3} = 0.975$$

Effective[s] width factor β for shear lag under elastic-plastic conditions. Relevant for ultimate limit state

3.2 Summary of shear lag factors for all cross-sections

CONCEPT K12									**Elastic (SLS, FLS)**		**Elsatic-plastic (ULS)**	
Span	125m	**b_0 top**	**b_0 bot**	**Le**	**κ top**	**κ bot**	**a_0 top**	**a_0 bot**	**β top**	**β bot**	**β top**	**β bot**
Cross-section		[m]	[m]	[m]	[–]	[–]	[–]	[–]	[–]	[–]	[–]	[–]
Field (F1_rev05)		13,51	13,71	87,50	0,20	0,19	1,27	1,24	0,80	0,80	0,96	0,96
Field (F2_rev00)		13,51	13,71	87,50	0,20	0,19	1,27	1,21	0,80	0,81	0,96	0,96
Transition (T1_rev00) – sagging bending												
	Section b0_1	4,95	5,05	87,50	0,07	0,07	1,27	1,21	0,97	0,97	1,00	1,00
	Section b0_2	3,60	3,60	87,50	0,05	0,05	1,27	1,23	0,98	0,98	1,00	1,00
	Section b0_3	4,95	5,05	87,50	0,07	0,07	1,27	1,21	0,97	0,97	1,00	1,00
Transition (T1_rev00) – hogging bending												
	Section b0_1	4,95	5,05	62,50	0,10	0,10	1,27	1,21	0,63	0,63	0,95	0,96
	Section b0_2	3,60	3,60	62,50	0,07	0,07	1,27	1,23	0,71	0,71	0,97	0,98
	Section b0_3	4,95	5,05	62,50	0,10	0,10	1,27	1,21	0,63	0,63	0,95	0,96
Transition (T1_rev00) – Linear interpolation between sagging bending and hogging bending												
	Section b0_1	4,95	5,05						0,80	0,80	0,98	0,98
	Section b0_2	3,60	3,60						0,84	0,85	0,99	0,99
	Section b0_3	4,95	5,05						0,80	0,80	0,98	0,98
Support (S1_rev02)												
	Section b0_1	2,84	2,95	62,50	0,06	0,06	1,27	1,18	0,77	0,77	0,99	0,99
	Section b0_2	2,10	2,10	62,50	0,04	0,04	1,27	1,17	0,83	0,85	0,99	0,99
	Section b0_3	3,59	3,60	62,50	0,07	0,07	1,27	1,19	0,71	0,73	0,98	0,98
	Section b0_4	2,10	2,10	62,50	0,04	0,04	1,27	1,17	0,83	0,85	0,99	0,99
	Section b0_5	2,84	2,95	62,50	0,06	0,06	1,27	1,18	0,77	0,77	0,98	0,99
Support (S2_rev00)												

	Section b0_1	2,84	2,95	62,50	0,06	0,06	1,27	1,19	0,76	0,77	0,98	0,99
	Section b0_2	2,10	2,10	62,50	0,04	0,04	1,27	1,17	0,83	0,85	0,99	0,99
	Section b0_3	3,59	3,60	62,50	0,07	0,07	1,27	1,17	0,71	0,73	0,97	0,98
	Section b0_4	2,10	2,10	62,50	0,04	0,04	1,27	1,17	0,83	0,85	0,99	0,99
	Section b0_5	2,84	2,95	62,50	0,06	0,06	1,27	1,19	0,76	0,77	0,98	0,99

4 Plate buckling effects

The bridge girder is a member in cross-section class 4, meaning local buckling will occur before the attainment of yield stress in one or more parts of the cross-section.

Sufficient capacity of the bridge girder subject to compression and biaxial bending is verified based on equation (4.15) in NS-EN 1993-1-5:2006 + NA 2009. Equation (4.15) is a linear summation of the utilization that each force component utilizes the capacity corresponding to the respective type of force. Due to the bridge girders geometric shape with an inclined bottom plate, the summation of the utilization will give conservative utilization results for biaxial bending when the utilization about each axis is large at the same time, see Figure 7.

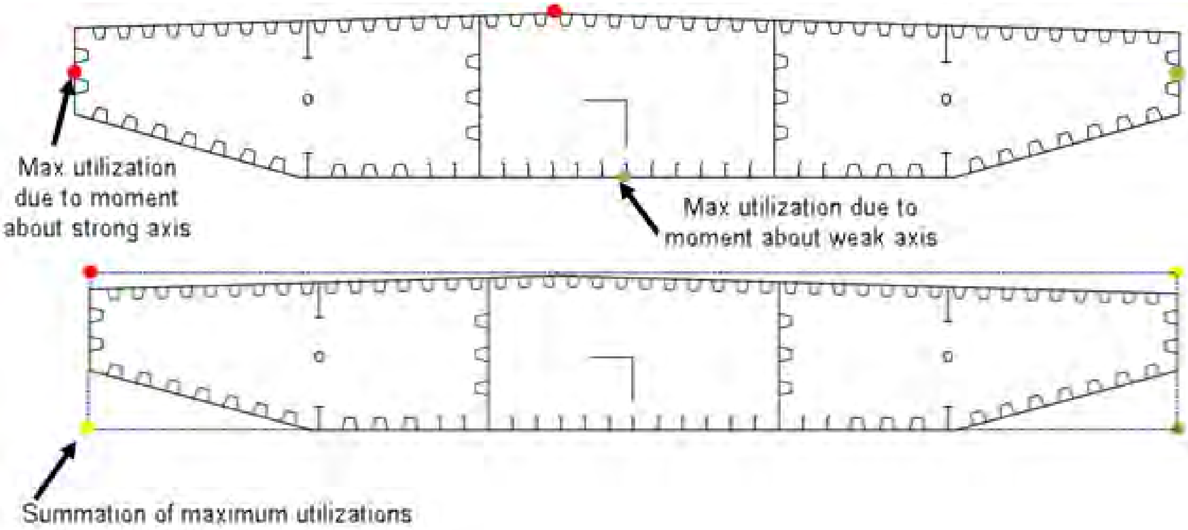


Figure 7 Illustration of the capacity check combining maximum utilizations of the moment about each axis

Since the Eurocode does not account for conservative utilizations due to geometric shapes, a second way of performing the capacity check has been introduced. This second method is denoted method 2 in the results given in a closure to 90-RE-107 Appendix G: Global Analyses – Response_0, while the method described above is denoted method 1.

For method 2, the utilization at all the 7 extremity points of the girder is calculated based on the effective elastic section modulus for the specific point.

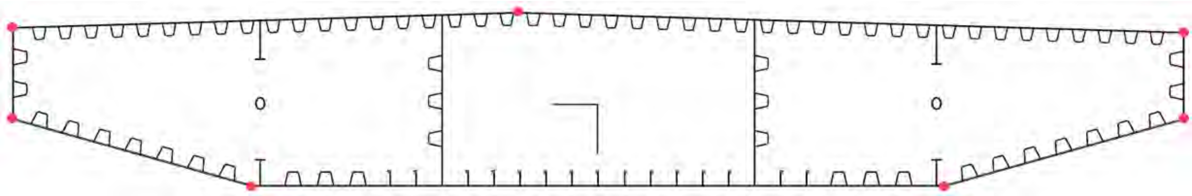


Figure 8 The 7 extremity points of the bridge girder controlled with method 2 of the capacity check

As shown in section 5 of this memo, the effective^p cross-sectional area of the girder in compression is always larger than 0.5 times the gross cross-sectional area, hence plate buckling effects on the stiffness is ignored in the global analysis in accordance with clause 2.2(5) in EC3-5.

4.1 Break-down of eqution 4.15 of EC3-5

A modified version of equation (4.15) is shown below. The equation is modified to adapt to the axis notation and force direction of this project.

$$\eta_1 = -\frac{N_{Ed}}{\frac{f_y A_{eff}}{\gamma_{M0}}} + \frac{M_{weak,Ed} + N_{Ed} e_{w,N}}{\frac{f_y W_{weak,eff}}{\gamma_{M0}}} + \frac{M_{strong,Ed} + N_{Ed} e_{s,N}}{\frac{f_y W_{strong,eff}}{\gamma_{M0}}} \quad modified\ (4.15)$$

Where

A_{eff} is

- $A_{eff,c}$ – effective^p cross-section area when N_{Ed} is axial compression
- $A_{eff,t}$ – gross cross-section area when N_{Ed} is axial tension

$e_{w,N}$ and $e_{s,N}$ is

- $e_{w,N,c}$ - eccentricity of the neutral axis in vertical direction when N_{Ed} is axial compression. Gives an additional moment about the weak axis.
- $e_{w,N,t}$ - zero when N_{Ed} is axial tension. No eccentricity moment
- $e_{s,N,c}$ - eccentricity of the neutral axis in horizontal direction when N_{Ed} is axial compression. Gives an additional moment about the strong axis.
- $e_{s,N,t}$ - zero when N_{Ed} is axial tension. No eccentricity moment

For method 1 of the capacity check, the equation is applied one time for the entire girder. Where $W_{weak,eff}$ is

- $W^+_{weak,eff}$ – effective elastic section modulus for a positive moment about the weak axis
- $W^-_{weak,eff}$ – effective elastic section modulus for a negative moment about the weak axis

$W_{strong,eff}$ is

- $W^+_{strong,eff}$ – effective^p elastic section modulus for a positive moment about the strong axis
- $W^-_{strong,eff}$ – effective^p elastic section modulus for a negative moment about the strong axis

For method 2 of the capacity check, the equation is applied for the 7 extremity points of the girder. Where

$W_{weak,eff}$ is

- $W^+_{weak,eff}$ – effective elastic section modulus for each specific point on the girder for a positive moment about the weak axis
- $W^-_{weak,eff}$ – effective elastic section modulus for each specific point on the girder for a negative moment about the weak axis

$W_{strong,eff}$ is

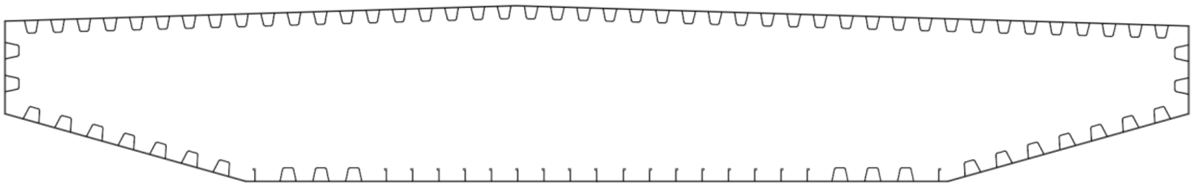
- $W^+_{strong,eff}$ – effective^p elastic section modulus for each specific point on the girder for a positive moment about the strong axis

- $W^{-}_{strong,eff}$ – effective^{p} elastic section modulus for each specific point on the girder for a negative moment about the strong axis

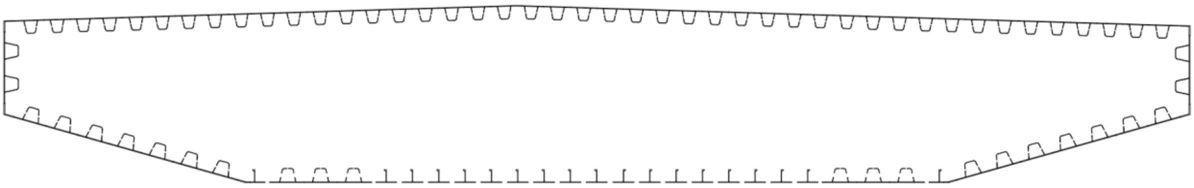
4.2 Effective cross-sections

As explained above, verification with equation (4.15) requires cross-sectional data for six different effective cross-sections depending on the direction of N_{Ed}, $M_{weak,Ed}$ and $M_{strong,Ed}$:

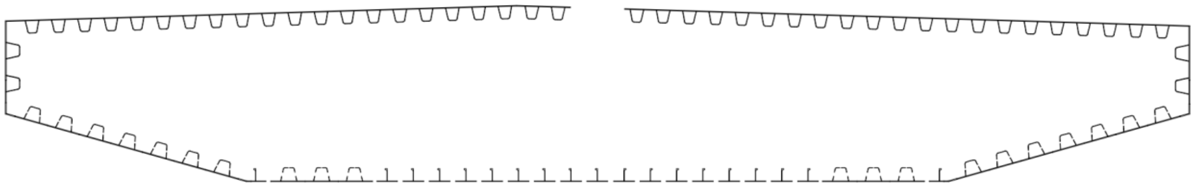
1. Gross cross-section for N_{ed} as a tensional force, ie. the whole cross-section is in the tension zone and there are no bucklings effects due to this force component



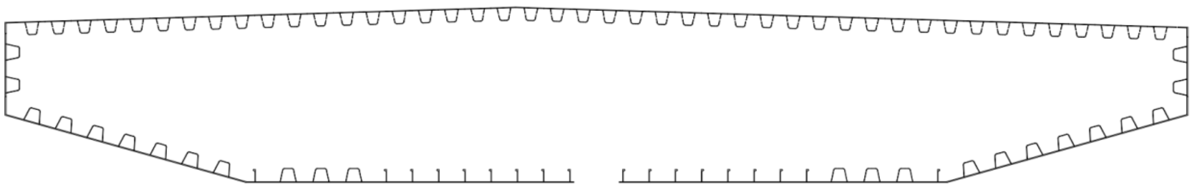
2. Effective^{p} cross-section for N_{ed} as a compressional force, ie. the whole cross-section is in the compression zone.



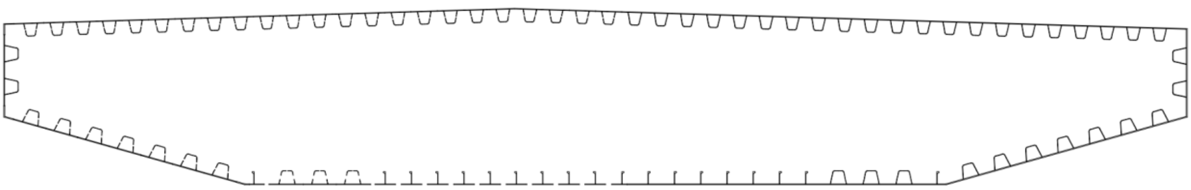
3. Effective cross-section for $M_{weak,Ed}$ as a positive moment about the horizontal axis, ie. all parts below the horizontal neutral axis is in the compression zone. Shear lag effects of the compression and tension flange are included.



4. Effective cross-section for $M_{weak,Ed}$ as a negative moment about the horizontal axis, ie. all parts above the horizontal neutral axis is in the compression zone. Shear lag effects of the compression and tension flange are included.



5. Effective^{p} cross-section for $M_{strong,Ed}$ as a positive moment about the vertical axis, ie. all parts east of the vertical neutral axis is in the compression zone.
6. Effective^{p} cross-section for $M_{strong,Ed}$ as a negative moment about the vertical axis, ie. all parts west of the vertical neural axis is in the compression zone.



Due to symmetry, the effective^{p} cross-sections for $M_{strong,Ed}$ as a positive moment is the mirrored of the effective^{p} cross-sections for $M_{strong,Ed}$ as a negative moment.

The effective^p area of the compression zone in each of the effective^p cross-sections is the effective^p area of each stiffener and the effective^p part of the panel between the stiffeners. Both local buckling of each plate element and global buckling of the stiffened panel is accounted for.

The reduction factors, ρ_{loc} and $\rho_{c,}$ due to plate buckling is calculated as explained in the following sections.

4.2.1 Local plate buckling effects

The reduction factor ρ_{loc} for all subpanels in cross-section class 4 in the compression zone is calculated according to clause 4.4(2) of EC3-5. The stress distribution within all internal compression elements are conservatively set to constant. This gives a buckling factor k_σ of 4.0 for all elements, and the effective width of the internal element is distributed with half of the effective width to each side of the element, see Figure 9.

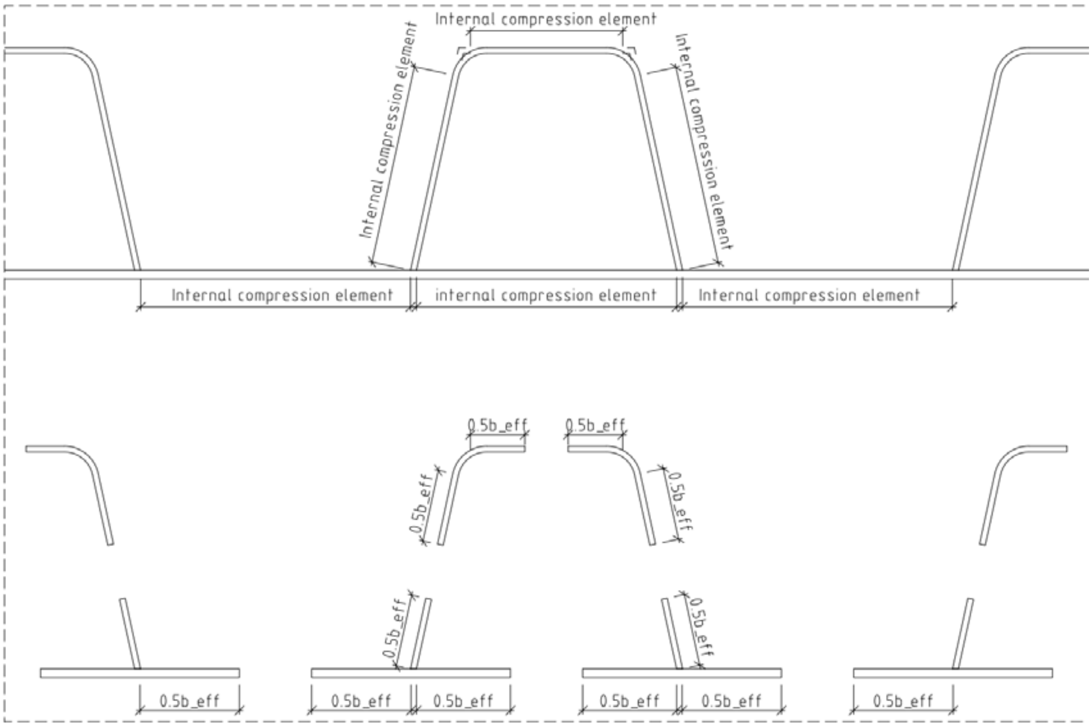


Figure 9 Illustration of effective^p widths due to local buckling of internal compression elements

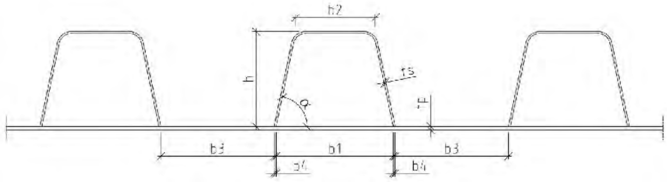
Calculation example of local buckling effects

NS-EN 1993-1-5 chapter 4 Plate buckling effects due to direct stresses at the ultimate limit state and 3.3 Shear lag at the ultimate limit state

$kNm := kN \cdot m$

Input

Concept K12, Stiffener ID K12-F1-T



$E_{mod} := 210000MPa$	modulus of elasticity
$\psi := 1.0$	stress ratio (constant)
$f_{yp} := 420MPa$	yield strength skin plate
$f_{ys} := 420MPa$	yield strength stiffener
$a := 4000mm$	plate length (distance between transverse stiffeners)
$c\_c\_stiffener := 600mm$	center distance between stiffeners
$b_1 := 300mm$	internal width of skin plate in stiffener
$b_2 := 185mm$	width of stiffener flange
$h := 286mm$	stiffener height
$t_p := 14mm$	thickness skin plate
$t_s := 8mm$	thickness stiffener
$\alpha_s := 0.34$	imperfection factor for stiffener (closed = 0.34, open = 0.49)
$\beta_{ULS} := 0.955$	shear lag factor at ULS

Calculations

$\varepsilon_s := \sqrt{\frac{235MPa}{f_{ys}}} = 0.75$ — correction factor for yield strength stiffener

$\varepsilon_p := \sqrt{\frac{235MPa}{f_{yp}}} = 0.75$ — correction factor for yield strength skin plate

$b_s := \sqrt{\left(h - \frac{t_s}{2}\right)^2 + \left[\frac{t_s}{2} + 0.5\cdot(b_1 - b_2)\right]^2} = 289\,mm$ — length of inclined stiffener web

$\alpha := asin\left[\frac{(h - 0.5t_s)}{b_s}\right] = 77.70\,deg$

$b_4 := \frac{t_s}{\sin(\alpha)} = 8.19\,mm$ — width of skin plate by stiffener

$b_3 := c\_c\_stiffener - b_1 - 2b_4 = 283.62\,mm$ — width of skin plate between stiffeners

Gross cross section properties

$A_{st} := t_s\cdot(2\cdot b_s + b_2) = 6098\,mm^2$ — area of stiffner

$A_p := t_p\cdot c\_c\_stiffener = 8400\,mm^2$ — area of skin plate

$A_{sl\_1} := A_{st} + A_p = 14498\,mm^2$ — area of stiffened plate

$$y_{cl} := \frac{b_2\cdot t_s\cdot\left(t_p + h - \frac{t_s}{2}\right) + 2\cdot b_s\cdot t_s\cdot\left(t_p + \frac{h - t_s}{2}\right) + A_p\cdot\frac{t_p}{2}}{A_{sl\_1}} = 83.01\,mm$$

CoG of stiffened plate from below skin plate

$$I_{sl\_1} := 2\cdot\frac{1}{12}\cdot h^3\cdot\frac{t_s}{\sin(\alpha)} + 2\cdot b_s\cdot t_s\cdot\left(\frac{h - t_s}{2} + t_p - y_{cl}\right)^2 \ldots + b_2\cdot t_s\cdot\left(t_p + h - \frac{t_s}{2} - y_{cl}\right)^2 + A_p\cdot\left(y_{cl} - \frac{t_p}{2}\right)^2 = 170217649\cdot mm^4$$

second moment of area for stiffened plate

$i := \sqrt{\frac{I_{sl\_1}}{A_{sl\_1}}} = 108\cdot mm$ — radius of gyration of stiffened plate

$$y_{st} := \frac{b_2\cdot t_s\cdot\left(h - \frac{t_s}{2}\right) + 2\cdot b_s\cdot t_s\cdot\left(\frac{h - t_s}{2}\right)}{A_{st}} = 174\cdot mm$$

CoG of stiffener from above skin plate

$e_1 := y_{st} + t_p - y_{cl} = 105\cdot mm$ — distance between CoG of stiffened plate CoG of stiffener

$e_2 := y_{cl} - \frac{t_p}{2} = 76\cdot mm$ — distance between CoG of stiffened plate and CoG of skin plate

Local buckling of internal plate elements according to NS-EN 1993-1-5 4.5.1(4)

Internal width of skin plate in stiffener, b1

$class_{b1} := \begin{cases} "1\text{-}3" & \text{if } \frac{b_1}{t_p} \le 42 \cdot \varepsilon_p \\ "4" & \text{otherwise} \end{cases} = "1\text{-}3"$ class

$k_{\sigma b1} := \begin{cases} \text{"no local buckling"} & \text{if } class_{b1} = "1\text{-}3" \\ 4 & \text{otherwise} \end{cases} = \text{"no local buckling"}$ buckling factor

$\lambda_{b1} := \begin{cases} \text{"no local buckling"} & \text{if } k_{\sigma b1} = \text{"no local buckling"} \\ \dfrac{\frac{b_1}{t_p}}{28.4 \cdot \varepsilon_p \cdot \sqrt{k_{\sigma b1}}} & \text{otherwise} \end{cases} = \text{"no local buckling"}$ slenderness

$\rho_{b1} := \begin{cases} 1 & \text{if } (\lambda_{b1} = \text{"no local buckling"}) \vee \lambda_{b1} \le 0.5 + \sqrt{0.085 - 0.055 \cdot \psi} \\ \min\left[1, \dfrac{\lambda_{b1} - 0.055 \cdot (3 + \psi)}{\lambda_{b1}^2}\right] & \text{otherwise} \end{cases} = 1.000$ reduction factor

$b_{eff\_b1} := b_1 \cdot \rho_{b1} = 300 \cdot mm$ effective width

Stiffener flange, b2

$class_{b2} := \begin{cases} "1\text{-}3" & \text{if } \frac{b_2}{t_s} \le 42 \cdot \varepsilon_s \\ "4" & \text{otherwise} \end{cases} = "1\text{-}3"$ class

$k_{\sigma b2} := \begin{cases} \text{"no local buckling"} & \text{if } class_{b2} = "1\text{-}3" \\ 4 & \text{otherwise} \end{cases} = \text{"no local buckling"}$ buckling factor

$\lambda_{b2} := \begin{cases} \text{"no local buckling"} & \text{if } k_{\sigma b2} = \text{"no local buckling"} \\ \dfrac{\frac{b_2}{t_s}}{28.4 \cdot \varepsilon_s \cdot \sqrt{k_{\sigma b2}}} & \text{otherwise} \end{cases} = \text{"no local buckling"}$ slenderness

$\rho_{b2} := \begin{cases} 1 & \text{if } (\lambda_{b2} = \text{"no local buckling"}) \vee \lambda_{b2} \le 0.5 + \sqrt{0.085 - 0.055 \cdot \psi} \\ \min\left[1, \dfrac{\lambda_{b2} - 0.055 \cdot (3 + \psi)}{\lambda_{b2}^2}\right] & \text{otherwise} \end{cases} = 1.000$ reduction factor

$b_{eff\_b2} := b_2 \cdot \rho_{b2} = 185 \cdot mm$ effective width

Width of skin plate between stiffeners, b3

$$class_{b3} := \begin{cases} "1\text{-}3" & \text{if } \frac{b_3}{t_p} \le 42 \cdot \varepsilon_p \\ "4" & \text{otherwise} \end{cases} = "1\text{-}3"$$ class

$$k_{\sigma b3} := \begin{cases} "\text{no local buckling}" & \text{if } class_{b3} = "1\text{-}3" \\ 4 & \text{otherwise} \end{cases} = "\text{no local buckling}"$$ buckling factor

$$\lambda_{b3} := \begin{cases} "\text{no local buckling}" & \text{if } k_{\sigma b3} = "\text{no local buckling}" \\ \dfrac{\frac{b_3}{t_p}}{28.4 \cdot \varepsilon_p \cdot \sqrt{k_{\sigma b3}}} & \text{otherwise} \end{cases} = "\text{no local buckling}"$$ slenderness

$$\rho_{b3} := \begin{cases} 1 & \text{if } (\lambda_{b3} = "\text{no local buckling}") \vee \lambda_{b3} \le 0.5 + \sqrt{0.085 - 0.055 \cdot \psi} \\ \min\left[1, \dfrac{\lambda_{b3} - 0.055 \cdot (3 + \psi)}{\lambda_{b3}^2}\right] & \text{otherwise} \end{cases} = 1.000$$ reduction factor

$$b_{eff\_b3} := b_3 \cdot \rho_{b3} = 284 \cdot mm$$ effective width

Inclined stiffener web, bs

$$class_{bs} := \begin{cases} "1\text{-}3" & \text{if } \frac{b_s}{t_s} \le 42 \cdot \varepsilon_s \\ "4" & \text{otherwise} \end{cases} = "4"$$ class

$$k_{\sigma bs} := \begin{cases} "\text{no local buckling}" & \text{if } class_{bs} = "1\text{-}3" \\ 4 & \text{otherwise} \end{cases} = 4$$ buckling factor

$$\lambda_{bs} := \begin{cases} "\text{no local buckling}" & \text{if } k_{\sigma bs} = "\text{no local buckling}" \\ \dfrac{\frac{b_s}{t_s}}{28.4 \cdot \varepsilon_s \cdot \sqrt{k_{\sigma bs}}} & \text{otherwise} \end{cases} = 0.85$$ slenderness

$$\rho_{bs} := \begin{cases} 1 & \text{if } (\lambda_{bs} = "\text{no local buckling}") \vee \lambda_{bs} \le 0.5 + \sqrt{0.085 - 0.055 \cdot \psi} \\ \min\left[1, \dfrac{\lambda_{bs} - 0.055 \cdot (3 + \psi)}{\lambda_{bs}^2}\right] & \text{otherwise} \end{cases} = 0.873$$ reduction factor

$$b_{eff\_bs} := b_s \cdot \rho_{bs} = 252 \cdot mm$$ effective width

Effective$^{p}_{loc}$ area after reduction due to local plate buckling

$$A_{st\_eff\_loc} := t_s \cdot (2 \cdot b_{eff\_bs} + b_{eff\_b2}) = 5509\,mm^2$$ effective$^{p}_{loc}$ area of stiffener

$$A_{p\_eff\_loc} := t_p \cdot (2 \cdot b_4 + b_{eff\_b1} + b_{eff\_b3}) = 8400\,mm^2$$ effective$^{p}_{loc}$ area of skin plate

$$A_{sl\_1\_eff\_loc} := A_{st\_eff\_loc} + A_{p\_eff\_loc} = 13909\,mm^2$$ effective$^{p}_{loc}$ area of stiffened plate

4.2.2 Global plate buckling effects

Plate type behavior

Since all plates of the bridge girder are heavily stiffened, the plate type buckling behavior is ignored because the column type behavior will prevail.

Column type buckling behavior

The global reduction factor ρ_c due to column type buckling behavior of a stiffener and the adjacent part of panel between the stiffeners is calculated in accordance with section 4.5.3 of EC3-5.

Clause 4.5.3(3) states that the elastic critical column buckling stress $\sigma_{cr,c}$ may be determined from the elastic critical column buckling stress $\sigma_{cr,sl}$ of the stiffener closest to the panel edge with the highest compressive stress.

Due to different types of stiffeners, trapezoidal and bulbs, in the bottom plate, the reduction factor ρ_c is calculated separately for each type of stiffener based on their respective elastic critical column buckling stress $\sigma_{cr,sl}$.

Example calculation of global buckling effects (continuation of example for local buckling effects)

Global column type buckling according to NS-EN 1993-1-5 4.5.3

$$\beta_{Ac} := \frac{A_{sl\_1\_eff\_loc}}{A_{sl\_1}} = 0.96$$ correction factor for column slenderness

$$\sigma_{cr.c} := \frac{\pi^2 \cdot E_{mod} \cdot I_{sl\_1}}{A_{sl\_1} \cdot a^2} = 1521 \cdot \text{MPa}$$ elastic critical column buckling stress

$$\lambda_c := \sqrt{\frac{\beta_{Ac} \cdot f_{ys}}{\sigma_{cr.c}}} = 0.51$$ relative column slenderness

$$\alpha_{s\_e} := \alpha_s + \frac{0.09}{\frac{i}{\max(e_1, e_2)}} = 0.43$$ modified imperfection factor NS-EN 1993-1-5 eq. 4.12

$$\Phi_c := 0.5 \cdot \left[1 + \alpha_{s\_c} \cdot (\lambda_c - 0.2) + \lambda_c^2\right] = 0.70$$ function used to calculate column type buckling reduction factor

$$\rho_c := \frac{1}{\Phi_c + \sqrt{\Phi_c^2 - \lambda_c^2}} = 0.852$$ global reduction factor due to column type buckling

4.2.3 Combined local and global plate buckling effects

In accordance with clause 4.5.1(3), the final effective^p area of the compression zone in the bridge girder is the effective^p area reduced due to local buckling times the reduction factor due to global buckling, except the effective^p parts of skin plate which is supported by an adjacent plate, which is not to be reduced due to global buckling effects:

$A_{c,eff} = \rho_c A_{c,eff,loc} + \Sigma b_{edge,eff}\, t$

As mentioned, the global reduction factor ρ_c will differ depending on the type of stiffener, hence the equation above may be rewritten as

$A_{c,eff} = \Sigma \rho_{c,sl} A_{sl,eff,loc} + \Sigma b_{edge,eff}\, t$

Where $A_{sl,eff,loc}$ is the effective^p area of a stiffener and the adjacent part of panel reduced for local buckling, and $\rho_{c,sl}$ is the global reduction factor corresponding to the same type of stiffener.

When calculating the geometric properties A_{eff} and W_{eff} for the effective^p girder composed of different plates, the global reduction factor $\rho_{c,sl}$ is taken into account by reducing the thickness of the skin plate and the thickness of the stiffeners.

Effective^p area after reduction due to local and global buckling

$A_{st\_eff\_p} := \rho_c \cdot A_{st\_eff\_loc} = 4695\,mm^2$	effective^p area of stiffener
$A_{p\_eff\_p} := \rho_c \cdot A_{p\_eff\_loc} = 7158\,mm^2$	effective^p area of skin plate
$A_{sl\_1\_eff\_p} := \rho_c \cdot A_{sl\_1\_eff\_loc} = 11852\,mm^2$	effective^p area of stiffened plate

4.2.4 Combined shear lag and plate buckling effects

The elastic-plastic shear lag effects are combined with the effects of plate buckling due to direct stresses at the ultimate limit state according to equation (3.5) of EC3-5:

$A_{eff} = A_{c,eff}\ \beta^{\kappa}$

Where $A_{c,eff}$ is the effective^p area of the compression flange. For the tension flange, the effective width $b_{eff} = b_0\ \beta^{\kappa}$ is adapted.

When calculating the geometric property W_{eff} for the effective girder, the shear lag reduction factor β^{κ} is taken into account by reducing the thickness of the skin plate and the thickness of the stiffeners in the compression flange.

Combined shear lag and buckling effects

Effective area after reduction due to shear lag and buckling effects

$A_{st\_eff} := \beta_{ULS} \cdot A_{st\_eff\_p} = 4483\,mm^2$	effective area of stiffener
$A_{p\_eff} := \beta_{ULS} \cdot A_{p\_eff\_p} = 6836\,mm^2$	effective area of skin plate
$A_{sl\_1\_eff} := \beta_{ULS} \cdot A_{sl\_1\_eff\_p} = 11319\,mm^2$	effective area of stiffened plate

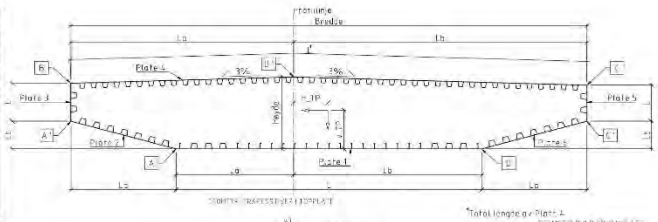
5 Cross-section data

On the following pages, cross-sectional data of the typical bridge girder sections at mid span and by columns are given:

Concept development, Floating bridge E39 Bjørnafjorden — K12_F1

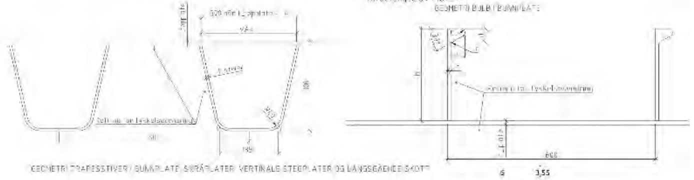
Section	K12_F1_rev05	Field section - normal - consept K12		Revision date:	07.06.2019 @ 13:30	
	K12_F1_05			Last revised by:	EDM	
Bredde	27 [m]	fra innside plate 3 til innside plate 5		Total bredde		27,024
Høyde	4 [m]	fra OK plate 1 til OK plate 4		Total høyde		4,012

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Thickness [mm]	12	12	12	16	12	12
La [m]	6,150	5,500		11,650		5,500
Lb [m]	9,850	1,540	-	15,350	-	1,540
L [m]	16,000	5,712	2,111	27,012	2,000	5,712
Trapezoidal type	K12_F1-B	K12_F1-IB	K12_F1-VW	K12_F1-T	K12_F1-VW	K12_F1-IB
Trapezoidal thickness [mm]	6	6	6	8	6	6
Trapezoidal c/c [m]	0,750	0,750	0,75	0,600	0,75	0,750
Bulb type	K12_F1 B_b					
Width h [mm]	280					
Thickness t [mm]	11					
Bulb radius r [mm]	12					
Bulb height c [mm]	40					
Bulb width [mm]	42					
Bulb c/c [m]	0,6					



Tyngdepunkt:
hTP (Fra Profillinje): -1,834 m
vTP (Fra UK)***: 2,331 m
vTP (Fra UK)*: 2,330 m
vTP (Fra UK)****: 2,323 m

Tetthet	7,85	t/m3
E-modul	2,10E+05	Mpa
Poisson ratio	0,3	
G-modul	8,08E+04	Mpa



Innesluten areal:	93,874	m2

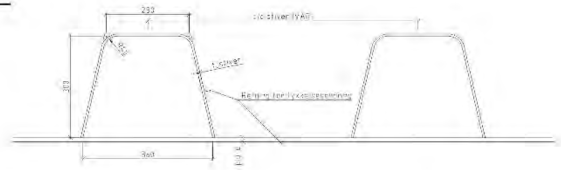
Tverrsnittsdata, kassetverrsnitt:

Areal:	1,270	m2	
Tyngdepunkt, fra OK:	1,682	m	
Tyngdepunkt, fra UK:	2,330	m	
Torsjonsmotstand*:	8,811	m4	
Skjærareal vertikalt*:	0,0281	m2	
Skjærareal transvers*:	0,7009	m2	
2. Arealmoment, svak akse***	2,569	m4	Benyttes i analyser
2. Arealmoment, svak akse****	3,271	m4	
2. Arealmoment, svak akse*	3,439	m4	
2. Arealmoment, sterk akse*	84,698	m4	
Treghetsmoment**	1318,687	tm2/m	
Masse Areal:	9,97	t/m	
Masse tverrstål:	2,00	t/m	Foreløpig estimat
Sum stål:	11,97	t/m	
Masse rekkverk:	0,71	t/m	Antatt 1 kN/m per rekkverk (6 stk) og 0,5 kN/m per rekkverk ytre (2 stk)
Masse asfalt:	4,62	t/m	2,0 kN/m2 på kjørebane og 1,5 kN/m2 på GS iht. N400 pkt. 5.2.2.2
Sum masse:	17,30	t/m	
Contingency:	1,70	t/m	
Masse brukt i analyse	19,00	t/m	

Stivheter

Aksialstivhet	2,67E+08	kN
Bøyestivhet svak akse***	5,39E+08	kN*m2
Bøyestivhet sterk akse*	1,78E+10	kN*m2
Torsjonsstivhet*	6,96E+08	kN*m2
Skjærstivhet vertikalt*	2,27E+06	kN
Skjærstivhet transvers*	5,66E+07	kN

1305,7
26373,7
1305,7

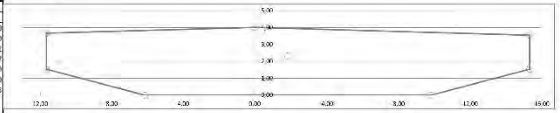


*basert på fullt tverrsnitt inkl. stivere (IDEA CSS)
** inkl asfalt, rekkverk etc.
*** basert på tverrsnitt redusert for shear lag i bruksgrense-/utmattingstilstand
**** basert på tverrsnitt redusert for shear lag i bruddgrensetilstand

Bøyemotstander

	Koordinater i forhold til UK og profillinje		Min tykkelse	Bøyemotstander					Skjærfaktor	
	horisontal	vertikal	tmin	Wweak***	Wweak****	Wweak*	Wstrong	Wt	Ks	Kv
Punkt C, topp øst	**-15,362**	**3,551**	**0,012**	**2,106**	**2,664**	**2,816**	**-6,261**	**2,253**	-0,00030	0,01190
Punkt C'	-15,362	1,544	0,012	-3,264	-4,199	-4,375	-6,261	2,253	0,00015	0,01140
Punkt D, bunn øst	**-9,850**	**0,000**	**0,012**	**-1,102**	**-1,408**	**-1,476**	**-10,566**	**2,253**	0,00124	0,00822
Punkt A, bunn vest	**6,150**	**0,000**	**0,012**	**-1,102**	**-1,408**	**-1,476**	**10,608**	**2,253**	0,00126	0,00817
Punkt A'	11,662	1,544	0,012	-3,264	-4,199	-4,375	6,276	2,253	0,00016	-0,01160
Punkt B, topp vest	**11,662**	**3,662**	**0,012**	**1,930**	**2,443**	**2,582**	**6,276**	**2,253**	-0,00030	-0,01200
Punkt B'	0,000	4,012	0,016	1,528	1,937	2,045	46,182	3,004	-0,00190	-0,00123

Navngivning av punkter iht. Auduns spenningssjekk — SHEAR LAG SLS — SHEAR LAG ULS (Benyttes for von-mises sjekk) — BRUTTO



METODE 1

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Basert på tverrsnitt:

Aeff,c	1,004	m2		Redusert for plateknekking lokal og global	79 % Aeff,c/Aeff,t
Aeff,t	1,270	m2		Bruttotverrsnitt	
ew,N,c	-0,064	m			
ew,N,t	0	m			
es,N,c	0,01	m			
es,N,t	0	m			
W+weak,eff	1,078	m3	TRYKK UK	Redusert for plateknekking lokal og global. Redusert for shear lag i bruddgrensetilstand	77 % Sammenlignet med Wweak****
W-weak,eff	-1,621	m3	TRYKK OK	Redusert for plateknekking lokal og global. Redusert for shear lag i bruddgrensetilstand	84 % Sammenlignet med Wweak****
W+strong,eff	5,306	m3		Redusert for plateknekking lokal og global	85 % Sammenlignet med Wstrong
W-strong,eff	5,306	m3		Redusert for plateknekking lokal og global	85 % Sammenlignet med Wstrong

METODE 2

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Effektivt areal og eksentrisiteter gjelder for alle punkter:

Aeff,c	1,004	m2
Aeff,t	1,270	m2
ew,N,c	-0,064	m
ew,N,t	0,000	m
es,N,c	0,010	m
es,N,t	0,000	m

Bøyemotstander gjelder pr. punkt

	W+weak,eff	W-weak,eff	W+strong,eff	W-strong,eff
Punkt C, topp øst	-2,693	-2,16	5,306	5,959
Punkt C'	2,749	4,91	5,306	5,959
Punkt D, bunn øst	1,078	1,39	8,632	10,508
Punkt A, bunn vest	1,078	1,39	10,508	8,632
Punkt A'	2,749	4,91	5,959	5,306
Punkt B, topp vest	-2,427	-2,00	-5,959	-5,306
Punkt B'	-1,852	-1,62	-71,149	-28,795
	For positivt moment Mweak	For negativt moment M	For positivt moment M	For negativt moment Mstrong

Reduction factors

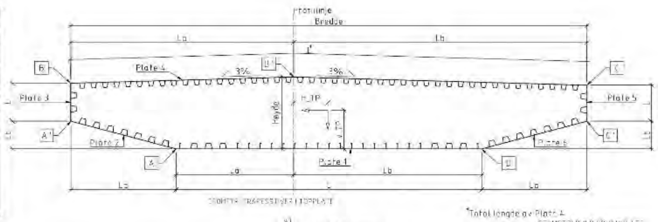
	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Trapezoidal stiffener and adjacent part of skin plate						
ρ buckling	0,743	0,777	0,742	0,806	0,742	0,777
ρ buckling and shear lag ULS	0,714	0,747	-	0,769	-	0,747
Bulb stiffener and adjacent part of skin plate						
ρ buckling	0,687					
ρ buckling and shear lag ULS	0,661					

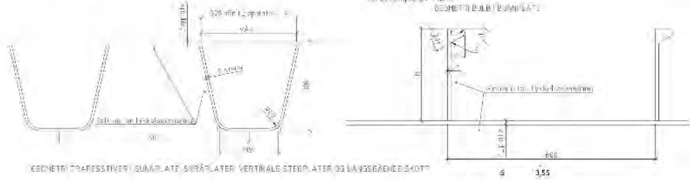
Concept development, Floating bridge E39 Bjørnafjorden

K12_F2

Section	K12_F2_rev00	Field section - normal - consept K12		Revision date:		11.06.2019 @ 13:30
	K12_F2_00			Last revised by:	EDM	
Bredde	27 [m]	fra inside plate 3 til inside plate 5			Total bredde	27,028
Høyde	4 [m]	fra OK plate 1 til OK plate 4			Total høyde	4,014

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Thickness [mm]	14	14	14	16	14	14
La [m]	6,150	5,500		11,650		5,500
Lb [m]	9,850	1,540		15,350	-	1,540
L [m]	16,000	5,712	2,111	12,115	2,000	5,712
Trapzoidal type	K12_F2-B	K12_F2-IB	K12_F2-VW	K12_F2-T	K12_F2-VW	K12_F2-IB
Trapezoidal thickness [mm]	6	6	6	8	6	6
Trapezoidal c/c [m]	0,750	0,750	0,75	0,600	0,75	0,750
Bulb type	K12_F2-B_b					
Width h [mm]	280					
Thickness t [mm]	11					
Bulb radius r [mm]	12					
Bulb height c [mm]	40					
Bulb width [mm]	42					
Bulb c/c [m]	0,6					





Tyngdepunkt:

hTP (Fra Profillinje):	-1,832	m
vTP (Fra UK)***:	2,262	m
vTP (Fra UK)*:	2,251	m
vTP (Fra UK)****:	2,245	m

Tetthet	7,85	t/m3
E-modul	2,10E+05	Mpa
Poisson ratio	0,3	
G-modul	8,08E+04	Mpa

Innesluten areal:		93,874	m2

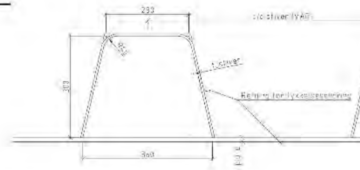
Tverrsnittsdata, kassetverrsnitt:

Areal:		1,331	m2	
Tyngdepunkt, fra OK:		1,763	m	
Tyngdepunkt, fra UK:		2,251	m	
Torsjonsmotstand*:		8,423	m4	
Skjærareal vertikalt*:		0,0312	m2	
Skjærareal transvers*:		0,7203	m2	
2. Arealmoment, svak akse***		2,781	m4	Benyttes i analyser
2. Arealmoment, svak akse****		3,496	m4	
2. Arealmoment, svak akse*		3,868	m4	
2. Arealmoment, sterk akse*		89,597	m4	
Treghetsmoment**		1331,458	tm2/m	
Masse Areal:		10,45	t/m	
Masse tverrstål:		2,00	t/m	Foreløpig estimat
Sum stål:		12,45	t/m	
Masse rekkverk:		0,71	t/m	Antatt 1 kN/m per rekkverk (6 stk) og 0,5 kN/m per rekkverk ytre (2 stk)
Masse asfalt:		4,62	t/m	2,0 kN/m2 på kjørebane og 1,5 kN/m2 på GS iht. N400 pkt. 5.2.2.2
Sum masse:		17,78	t/m	
Contingency:		1,22	t/m	
Masse brukt i analyse		19,00	t/m	

Stivheter

Aksialstivhet	2,80E+08	kN
Bøyestivhet svak akse***	5,84E+08	kN*m2
Bøyestivhet sterk akse*	1,88E+10	kN*m2
Torsjonsstivhet*	7,61E+08	kN*m2
Skjærstivhet vertikalt*	2,52E+06	kN
Skjærstivhet transvers*	5,82E+07	kN

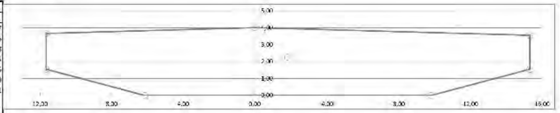
1318,7
26627,2
1318,7



*basert på fullt tverrsnitt inkl. stivere (IDEA CSS)
** inkl asfalt, rekkverk etc.
*** basert på tverrsnitt redusert for shear lag i bruksgrense-/utmattingstilstand
**** basert på tverrsnitt redusert for shear lag i bruddgrensetilstand

Bøyemotstander

	Koordinater (i forhold til UK og profillinje)		Min tykkelse	Bøyemotstander					Skjærfaktor	
	horisontal	vertikal	tmin	Wweak***	Wweak****	Wweak*	Wstrong	Wt	Ky	Kv
Punkt C, topp øst	**-15,364**	**3,553**	**0,014**	**2,154**	**2,673**	**2,817**	**-6,621**	**2,628**	-0,00024	0,01027
Punkt C'	-15,364	1,546	0,014	-3,884	**-5,001**	**-5,203**	-6,621	2,628	0,00017	0,00985
Punkt D, bunn øst	**-9,850**	**0,000**	**0,014**	**-1,229**	**-1,557**	**-1,630**	**-11,174**	**2,628**	0,00116	0,00708
Punkt A, bunn vest	**6,150**	**0,000**	**0,014**	**-1,229**	**-1,557**	**-1,630**	**11,225**	**2,628**	0,00117	0,00704
Punkt A'	11,664	1,546	0,014	-3,884	**-5,001**	**-5,203**	6,639	2,628	0,00018	-0,00995
Punkt B, topp vest	**11,664**	**3,664**	**0,014**	**1,984**	**2,464**	**2,596**	**6,639**	**2,628**	-0,00024	-0,01020
Punkt B'	0,000	4,014	0,016	1,587	**1,976**	**2,081**	48,307	3,004	-0,00179	-0,00121
	Navngivning av punkter iht. Auduns spenningssjekk			SHEAR LAG SLS	SHEAR LAG ULS	BRUTTO				
					Benyttes for von-mises sjekk					



METODE 1
Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Basert på tverrsnitt:

Aeff,c	1,049	m2		Redusert for plateknekking lokal og global	79 % Aeff,c/Aeff,t
Aeff,t	1,331	m2		Bruttotverrsnitt	
ew,N,c	-0,071	m			
ew,N,t	0	m			
es,N,c	-0,015	m			
es,N,t	0	m			
W⁺weak,eff	1,186	m3	TRYKK UK	Redusert for plateknekking lokal og global. Redusert for shear lag i bruddgrensetilstand	76 % Sammenlignet med Wweak****
W⁻weak,eff	-1,654	m3	TRYKK OK	Redusert for plateknekking lokal og global. Redusert for shear lag i bruddgrensetilstand	84 % Sammenlignet med Wweak****
W⁺strong,eff	5,585	m3		Redusert for plateknekking lokal og global	84 % Sammenlignet med Wstrong
W⁻strong,eff	5,585	m3		Redusert for plateknekking lokal og global	84 % Sammenlignet med Wstrong

METODE 2
Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Effektivt areal og eksentrisiteter gjelder for alle punkter:

Aeff,c	1,049	m2
Aeff,t	1,331	m2
ew,N,c	-0,071	m
ew,N,t	0,000	m
es,N,c	-0,015	m
es,N,t	0,000	m

Bøyemotstander gjelder pr. punkt

	W⁺weak,eff	W⁻weak,eff	W⁺strong,eff	W⁻strong,eff
Punkt C, topp øst	-2,697	-2,17	5,585	8,293
Punkt C'	3,160	5,91	5,585	8,293
Punkt D, bunn øst	1,186	1,53	9,080	11,114
Punkt A, bunn vest	1,186	1,53	11,114	-9,080
Punkt A'	3,160	5,91	6,293	5,585
Punkt B, topp vest	-2,448	-2,02	-6,293	-5,585
Punkt B'	-1,596	-1,65	-76,604	-28,795
	For positivt moment Mweak	For negativt moment M	For positivt moment M	For negativt moment Mstrong

Reduction factors

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Trapezoidal stiffener and adjacent part of skin plate						
ρ buckling	0,78	0,780	0,758	0,806	0,758	0,780
ρ buckling and shear lag ULS	0,750	0,750	-	0,772	-	0,750
Bulb stiffener and adjacent part of skin plate						
ρ buckling	0,687					
ρ buckling and shear lag ULS	0,661					

Concept development, Floating bridge E39 Bjørnafjorden

Section	K12_T1_rev00	Translationsection - normal - concept K12	Revision date:	4.05.2019 @ 10:33	
	K12_T1_00		Last revised by:	SDM	
Bredde	27 [m]	fra innside plate 3 til innside plate 5	Total bredde		27,029
Høyde	4 [m]	fra OK plate 1 til OK plate 4	Total høyde		4,016

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Thickness [mm]	16	16	14	16	14	16
La [m]	6,150	5,500		11,650		5,500
Lb [m]	9,850	1,540	-	15,350	-	1,540
L [m]	16,000	5,712	[illegible]	27,017	2,000	5,712
Trapezoidal type	K12_T1-3	K12_T1-6	K12_T1-VW	K12_T1-1	K12_T1-VW	K12_T1-6
Trapezoidal thickness [mm]	9	9	8	8	8	8
Trapezoidal c/c [m]	0,750	0,750	0,73	0,000	0,75	0,750
Bulb type	K12_T1 B_3					
Width h [mm]	320					
Thickness t [mm]	12					
Bulb radius r [mm]	14					
Bulb height c [mm]	46					
Bulb width [mm]	48,5					
Bulb c/c [m]	0,6					

	Bjelke 1	Bjelke 2	Bjelke 3	Bjelke 4
Type	Ingen bjelke	K12_T1_B2_rev00	K12_T1_B3_rev00	Ingen bjelke
Height top [mm]		800	800	
Thickness web top [mm]		14	14	
Width flange top [mm]		214	214	
Thickness flange top [mm]		18	18	
Height bottom [mm]		600	600	
Thickness web bottom [mm]		14	14	
Width flange bottom [mm]		214	214	
Thickness flange bottom [mm]		18	18	
Profile		CHS220x10	CHS220x10	
Thickness [mm]				
Trapezoidal type				
Trapezoidal thickness [mm]				
Trapezoidal c/c [m]				

Tyngdepunkt:

yTP (Fra Profillinje):	-1,835	m
yTP (Fra UK)***:	2,154	m
yTP (Fra UK)*:	2,122	m
yTP (Fra UK)****:	2,141	m

Tetthet	7,85	t/m3
E-modul	2,10E+05	Mpa
Poisson ratio	0,3	
G-modul	8,08E+04	Mpa

Innesluttet areal:	93,995	m2

Tverrsnittsdata, kassetverrsnitt:

Areal:	1,521	m2	
Tyngdepunkt, fra OK:	1,878	m	
Tyngdepunkt, fra UK:	2,122	m	
Torsjonsmotstand*:	10,105	m4	
Skjærareal vertikalt*:	0,0545	m2	
Skjærareal transvers*:	0,7972	m2	
2. Arealmoment, svak akse***:	3,811	m4	Benyttes i analyser
2. Arealmoment, svak akse****:	4,007	m4	
2. Arealmoment, svak akse*:	4,123	m4	
2. Arealmoment, sterk akse*:	98,503	m4	
Treghetsmoment**:	1282,978	tm2/m	
Masse Areal:	11,94	t/m	
Masse tverrstål:	2,00	t/m	Foreløpig estimat
Sum stål:	13,94	t/m	
Masse rekkverk:	0,71	t/m	Antatt 1 kN/m per rekkverk (6 stk) og 0,5 kN/m per rekkverk ytre (2 stk)
Masse asfalt:	4,62	t/m	2,0 kN/m2 på kjørebane og 1,5 kN/m2 på GS-felt. N400 pkt. 5.2.2.2
Sum masse:	19,27	t/m	
Contingency:	0,27	t/m	
Masse brukt i analyse:	19,00	t/m	

Stivheter		
Aksialstivhet	3,19E+08	kN
Bøyestivhet svak akse***	8,00E+08	kN*m2
Bøyestivhet sterk akse*	2,07E+10	kN*m2
Torsjonsstivhet*	8,15E+08	kN*m2
Skjærstivhet vertikalt*	4,40E+06	kN
Skjærstivhet transvers*	6,44E+07	kN

1272,8

25959,3

1272,8

*basert på fullt tverrsnitt inkl. stivere (IDEA CSS)

** inkl asfalt, rekkverk etc.

***basert på tverrsnitt redusert for shear lag i bruksgrense-/utmattingstilstand

**** basert på tverrsnitt redusert for shear lag i bruddgrensetilstand

Bøyemotstander (Brudd i formel)

	Koordinater (i forhold til UK og profillinje) horisontal	vertikal	Min tykkelse [mm]	Bøyemotstander Wweak***	Wweak****	Wweak*	Wstrong	Wt	Skjærfaktor Ky	Kz
Punkt C, topp øst	**-15,364**	**3,555**	**0,014**	**2,363**	2,894	2,877	**-7,287**	**2,632**	-0,00024	0,00681
Punkt C'	-15,364	1,548	0,014	-5,464	-6,757	-7,183	-7,287	2,632	0,00016	0,00715
Punkt D, bunn øst	**-9,850**	**0,000**	**0,016**	**-1,537**	-1,872	-1,943	**-12,300**	**3,008**	0,00109	0,00348
Punkt A, bunn vest	**6,150**	**0,000**	**0,016**	**-1,537**	-1,872	1,943	**12,346**	**3,008**	0,00110	-0,00345
Punkt A'	11,664	1,548	0,014	5,464	6,737	7,188	7,303	2,632	0,00019	0,00734
Punkt B, topp vest	**11,664**	**3,666**	**0,014**	**2,190**	2,528	2,570	**7,303**	**2,632**	-0,00024	-0,00694
Punkt B'	0,000	4,016	0,016	1,778	2,137	2,177	53,724	3,008	-0,00170	-0,00114

Navngivning av punkter iht. Aurecon spenningssjekk — SHEAR LAG SLS — SHEAR LAG ULS — BRUTTO

Benyttes for von-mises sjekk

METODE 1

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Aeff,c	1,240	m2	Basert på tverrsnitt. Redusert for platebrekking lokal og global — 82 % Aeff,c/Aeff,t
Aeff,t	1,521	m2	Bruttotverrsnitt
ew,N,c	-0,008	m	
ew,N,t	0	m	
es,N,c	0,312	m	
es,N,t	0	m	
W'weak,eff	1,540	m3	Redusert for platebrekking lokal og global. Redusert for shear lag i bruddgrensetilstand — 82 % Sammenlignet med Wweak****
W weak,eff	-1,772	m3	Redusert for platebrekking lokal og global. Redusert for shear lag i bruddgrensetilstand — 61 % Sammenlignet med Wweak****
W'strong,eff	6,284	m3	Redusert for platebrekking lokal og global — 86 % Sammenlignet med Wstrong
W'strong,eff	-6,284	m3	Redusert for platebrekking lokal og global — 88 % Sammenlignet med Wstrong

METODE 2

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Effektivt område eksentrisiteter gjelder for alle punkter

Aeff,c	1,240	m2
Aeff,t	1,521	m2
ew,N,c	-0,01	m
ew,N,t	0	m
es,N,c	0,012	m
es,N,t	0	m

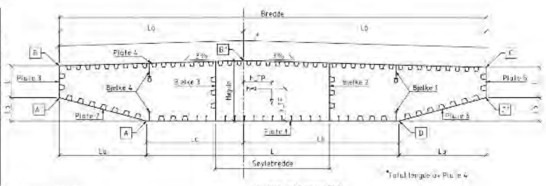
Bøyemotstander gjelder for punkt

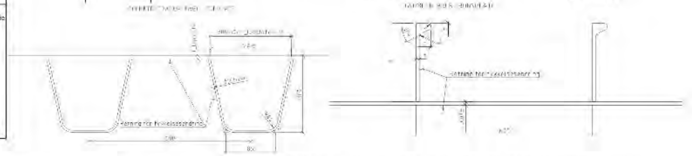
	W'weak,eff	W weak,eff	W'strong,eff	W strong,eff
Punkt C, topp øst	2,012	-2,295	6,284	-5,949
Punkt C'	4,582	8,582	6,284	5,949
Punkt D, bunn øst	1,540	1,846	10,273	12,177
Punkt A, bunn vest	1,540	1,846	-12,177	-10,273
Punkt A'	6,582	4,582	-6,545	-6,284
Punkt B, topp vest	-2,581	-2,135	-6,545	-6,284
Punkt B'	2,058	1,772	70,295	50,204

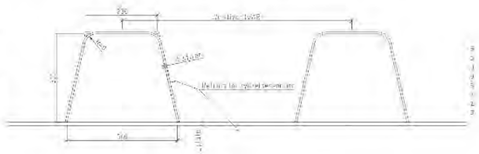
For positivt moment Mweak — For negativt moment Mw For positivt moment Mstr or negativt moment Mstrong

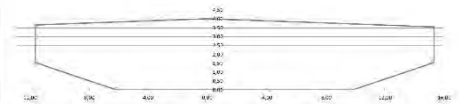
Reduction factors

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6	Bjelke 2/3 mot	Bjelke 2/3 mot bunnplate
Trapezoidal stiffener and adjacent part of skin plate								
ρ buckling	0,737	0,822	0,803	0,803	0,803	0,822	0,774	0,850
ρ buckling and shear lag ULS	0,763	0,787		0,738		0,787		
Bulb stiffener and adjacent part of skin plate								
ρ buckling	0,779							
ρ buckling and shear lag ULS	0,760							









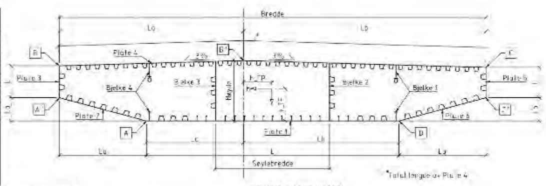
Concept development, Floating bridge E39 Bjørnafjorden

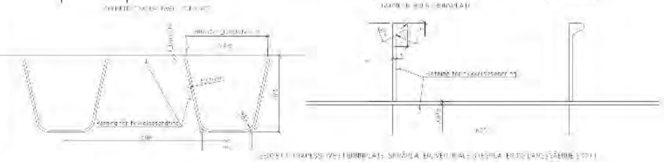
K12_S1

Section:	K12_S1_rev02	Support section - normal - K12		Revision date:	14.05.2019 @ 10:30	
	K12_S1_02			Last revised by:	EDM	
Bredde	27	[m]	fra inside plate 3 til inside plate 5	Total bredde		27,928
Høyde	4	[m]	fra OK plate 1 til OK plate 4	Total høyde		4,020
Søylebredde	7,2	[m]				

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Thickness [mm]	20	20	14	16	14	20
La [m]	6,150	5,500		11,650		5,533
Lb [m]	9,850	1,540	-	15,350	-	1,540
L [m]	16,000	5,712	[illegible]	27,012	2,000	5,712
Trapezoidal type	K12_S1-B	K12_S1-H	K12_S1-VW	K12_S1-T	K12_S1-VW	K12_S1-HV
Trapezoidal thickness [mm]	9	8	8	8	8	8
Trapezoidal c/c [m]	0,750	0,750	0,75	0,000	0,75	0,750
Bulb type	K12_S1 B_b					
Width h [mm]	320					
Thickness t [mm]	12					
Bulb radius r [mm]	10					
Bulb height c [mm]	46					
Bulb width [mm]	48,6					
Bulb c/c [m]	0,6					

	Bjelke 1	Bjelke 2	Bjelke 3	Bjelke 4
Type	K12 S1 B1 rev01	K12 S1 B2 rev01	K12 S1 B3 rev01	K12 S1 B4 rev01
Height top [mm]	900			900
Thickness web top [mm]	16			16
Width flange top [mm]	220			220
Thickness flange top [mm]	20			20
Height bottom [mm]	600			600
Thickness web bottom [mm]	16			16
Width flange bottom [mm]	220			220
Thickness flange bottom [mm]	20			20
Profile	CHS220x10			CHS220x10
Thickness [mm]		14	14	
Trapezoidal type		K12 S1 LD	K12 S1 LD	
Trapezoidal thickness [mm]		8	8	
Trapezoidal c/c [m]		0,87	0,87	

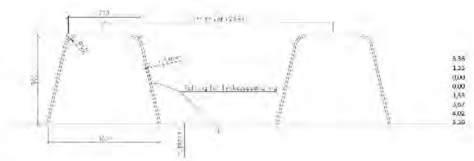




Tyngdepunkt:

yTP (Fra Profillinje):	-1,835	m
zTP (Fra UK)***:	1,998	m
zTP (Fra UK)*:	2,011	m
zTP (fra UK)****:	2,018	m

Tetthet	7,85	t/m3
E-modul	2,10E+05	Mpa
Poisson ratio	0,3	
G-modul	8,08E+04	Mpa



Innesluttet areal:	93,990	m2

Tverrsnittsdata, kassetverrsnitt:

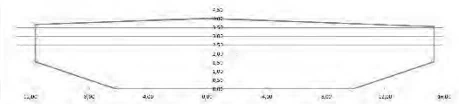
Areal:	1,779	m2	
Tyngdepunkt, fra OK:	1,999	m	
Tyngdepunkt, fra UK:	2,011	m	
Torsjonsmotstand*:	11,349	m4	
Skjærareal vertikalt*:	0,1578	m2	
Skjærareal transvers*:	0,8773	m2	
2. Arealmoment, svak akse***:	3,668	m4	Benyttes i analyser
2. Arealmoment, svak akse****:	4,531	m4	
2. Arealmoment, svak akse*:	4,614	m4	
2. Arealmoment, sterk akse*:	110,500	m4	
Treghetsmoment**:	1220,363	tm2/m	
Masse Areal:	13,96	t/m	
Masse tverrstål:	2,63	t/m	Foreløpig estimat
Sum stål:	16,59	t/m	
Masse rekkverk:	0,71	t/m	Antatt 1 kN/m per rekkverk (6 stk) og 0,5 kN/m per rekkverk ytre (2 stk)
Masse asfalt:	4,62	t/m	2,0 kN/m2 på kjørebane og 1,5 kN/m2 på GS-felt. N400 pkt. 5.2.2.2
Sum masse:	21,93	t/m	
Contingency:	2,93	t/m	
Masse brukt i analyse:	19,00	t/m	

*basert på fullt tverrsnitt inkl. stivere (IDEA CSS)
** inkl asfalt, rekkverk etc.
***basert på tverrsnitt redusert for shear lag i bruksgrense-/utmattingstilstand
**** basert på tverrsnitt redusert for shear lag i bruddgrensetilstand

Stivheter

Aksialstivhet	3,74E+08	kN
Bøyestivhet svak akse***	7,70E+08	kN*m2
Bøyestivhet sterk akse*	2,32E+10	kN*m2
Torsjonsstivhet*	9,17E+08	kN*m2
Skjærstivhet vertikalt*	1,27E+07	kN
Skjærstivhet transvers*	7,09E+07	kN

1210,3
24567,3
1218,3



Bøyemotstander: (Brukes i Formel)

	Koordinater (i forhold til UK og profillinje)		Min tykkelse	Bøyemotstander					Skjærfaktor	
	horisontal	vertikal	[mm]	Wweak***	Wweak****	Wweak*	Wstrong	Wt	Ky	Kz
Punkt C, topp øst	**-15,364**	**3,559**	**0,014**	**2,350**	2,936	2,983	**-8,160**	**2,632**	-0,00012	0,00256
Punkt C'	-15,364	1,552	0,014	-8,224	-9,755	-10,051	-8,160	2,632	0,00021	0,00372
Punkt D, bunn øst	**-9,850**	**0,000**	**0,02**	**-1,836**	-2,248	-2,294	**-13,772**	**3,700**	0,00093	0,00055
Punkt A, bunn vest	**6,150**	**0,000**	**0,02**	**-1,836**	2,248	2,294	**13,828**	**3,700**	0,00094	0,00052
Punkt A'	11,664	1,552	0,014	8,224	9,755	10,051	8,179	2,632	0,00022	0,00325
Punkt B, topp vest	**11,664**	**3,670**	**0,014**	**2,194**	2,733	2,781	**8,179**	**2,632**	-0,00015	-0,00320
Punkt B'	0,000	4,020	0,016	1,814	2,261	2,298	60,196	3,008	-0,00158	-0,00113

Navngivning av punkter iht. Ansys spenningssjekk — SHEAR LAG SLS — SHEAR LAG ULS — BRUTTO

Benyttes for von-mises sjekk

METODE 1

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Aeff,c	1,451	m2	Basert på tverrsnitt. Redusert for platebnekking lokal og global. 82 % Aeff,c/Aeff,t
Aeff,t	1,779	m2	Bruttotverrsnitt
ew,N,c	0,02	m	
ew,N,t	0	m	
es,N,c	0,018	m	
es,N,t	0	m	
$W^+_{weak,eff}$	1,903	m3	Redusert for platebnekking lokal og global. Redusert for shear lag i bruddgrensetilstand. 85 % Sammenlignet med Wweak****
$W^-_{weak,eff}$	-1,872	m3	Redusert for platebnekking lokal og global. Redusert for shear lag i bruddgrensetilstand. 83 % Sammenlignet med Wweak****
$W^+_{strong,eff}$	7,089	m3	Redusert for platebnekking lokal og global. 87 % Sammenlignet med Wstrong
$W^-_{strong,eff}$	-7,089	m3	Redusert for platebnekking lokal og global. 87 % Sammenlignet med Wstrong

METODE 2

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Effektivt areal og eksentrisiteter gjelder for alle punkter:

Aeff,c	1,451	m2
Aeff,t	1,779	m2
ew,N,c	0,02	m
ew,N,t	0	m
es,N,c	0,018	m
es,N,t	0	m

Bøyemotstander gjelder art. punkt

	$W^+_{weak,eff}$	$W^-_{weak,eff}$	$W^+_{strong,eff}$	$W^-_{strong,eff}$
Punkt C, topp øst	-2,935	-2,376	7,089	7,825
Punkt C'	6,670	13,179	7,089	7,825
Punkt D, bunn øst	1,903	2,193	11,596	13,706
Punkt A, bunn vest	1,903	2,193	-13,706	-11,596
Punkt A'	6,670	13,179	-7,826	-7,089
Punkt B, topp vest	-2,719	-2,231	-7,826	-7,089
Punkt B'	-2,208	1,872	64,984	39,927
	For positivt moment Mweak	For negativt moment Mw	For positivt moment Mst	For negativt moment Mstrong

Reduction factors

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6	Bjelke 2	Bjelke 3
Trapezoidal stiffener and adjacent part of skin plate								
ρ buckling	0,807	0,813	0,809	0,808	0,809	0,817	0,710	0,710
ρ buckling and shear lag ULS	0,800	0,801		0,793		0,802		
Bulb stiffener and adjacent part of skin plate								
ρ buckling	0,812							
ρ buckling and shear lag ULS	0,795							

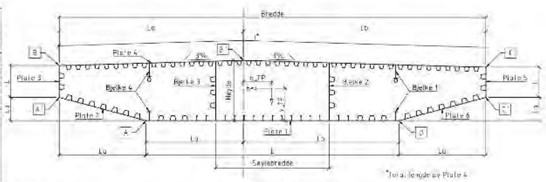
Concept development, Floating bridge E39 Bjørnafjorden

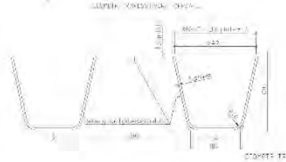
K12_S2

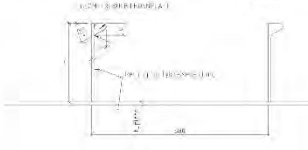
Section	K12_S2_rev00	Support section - normal - K12		Revision date:		4.05.2019 @ 10:02
	K12_S2_00			Last revised by:	SDM	
Bredde	27 [m]	fra inside plate 3 til inside plate 5		Total bredde		27,04
Høyde	4 [m]	fra OK plate 1 til OK plate 4		Total høyde		4,022
Søylebredde	8,6 [m]					

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Thickness [mm]	22	22	20	16	20	22
La [m]	6,150	5,500		11,650		5,500
Lb [m]	9,850	1,540	-	15,350	-	1,540
L [m]	16,000	5,712	2,111	27,000	2,111	5,712
Trapezoidal type	K12_S2-3	K12_S2-B	K12_S2-VW	K12_S2-?	K12_S2-VW	K12_S2-B
Trapezoidal thickness [mm]	9	10	8	8	8	10
Trapezoidal c/c [m]	0,750	0,750	0,75	0,600	0,75	0,750
Bulb type	K12_S2 B_b					
Width h [mm]	320					
Thickness t [mm]	12					
Bulb radius r [mm]	14					
Bulb height c [mm]	46					
Bulb width [mm]	48,6					
Bulb c/c [m]	0,6					

	Bjelke 1	Bjelke 2	Bjelke 3	Bjelke 4
Type	K12_S2_B1_rev00	K12_S2_B2_rev00	K12_S2_B3_rev00	K12_S2_B4_rev00
Height top [mm]	900			900
Thickness web top [mm]	16			16
Width flange top [mm]	220			220
Thickness flange top [mm]	20			20
Height bottom [mm]	600			600
Thickness web bottom [mm]	16			16
Width flange bottom [mm]	220			220
Thickness flange bottom [mm]	20			20
Profile	CHS220x10			CHS220x10
Thickness [mm]		14	14	
Trapezoidal type		K12_S2_LD	K12_S2_LD	
Trapezoidal thickness [mm]		8	8	
Trapezoidal c/c [m]		0,87	0,87	



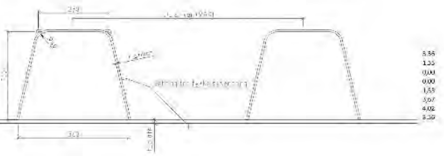




Tyngdepunkt:

hTP (Fra Profillinje):	-1,931	m
vTP (Fra UK)***:	1,948	m
vTP (Fra UK)*:	1,959	m
vTP (Fra UK)****:	1,867	m

Tetthet	7,85	t/m3
E-modul	2,10E+05	Mpa
Poisson ratio	0,3	
G-modul	8,08E+04	Mpa



Innesluttet areal:		93,990	m2

Tverrsnittsdata, kassetverrsnitt:

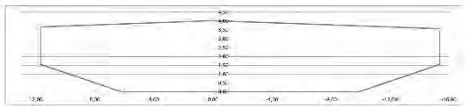
Areal:	1,883	m2	
Tyngdepunkt, fra OK:	2,071	m	
Tyngdepunkt, fra UK:	1,959	m	
Torsjonsmotstand*:	12,010	m4	
Skjærareal vertikalt*:	0,1648	m2	
Skjærareal transverst*:	0,9352	m2	
2. Arealmoment, svak akse***	3,785	m4	Benyttes i analyser
2. Arealmoment, svak akse****	4,714	m4	
2. Arealmoment, svak akse*	4,821	m4	
2. Arealmoment, sterk akse*	121,830	m4	
Treghetsmoment**	1270,039	tm2/m	
Masse Areal:	14,78	t/m	
Masse tverrstål:	2,63	t/m	Foreløpig estimat
Sum stål:	17,41	t/m	
Masse rekkverk:	0,71	t/m	Antatt 1 kN/m per rekkverk (6 stk) og 0,5 kN/m per rekkverk ytre (2 stk)
Masse asfalt:	0,62	t/m	2,0 kN/m2 på kjørebane og 1.5 kN/m2 på GS-felt. N400 pkt. 5.2.2.2
Sum masse:	22,75	t/m	
Contingency:	3,75	t/m	
Masse brukt i analyse:	19,00	t/m	

1267,5
25560,2
1267,5

Stivheter

Aksialstivhet	3,95E+08	kN
Bøyestivhet svak akse***	7,95E+08	kN*m2
Bøyestivhet sterk akse*	2,55E+10	kN*m2
Torsjonsstivhet*	9,70E+08	kN*m2
Skjærstivhet vertikalt*	1,33E+07	kN
Skjærstivhet transverst*	7,55E+07	kN

*basert på fullt tverrsnitt inkl. stivere (IDEA CSS)
** inkl asfalt, rekkverk etc.
***basert på tverrsnitt redusert for shear lag i bruksgrense-/utmattingstilstand
**** basert på tverrsnitt redusert for shear lag i bruddgrensetilstand



Bøyemotstander:

(Bredde i formel)

	Koordinater (i forhold til UK og profillinje)		Min tykkelse	Bøyemotstander					Skjærfaktor	
	horisontal	vertikal	[mm]	Wweak***	Wweak****	Wweak*	Wstrong	Wt	Ky	Kz
Punkt C, topp øst	-15,370	3,561	0,016	2,339	2,057	3,039	-8,998	3,008	-0,00017	0,00314
Punkt C'	-15,370	1,554	0,02	-9,730	-11,414	-11,903	-8,998	3,760	0,00018	0,00285
Punkt D, bunn øst	-9,850	0,000	0,022	-1,948	-2,397	-2,461	-15,197	4,136	0,00090	0,00003
Punkt A, bunn vest	6,150	0,000	0,022	-1,948	2,397	2,461	15,265	4,136	0,00091	0,00061
Punkt A'	11,670	1,554	0,02	9,730	11,414	11,908	9,024	3,760	0,00018	0,00292
Punkt B, topp vest	11,670	3,672	0,016	2,189	2,765	2,814	9,024	3,008	-0,00017	-0,00326
Punkt B'	0,000	4,022	0,016	1,871	2,204	2,337	66,537	3,008	-0,00148	-0,00192

Navngiving av punkter iht. Aurora spenningssjekk — SHEAR LAG SLS — SHEAR LAG ULS — BRUTTO

Benyttes for von-mises sjekk

METODE 1

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Aeff,c	1,552	m2	Basert på tverrsnitt. Redusert for platoknekking lokal og global. 82 % Aeff,c/Aeff,t
Aeff,t	1,883	m2	Bruttotverrsnitt
ew,N,c	0,08	m	
ew,N,t	0	m	
es,N,c	0,007	m	
es,N,t	0	m	
W+weak,eff	2,054	m3	Redusert for plateknekking lokal og global. Redusert for shear lag i bruddgrensetilstand. 86 % Sammenlignet med Wweak****
W-weak,eff	-1,906	m3	Redusert for plateknekking lokal og global. Redusert for shear lag i bruddgrensetilstand. 83 % Sammenlignet med Wweak****
W+strong,eff	7,878	m3	Redusert for plateknekking lokal og global. 87 % Sammenlignet med Wstrong
W-strong,eff	-7,878	m3	Redusert for plateknekking lokal og global. 87 % Sammenlignet med Wstrong

METODE 2

Effektive tverrsnittsdata for påvisning av brubjelkens kapasitet mot trykk og toaksial bøyning iht. NS-EN 1993-1-5

Effektivt areal og eksentrisiteter gjelder for alle punkter:		
Aeff,c	1,552	m2
Aeff,t	1,883	m2
ew,N,c	0,03	m
ew,N,t	0	m
es,N,c	0,007	m
es,N,t	0	m

Bøyemotstander gjelder pr. punkt

	W+weak,eff	W-weak,eff	W+strong,eff	W-strong,eff
Punkt C, topp øst	[illegible]	[illegible]	[illegible]	[illegible]
Punkt C'	[illegible]	[illegible]	[illegible]	[illegible]
Punkt D, bunn øst	2,054	[illegible]	[illegible]	[illegible]
Punkt A, bunn vest	2,054	[illegible]	[illegible]	[illegible]
Punkt A'	[illegible]	[illegible]	[illegible]	[illegible]
Punkt B, topp vest	[illegible]	[illegible]	[illegible]	[illegible]
Punkt B'	[illegible]	[illegible]	[illegible]	[illegible]
	For positivt moment Mweak	For negativt moment Mweak	For positivt moment Mstrong	For negativt moment Mstrong

Reduction factor

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6	Bjelke 2	Bjelke 3
Trapezoidal stiffener and adjacent part of skin plate								
ρ buckling	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ρ buckling and shear lag ULS	[illegible]	[illegible]		[illegible]		[illegible]		
Bulb stiffener and adjacent part of skin plate								
ρ buckling	[illegible]							
ρ buckling and shear lag ULS	[illegible]							