Appendix to report:

SBJ-33-C5-OON-22-RE-017 DESIGN OF BRIDGE GIRDER

Appendix title:

APPENDIX C - OPTIMALIZATION STUDY OF BOTTOM PLATE STIFFENERS

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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN





Prodex F2 Pure Logic HEYERDAHL ARKITEKTER AS HEEB ANIKO BURSÉR (S) SWERIM

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1 INTRODUCTION

1.1 Motivation

This study investigates the potential of changing/reducing the stiffeners in the bottom plate of the girder in the mid span where the compressional stresses are smaller. The bridge section considered ranges from 1360 m and 3850 m and has the cross section BCS1, with type 2A stiffeners. In the analysis, certain axial stress levels have been tested on the cross section between stress point P3 and P5. The stress levels tested are -200 MPa, -100 MPa, - 50 MPa. Spacing between the stiffeners and the bottom width are held constant while stiffener profile and stiffener cross section has been changed. The profile tested are variations of T-profile, bulbflats-profile and trapezoidal profile.

1.2 Assumptions

The results are based on a constant axial stress distribution between P3 and P5, as this is the most critical situation for the tested stresses. Parts of the stress are a result of axial forces, but in the calculations, it is assumed that all stresses are caused by bending moment, M_y . This because it simplifies later calculations of changes in stress due to reduction in cross section.

In the analysis, external pressure and stress in the transverse direction have been set equal to zero. The distance between sideways support of stiffener/torsional buckling length is kept constant and equal to the length between the cross frames in the girder.

2 ANALYSIS

2.1 Input

A STIPLA analysis has been performed, in accordance with DNV-RP-C201, with input shown in tables below:

Material Properties	
Safety factor for cross section resistance	γm = 1,10
Young's modulus	E = 210000 MPa
Yield strength for plate thickness t \leq 40mm	$f_{y_p} = 420 \text{ MPa}$
Yield strength for trapezoidal stiffeners.	$f_{y_s} = 420 \text{ MPa}$
Yield strength for T-profile stiffeners	$f_{y_s} = 420 \text{ MPa}$
Yield strength for HP Bulbflats profile	f _{y_s} = 355 MPa

Geometry	
Length between the cross frames in the box girder	L = 4000 mm
Width of the considered cross section, in this case between P3 and P5	Lg = 16500 mm
Plate thickness	t = 12 mm
Stiffener spacing	s1 = s2 = 600 mm
Lat tors buckl length	Lt = 4000 mm

2.2 Span length for the tested stress levels

The corresponding span length for which the tested stress levels occur are given in the table below. The distances are estimated from the global response analyses for the bridge in the range between 1360 m and 3850 m (OO interactive), and it can therefore be some deviations from theoretical values.

Load combination	Axial stress	Length
Comb. 31	- 200 MPa	100 m
	- 100 MPa	70 m
	- 50 MPa	45 m

Comb. 32	- 200 MPa	104 m
	- 100 MPa	60 m
	- 50 MPa	40 m
Comb. 33	- 200 MPa	90 m
	- 100 MPa	55 m
	- 50 MPa	20 m
Comb. 34	- 200 MPa	100 m
	- 100 MPa	60 m
	- 50 MPa	40 m

2.3 Original cross section properties

Table below shows data for original bridge box cross section BCS1 with stiffener type 2A in the bottom part. The values differ slightly from the values from the bridge girder design report, SBJ-33-C5-OON-22-RE-017. This because the values are calculated based on a spreadsheet which do not consider all the details, but the difference is small. Later, the cross section has been updated in upper area of the box girder and one stiffener has been added in the lower section, and therefor the real cross section area is larger than the area used in this report. This will have a small effect on the results, as they are based on changes in area in the lower part of the girder.

Bridge box BCS1	Symbol	Value
Cross section area	А	1,468 m ²
Moment of inertia weak axis	Iy	2,737 m ⁴
Distance from bottom of cross section to NA	z _c	1,91 m
Plate thickness, bottom plate	t	12 mm

2.4 Axial stress and shear stress in the analysis

2.4.1 Axial stress

By changing the stiffeners, the neutral axis also changes relative to the original cross section. The stress which occurs in the considered part of the bridge section becomes larger, and the stress have to be re-calculated based on the new neutral axis. The new stress is found by assuming that the tested stresses {-200, -100, -50} MPa are a result of the bending moment, My, alone. The bending moment acting on the original cross section due to the given stresses is equal to the bending moment acting on the modified cross section. Thus, the new stresses due to change in stiffeners can be calculated using $\sigma_x = \frac{My}{l_y} * z$. See section 6.1 details.

The table below shows the bending moment corresponding to the tested stress levels.

Axial stress Bending moment, M_y

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- 200 MPa	- 286,7 kNm
- 100 MPa	- 143,4 kNm
- 50 MPa	- 71,7 kNm

Note: The values of bending moment and new stresses will vary a little from the values when using the updated cross section.

2.4.2 Shear stress

An estimate gives that most occurring shear stress is around 72 MPa. This is based on the most occurring value of the torsional moment and shear force in y-direction on the interval between 1400 m and 3800 m, respectively 125 MNm and 5 MN. Between 3400 m and 3900 m there is an increase in torsional moment by a factor of 1,24. In this area, the shear stress will be higher than 60 MPa, and the results will not here. See section 6.2 for calculation details.

3 RESULTS

Original stiffener, type 2A (Trapezoidal 300x150/75x8,0), does not meet Stiplas local buckling check, which is based on recommendations and requirements in DNV-RP-C201 for buckling check of plated structures. The buckling checks in DNV-RP-C201 assumes a cross section class 3 for the stiffeners, which is not fulfilled for trapezoidal-stiffener 2A, hence the trapezoidal-stiffener must be treated as a cross section of class 4. This is not persued further in this report, reference is made to bridge girder design report, SBJ-33-C5-OON-22-RE-017. This stiffener 2A is used in the original cross section area, so the results below are based on this stiffener. In the considered interval, between 1360 m and 3850 m, there are 22 pontoons supporting the bridge girder. When excluding the area with increasing torsional moment, it gives 17 spans of 120 m. The calculations are based on a cross section with 27 stiffeners in the considered section of the bridge girder. Note that the updated cross section has 28 stiffeners. See section **Error! Reference source not found.** for drawings of updated cross section with stiffners in the bottom part from the results.

For a summery of the results, se section 3.5.

Note: Results have not been checked against NS-EN 1993-1-5:2006+NA:2009

3.1 T-profile

The table below shows modified geometry:

Plate thickness: 12 mm	T200x150x10x20	T200x120x10x13	T150x100x8x10	T150x100x6x7
New cross section area	A = 1,436	$A = 1,399 m^2$	$A = 1,363 \text{ m}^2$	$A = 1,348 \text{ m}^2$
New moment of inertia weak axis	$I_y = 2,649 \text{ m}^4$	$I_y = 2,533 \text{ m}^4$	$I_y = 2,416 \text{ m}^4$	$I_y = 2,360 \text{ m}^4$
New distance from bottom of cross section to NA	$z_c = 1,94 m$	z _c = 1,99 m	$z_c = 2,04 m$	z _c = 2,06 m

The table shows a summary of the STIPLA analysis, see section **Error! Reference source not found.** details:

Axial stress	Shear stress	Profile	New axial stress	Buckling	Buckling + Yield	Local buckling
-200 MPa	72 MPa	T200x150x10x20	-210 MPa	Ok	ОК	ОК
-100 MPa	72 MPa	T200x120x10x13	-113 MPa	OK	OK	OK
-100 MPa	72 MPa	T150x100x8x10	-121 MPa	ОК	ОК	Ok
-100 MPa	72 MPa	T150x100x6x7	-125 MPa	Ok	Ok	OK

By setting Lt = 1600 mm, the T200x120x10x13 would be OK for a stress of 200 MPa. The changes because of this are not calculated here.

The table below shows the impact the different stiffeners have on the area:

Profile	Reduction in area*	Length	Reduction in steel weight pr. 120 m
T200x150x10x20	0,032 m ²	90 m	22,6 ton

T200x120x10x13	0,069 m ²	55 m	29,7 ton
T150x100x8x10	0,105 m ²	55 m	45,3 ton
T150x100x6x7	0,120 m ²	55 m	51,8 ton

*This reduction is in the section where the stiffeners are changed, and is not an average reduction over the span of 120 m.

Note: The lengths are roughly read from the stress profile (Comb. 31-34), and it can therefore be some deviations from the real value.

3.2 Bulbflats-profile

The table below shows modified geometry:

Plate thickness: 12 mm	BF 300x11	BF 160x9	BF 140x7
New cross section area	$A = 1,432 \text{ m}^2$	$A = 1,354 \text{ m}^2$	$A = 1,340 \text{ m}^2$
New moment of inertia weak axis	$I_y = 2,622 \text{ m}^4$	$I_y = 2,384 \text{ m}^4$	$I_y = 2,330 \text{ m}^4$
New distance from bottom of cross section to NA	z _c = 1,95 m	$z_c = 2,05 m$	$z_c = 2,07 m$

The table shows a summary of the STIPLA analysis, see section **Error! Reference source not found.** details:

Axial stress	Shear stress	Profile	New axial stress	Buckling	Buckling + Yield	Local buckling
-200 MPa	72 MPa	BF 300x11	-213 MPa	ОК	ОК	OK
-100 MPa	72 MPa	BF 160x9	-123 MPa	Ok	OK	ОК
-50 MPa	72 MPa	BF 140x7	-64 MPa	ОК	ОК	ОК

The table below shows the impact the different stiffeners have on the area:

Profile	Reduction in area*	Length	Reduction in steel weight pr. 120 m
BF 300x11	0,036 m ²	90 m	25,4 ton
BF 160x9	0,114 m ²	55 m	49,2 ton
BF 140x7	0,128 m ²	20 m	20,1 ton

*This reduction is in the section where the stiffeners are changed, and is not an average reduction over the span of 120 m.

Note: The lengths are roughly read from the stress profile (Comb. 31-34), and it can therefore be some deviations from the real value.

3.3 Trapezoidal-profile

The table below shows modified geometry:

Plate thickness: 12 mm	Trapezoidal 200x100/50x8	Trapezoidal 150x60/30x5	Trapezoidal 115x50/25x5
New cross section area	A = 1,413 m ²	$A = 1,354 \text{ m}^2$	A = 1,343 m ²
New moment of inertia weak axis	$I_y = 2,590 \text{ m}^4$	$I_y = 2,386 \text{ m}^4$	$I_y = 2,346 \text{ m}^4$
New distance from bottom of cross section to NA	z _c = 1,97 m	z _c = 2,05 m	z _c = 2,06 m

The table shows a summary of the STIPLA analysis, see section **Error! Reference source not found.** details:

Axial stress	Shear stress	Profile	New axial stress	Buckling	Buckling + Yield	Local buckling
-200 MPa	72 MPa	Trapezoidal 200x100/50x8	-218 MPa	ОК	ОК	ОК
-100 MPa	72 MPa	Trapezoidal 150x60/30x5	-123 MPa	Ok	ОК	ОК
-50 MPa	72 MPa	Trapezoidal 115x50/25x5	-63 MPa	ОК	ОК	ОК

The table below shows the impact the different stiffeners have on the area:

Profile	Reduction in area	Length	Reduction in steel weight pr. 120 m
Trapezoidal 200x100/50x8	0,055 m ²	90 m	38,8 ton
Trapezoidal 150x60/30x5	0,114 m ²	55 m	49,2 ton
Trapezoidal 115x50/25x5	0,125 m ²	20 m	19,6 ton

*This reduction is in the section where the stiffeners are changed, and is not an average reduction over the span of 120 m.

Note: The lengths are roughly read from the stress profile (Comb. 31-34), and it can therefore be some deviations from the real value.

3.4 Plate thickness

It is also possible to reduce the plate thickness from 12 mm to 8 mm, which is the minimum requirement according to N400 Bruprosjektering (N400 Bruprosjektering, 8.10.2.1 Platetykkelser). If so, the stiffeners above does not apply.

Table shows modified geometry:

Plate thickness: 8 mm	Stiffener type 2A (Trapezoidal 300x150/75x8)	Trapezoidal 175x50/25x8
New cross section area	$A = 1,402 \text{ m}^2$	$A = 1,324 \text{ m}^2$
New moment of inertia weak axis	$I_y = 2,489 \text{ m}^4$	$I_y = 2,239 \text{ m}^4$
New distance from bottom of cross section to NA	z _c = 1,99 m	$z_{c} = 2,10 m$

A summary of the STIPLA analysis for plate thickness 8 mm, se section **Error! Reference source not found.** for details:

	Shear stress	Profile	New axial stress	Buckling	Buckling + Yield	Local buckling
-200 MPa	72 MPa	Trapezoidal 300x150/75x8	-230 MPa	ОК	ОК	Not OK
-100 MPa	72 MPa	Trapezoidal 175x50/25x8	-135 MPa	ОК	ОК	ОК

The STIPLA analysis shows that the original stiffeners are OK for "Buckling" and "Buckling + Yield" for stiffener spacing of 1200 mm. This gives a reduction in area of 0,084 m^2. Local buckling check is still not OK according to DNV-RP-C201, which assumes a cross section class 3, hence the trapezoidal-stiffener will be of cross section class 4. This is not persued further in this report, reference is made to bridge girder design report, SBJ-33-C5-OON-22-RE-017.

The table below shows the impact the different stiffeners have on the area:

Profile	Reduction in area*	Length	Reduction in steel weight pr. 120 m
Trapezoidal 300x150/75x8	0,066 m ²	90 m	46,6 ton
Trapezoidal 175x50/25x8	0,144	55 m	62,1 ton

*This reduction is in the section where the stiffeners are changed, and is not an average reduction over the span of 120 m.

APPENDIX C – OPTIMALIZATION STUDY OF BOTTOM PLATE STIFFENERS SBJ-33-C5-00N-22-RE-017, rev. 0

	Profile	Reduction in area*	Length	Reduction in steel weight pr. 120 m
T-profile	T200x150x10x20	0,032 m ²	90 m	22,6 ton
	T200x120x10x13	0,069 m ²	55 m	29,7 ton
	T150x100x8x10	0,105 m ²	55 m	45,3 ton
	T150x100x6x7	0,120 m ²	55 m	51,8 ton
Bulbflats-profile	BF 300x11	0,036 m ²	90 m	25,4 ton
	BF 160x9	0,114 m ²	55 m	49,2 ton
	BF 140x7	0,128 m ²	20 m	20,1 ton
Trapezoidal-profile:	Trapezoidal 200x100/50x8	0,055 m ²	90 m	38,8 ton
	Trapezoidal 150x60/30x5	0,114 m ²	55 m	49,2 ton
	Trapezoidal 115x50/25x5	0,125 m ²	20 m	19,6 ton
Plate thickness 8 mm	Trapezoidal 300x150/75x8 (stiffeners type 2A)	0,066 m ²	90 m	46,6 ton
	Trapezoidal 175x50/25x8	0,144	55 m	62,1 ton

3.5 Summary of the results

3.6 Reduction in bending moment

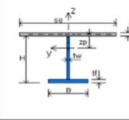
The table below shows the reduction in bending moment at the supports because of reduction in cross section. In the calculations, only self weight is considered, and the original bending moment at the supports is calculated to be 163 MNm by using the original cross section. The considered part of the bridge is simplified to a continuous beam with constant EI. In fact, the bending stiffness, EI, will vary over the span because the change in cross section happens over a shorter length than 120 m. The variation is small and will have little to say in relation to total bending moment. See section **Error! Reference source not found.** for details.

	Profile	Reduction in bending moment at the supports, ΔM	Reduction in %
T-profile	T200x150x10x20	2,66 MNm	1,63 %
	T200x120x10x13	3,51 MNm	2,15 %
	T150x100x8x10	5,34 MNm	3,28 %
	T150x100x6x7	6,10 MNm	3,75 %
Bulbflats-profile	BF 300x11	2,99 MNm	1,84 %
	BF 160x9	5,79 MNm	3,56 %
	BF 140x7	2,37 MNm	1,45 %
Trapezoidal-profile:	Trapezoidal 200x100/50x8	4,57 MNm	2,81 %
	Trapezoidal 150x60/30x5	5,79 MNm	3,56 %
	Trapezoidal 115x50/25x5	2,31 MNm	1,42 %
Plate thickness 8 mm	Trapezoidal 300x150/75x8	5,49 MNm	3,37 %
	Trapezoidal 175x50/25x8	7,32 MNm	4,50 %

STIPLA ANALYSES 4

4.1 T-profile

		RPS					Project: Sensitivitetsstudie stiverkasse						
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Material Plate/St			gm	=	1,10 al/General		- S Continuous s	upport	km1	=	12,0		
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roungs	modul	us	C	-	2,10E+5	WP2							
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						в		00 mm	ZD	=		mm	
		. Z				tw		5,0 mm	Ae	-	6.542E+3		
k		se 1-				tf		.0 mm	le	_	1.837E+7		
	-		1			A		58 mm2	Wep	-	6.936E+5		



ffener proper	ty:		Incl. eff.	plate:		
=	150	mm	se	=	415,3	mm
=	100	mm	zp	=	26,5	mm
=	6,0	mm	Ae	=	6,542E+3	mm2
=	7,0	mm	le	=	1,837E+7	mm4
=	1558	mm2	Wep	=	6,936E+5	mm3
=	12,2	kg/m	Wes	=	1,418E+5	mm3
=	105,2	mm	Flange:	c = 47,	0 <= 73,3	OK (Eq 9.1)
=	3,633E+6	mm4	Web: h	N = 143	0 <= 188,5	OK (Eq 9.2)
=	5,833E+5	mm4				

STIFFENER BUCKLING CHECK (DNV-RP-C201); (1 = Support, 2 = field; s = stiffener, p = plate)

se = 415.3 mm Sigxsd = -125.0 MPa Sigysd = 0.0 MPa p0 = 0.000 MPa z* = 8.0 mm

UF1s=Nsd/Nks1Rd+(M1Sd-NSd*z)/(Ms1Rd*(1-Nsd/Ne))+u = 1094,8/899,3+(0.0-1094,8*0,008)/(48,3*(1-1094,8/2379,6))+0,107 = 0,99 < 1.00 (Eq 7.50) UF1p=Nsd/Nkp1Rd-2*NSd/N1Rd+(M1Sd-Nsd*z*)/(Mp1Rd*(1-Nsd/Ne))+u = $1094.8/1336.2-2^{\bullet}1094.8/2497.8+(0.0-1094.8^{\bullet}0.008)/(264.8^{\bullet}(1-1094.8/2379.6))+0.107=$ -0.01 < 1.00 (Eq 7.51) UF2s=Nsd/Nks2Rd-2*NSd/NRd+(M2Sd+NSd*z)/(Mst2Rd*(1-Nsd/Ne))+u = 1094,8/899,3-2*1094,8/2497,8+(0.0+1094,8*0,008)/(54,2*(1-1094,8/2379,6))+0,107 = 0.75 < 1.00 (Eq 7.52)

UF2p=Nsd/Nkp2Rd+(M2Sd+NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u = 1094,8/1338,2+(0,0+1094,8*0,008)/(264,8*(1-1094,8/2379,8))+0,107 = 0,99 < 1,00 (Eq 7.53)

g ez ly Iz

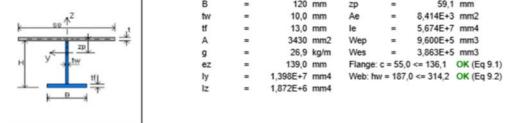


DNVRPS				P	Project: Sensitivitetsstudie stiverkasse							
Plate/Stiff check based Version 2.2	on DNV-RP	-C201			ntification: Biørnafjorden fase 5 Date: 28	3.06.2019						
Copyright (C) 2004-201	4 StruProg	AB		1.	Time: 10:							
File: c:\program files (x	86)\struprog	2014\s	tipla dnvrp	db\sti	ere.drps							
Safety Format/Materia	<u>l:</u>				General:							
Design Condition:			LRFD		Buckling length Lk = 4000 mm							
Allowable Usage Factor	: UF	=	1,00		Mom fact - Field km2 = 24,0							
Material Factor:	gm	=	1,10		- Support km1 = 12,0							
Plate/Stiffener:		Genera	al/General		Continuous stiffener							
rield stress	fyp/fys	=	420/420	MPa								
Youngs modulus	E	=	2,10E+5	MPa								
Geometry:					Figure:							
Stiffener span	L	=	4000	mm	у							
ength of girder	Lg	=	16500	mm	Ĺ,x							
Plate thickness	t	=	12,0	mm								
Stiffener spacing	s1	=	600	mm								
	s2	=	600	mm								
at tors buckl length	Lt	=	4000	mm	S1 PL1							
Stresses:												
SigxA = -121,0					s2 N ma							
SigxB = -121,0					PL2							
	MPa											
31	MPa				Sigx L Lt L							
Tau = 72,0	MPa				L>= s							
Stiffener: T 150x100x8	0x10.0			Stiffer	r property: Incl. eff. plate:							
		_		H	= 150 mm se = 415.3 mm							
				в	= 100 mm zp = 33.2 mm							
.2				tw	= 8.0 mm Ae = 7.104E+3 mm2							
k se 1-	* *			tf	= 10.0 mm le = 2.332E+7 mm4							
Concession of the local division of the loca				A	= 2120 mm2 Wep = 7.016E+5 mm3							
ZP.	- T			q	= 16,6 kg/m Wes = 1,900E+5 mm3							
				ez	= 105,4 mm Flange: c = 46,0 <= 104,7 OK (Eq.	9.1)						
	10			ly	= 4,809E+6 mm4 Web: hw = 140,0 <= 251,3 OK (Eq.							
	<u></u>			Iz	= 0.333E+5 mm4							
1 B J	4,			14	- 0,0002+0 111114							

STIFFENER BUCKLING CHECK (DNV-RP-C201): (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 415,3 mm Sigxsd = -121,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 6,0 mm	
UF1s=Nsd/Nks1Rd+(M1Sd-NSd*z)/(Ms1Rd*(1-Nsd/Ne))+u = 1127,7/1263,3+(0.0-1127,7*0.006)/(69,1*(1-1127,7/3020,8))+0.107 =	0,84 < 1.00 (Eq 7.50)
UF1p=Nsd/Nkp1Rd-2*NSd/N1Rd+(M1Sd-Nsd*z*)/(Mp1Rd*(1-Nsd/Ne))+u =	
1127,7/1576,7-2*1127,7/2712,4+(0,0-1127,7*0,008)/(267,9*(1-1127,7/3020.8))+0,107 =	-0,05 < 1.00 (Eq 7.51)
UF2s=Nsd/Nks2Rd-2*NSd/NRd+(M2Sd+NSd*z)/(Mst2Rd*(1-Nsd/Ne))+u =	
1127.7/1263.3-2*1127.7/2712,4+(0,0+1127,7*0,008)/(72,5*(1-1127,7/3020,8))+0,107 =	0.32 < 1.00 (Eq 7.52)
UF2p=Nsd/Nkp2Rd+(M2Sd+NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u = 1127.7/1576.7+(0.0+1127.7*0.006)/(267.9*(1-1127.7/3020.8))+0.107 =	0,86 < 1.00 (Eq 7.53)



DNVRPS Plate/Stiff check based on DNV-RP-C201							Project: Sensitivitetsstudie stiverkasse						
Plate/S Version		eck based	on DNV-RP-	C201		h	tification: Bjørnafjorden fase 5 Date: 28.0	6 2010					
		2004-201	4 StruProg	AB		- I'	Time: 10:3						
			6)\struprog		stipla dnvro	db\s							
		at/Material.					General:						
Design					LRFD		Buckling length Lk = 4000 mm						
		age Factor:		=	1,00		Mom fact - Field km2 = 24,0						
	aterial Factor: gm = 1,10			- Support km1 = 12,0									
Plate/St		r:			al/General		Continuous stiffener						
Yield str			fyp/fys	=	420/420								
Youngs	modu	lus	E	=	2,10E+5	MPa							
Geome	try:						Figure:						
Stiffener		i.	L	=	4000	mm	y						
Length			Lg	=	16500	mm	1 Lix						
Plate thi	-		t	=	12.0	mm							
Stiffener	r spac	ing	s1	=		mm							
		<u>್</u>	s2	=	600	mm							
Lat tors	buckl	length	Lt	=	4000	mm	s1 PL1						
Stresse													
SigxA	=	-113,0					s2						
SigxB	=	-113,0					PL2						
SigyA	=		MPa										
SigyC	=		MPa				Sigx L Lt L						
Tau	=	72,0	MPa										
Stiffene	er: T 2	200x120x10	0,0x13,0			_	<u>property:</u> <u>Incl. eff. plate:</u> = 200 mm se = 415.3 mm						
						H							
		-				В	= 120 mm zp = 59,1 mm						
		co ↑ ²				tw	= 10,0 mm Ae = 8,414E+3 mm2						

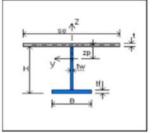


STIFFENER BUCKLING CHECK (DNV-RP-C201); (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 415,3 mm Sigxsd = -113,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 11,0 mm	
UF1s=Nsd/Nks1Rd+(M1Sd-NSd*z)/(Ms1Rd*(1-Nsd/Ne))+u = 1201,2/1877,2+(0,0-1201,2*0,011)/(144,9*(1-1201,2/7350,3))+0.107 =	0,64 < 1,00 (Eq 7.50)
UF1p=Nsd/Nkp1Rd-2*NSd/N1Rd+(M1Sd-Nsd*z*)/(Mp1Rd*(1-Nsd/Ne))+u =	
1201,2/2452,5-2*1201,2/3212,8+(0,0-1201,2*0,011)'(386,6*(1-1201,2/7350,3))+0,107 =	-0,19 < 1.00 (Eq 7.51
UF2s=Nsd/Nks2Rd-2*NSd/NRd+(M2Sd+NSd*z)/(Mst2Rd*(1-Nsd/Ne))+u =	
1201,2/1877,2-2*1201,2/3212,8+(0,0+1201,2*0,011)/(147,5*(1-1201,2/7350,3))+0,107 =	0,11 < 1,00 (Eq 7.52)
UF2p=Nsd/Nkp2Rd+(M2Sd+NSd*2)/(Mp2Rd*(1-Nsd/Ne))+u = 1201.2/2452.5+(0.0+1201.2*0.011)/(368.6*(1-1201.2/7350.3))+0.107 =	0.64 < 1.00 (Eq 7.53)

APPENDIX C – OPTIMALIZATION STUDY OF BOTTOM PLATE STIFFENERS SBJ-33-C5-OON-22-RE-017, rev. 0



			on DNV-RP-	C201			Project: Sensitivitetsstudie stiverkasse							
Version	n 2.2					1	tification: Bjørnafjorden fase 5				Date: 28.	06.2019		
Copyri	ght (C)) 2004-201	4 StruProg	AB			Time: 1							
File: c:	\progra	am files (x8	36)\struprog	2014\	stipla dnvrp	db\s	re.drps							
Safety	Forma	at/Material	:				General:							
Design	Condit	tion:	-		LRFD		Buckling length Lk		=	4000	mm			
Allowab	Allowable Usage Factor: UF = 1,00				Mom fact - Field km2	2	=	24,0						
Materia	terial Factor: gm = 1,10			- Support km1	1	=	12,0							
Plate/S	tiffener	r.	(Gener	al/General		Continuous stiffener							
Yield st	ress		fyp/fys	=	420/420	MP								
Youngs	modu	lus	E	=	2,10E+5	MP								
Geome	try:						Figure:							
Stiffene	r span		L	=	4000	mm	у							
Length	of gird	er	Lg	=	16500	mm	L Lx							
Plate th	hicknes	s	t	=	12,0	mm								
Stiffene	r spac	ing	s1	=	600	mm		_	2	→ ^c	-			
			s2		600	mm					· · · ·			
Lat tors	buckl	length	Lt	=	4000	mm	s1	PL1						
Stresse	es:							2		3	_			
SigxA	=	-210,0	MPa				s2				с. 			
SigxB	=	-210,0	MPa					PL2						
SigyA	=	0,0	MPa							- D	-			
SigyC	=	0,0	MPa				Sigx 11		-	_ 5				
Tau	=	72,0	MPa				<u> </u>	>= s		_				
Stiffen	er: T 2	200x150x1	0,0x20,0			Stiff H	<u>property:</u> Incl. et = 200 mm se		te:	415.3				
						В					mm			
		7				_								
1		se ↑ ^Z	4			tw tf	= 10,0 mm Ae = 20.0 mm Ie			9,784E+3 7,770E+7				



0x10,0x20,0	Stiffene	er proper	ty:		Incl. eff.	plate:		
	н	=	200	mm	se	=	415,3	mm
	в	=	150	mm	zp	=	77,8	mm
	tw	=	10,0	mm	Ae	=	9,784E+3	mm2
, t	tf	=	20,0	mm	le	=	7,770E+7	mm4
	A	=	4800	mm2	Wep	=	9,992E+5	mm3
zp	g	=	37,7	kg/m	Wes	=	6,059E+5	mm3
ć.	ez	=	152,5	mm	Flange:	c = 70,0	0 <= 209,4	OK (Eq 9.1)
t().	ly	=	1,621E+7	mm4	Web: hv	w = 180	0 <= 314,2	OK (Eq 9.2)
	Iz	=	5,625E+6	mm4				

STIFFENER BUCKLING CHECK (DNV-RP-C201): (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 415.3 mm Sigxsd = -210.0 MPa Sigysd = 0.0 MPa p0 = 0.000 MPa z* = 3.0 mm	
UF1s=Nsd/Nks1Rd+(M1Sd-NSd*z)/(Ms1Rd*(1-Nsd/Ne))+u = 2520,0/2706,7+(0.0-2520,0*0.003)/(231,3*(1-2520,0/10064,6))+0,107 =	0,99 < 1,00 (Eq 7.50)
UF1p=Nsd/Nkp1Rd-2*NSd/N1Rd+(M1Sd-Nsd*z*)/(Mp1Rd*(1-Nsd/Ne))+u =	
2520,0/2951,8-2*2520,0/3735,6+(0,0-2520,0*0,003)/(381,5*(1-2520,0/10064,6))+0,107 =	-0,42 < 1,00 (Eq 7.51)
UF2s=Nsd/Nks2Rd-2*NSd/NRd+(M2Sd+NSd*z)/(Mst2Rd*(1-Nsd/Ne))+u =	
2520,0/2706,7-2*2520,0/3735,6+(0,0+2520,0*0,003)/(231,3*(1-2520,0/10064,6))+0,107 =	-0,27 < 1,00 (Eq 7.52)
${\sf UF2p=Nsd/Nkp2Rd+(M2Sd+NSd^2z)/(Mp2Rd^{(1-Nsd/Ne))+u}=2520,0/2951,8+(0.0+2520,0^{\circ}0,003)/(381,5^{\circ}(1-2520,0/10064,6))+0,107=0}$	0,99 < 1.00 (Eq 7.53)



4.2 Bulbflats-profile

DNVRPS				F	ject: Sensitivitetsstudie stiverkasse	Page 1/1						
Plate/Stiff check based Version 2.2	on DNV-RF	P-C201		Ŀ	ntification: Bjørnafjorden fase 5 Date: 28.06	2010						
Copyright (C) 2004-201	4 StruProc	AB		!"	Time: 10:13							
File: c:\program files (x		·	stipla dnvrp	db\sti								
Safety Format/Materia	<u>l:</u>				General:							
Design Condition:			LRFD		Buckling length Lk = 4000 mm							
Allowable Usage Factor: UF = 1,00			1,00		Mom fact - Field km2 = 24,0							
Material Factor:	gm	=	1,10		- Support km1 = 12,0							
Plate/Stiffener:		Gener	al/General		Continuous stiffener							
Yield stress fyp/fys = 420/355 Mi			420/355	MPa								
oungs modulus	E	=	2,10E+5	MPa								
Geometry:					Figure:							
Stiffener span	L	=	4000	mm	y							
ength of girder	Lg	=	16500	mm	Ĺx.							
Plate thickness	t	=	12,0	mm								
Stiffener spacing	s1	=	600	mm								
	s2	=	600	mm								
Lat tors buckl length	Lt	=	4000	mm	s1 PL1							
-												
Stresses:	MDa											
-	MPa				s2 V PL2							
	MPa											
	MPa											
37	MPa				Sigx L Lt L							
rau = 72,0	MPa				L>=s							
Stiffener: BF 140x7,0					r property; Incl. eff. plate:							
				н	= 140 mm se = 415,3 mm							
Z _A Z _A				tw	= 7,0 mm zp = 17,8 mm							
. 1 . 1				с	= 19,0 mm Ae = 6,227E+3 mm2							
K se				r	= 5,5 mm le = 1,037E+7 mm4							
V = 2₽ _ ↑	*			В	= 23,5 mm Wep = 5,827E+5 mm3							
y <u>←</u> <u>−</u> tf					= 15,9 mm Wes = 8,086E+4 mm3							
					= 1243 mm2 Web: hw = 124,1 <= 239,2 OK (Eq 9.2)	6						
	ti			g	= 9,8 kg/m							
ken k	B. *			ez	= 83,1 mm							
K-4 K-	-			ly	= 2,404E+6 mm4							
				Iz	= 3,513E+4 mm4							

 STIFFENER BUCKLING CHECK (DNV-RP-C201); (1 = Support, 2 = field; s = stiffener, p = plate)

 se = 415,3 mm
 Sigxsd = -84.0 MPa
 Sigysd = 0.0 MPa
 p0 = 0.000 MPa
 z* = 3.0 mm

 UF1s=Nsd/Nks1Rd-2*NSd/N1Rd+(M1Sd+NSd*z)/(Mst1Rd*(1-Nsd/Ne))+u =
 540.4/751,0-2*640.4/2304,1+(0.0+540.4*0,003)/(28,1*(1-540.4/1342,0))+0.131 =
 0.49 < 1.00 (Eq 7.54)</td>

 UF1p=Nsd/Nkp1Rd+(M1Sd+NSd*z)/(Mp1Rd*(1-Nsd/Ne))+u = 540.4/885,5+(0.0+540.4*0,003)/(22,5*(1-540.4/1342,0))+0.131 =
 0.75 < 1.00 (Eq 7.55)</td>

 UF2p=Nsd/Nkp2Rd-2*NSd*Z/(Ms2Rd*(1-Nsd/Ne))+u = 540.4/751.0+(0.0-540.4*0,003)/(25,0*(1-540.4/1342,0))+0.131 =
 0.75 < 1.00 (Eq 7.56)</td>

 UF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =
 540.4/885,5-2*640.4/2304,1+(0.0-540.4*0,003)/(22,5*(1-540.4/1342,0))+0.131 =
 0.26 < 1.00 (Eq 7.57)</td>

DNV					P	Project: Sensitivitetsstudie stiverkasse							Page 1/1
Plate/Stiff ch Version 2.2	neck based	on DNV-RP-	C201			lentificati	on: Bjørnafjor	den fase	5			Date: 28	06 2019
Copyright (C) 2004-201	4 StruProg	AB		1.	Time: 10:							
File: c:\progr	ram files (x8	36)\struprog	2014\	stipla dnvrp	db\sti	vere.drps	;					1	
Safety Form	at/Material	•				G	eneral:						
Design Cond	lition:	-		LRFD		B	uckling length		Lk	=	4000	mm	
Allowable Us	age Factor:	UF	=	1,00		м	om fact - Field	1	km2	=	24,0		
Material Fact	or:	gm	=	1,10			- Supp	port	km1	=	12,0		
Plate/Stiffene	er:	-	Gener	al/General		c	ontinuous stiff	ener			-		
rield stress		fyp/fys	=	420/355	MPa								
Youngs modu	ulus	E	=	2,10E+5	MPa								
Geometry:						E	qure:						
Stiffener spar	n	L	=	4000	mm		У						
Length of gire	der	Lg	=	16500	mm		Ĺыx						
Plate thickne	\$\$	t	=	12,0	mm								
Stiffener spacing s1 = 600 m				mm		\rightarrow	* A			-c	Ь		
		s2	=	600	mm		H	1 1	1.6593	122			
Lat tors buck	l length	Lt	=	4000	mm		II s	1	PL	.1			
Channel							H	1	2	2	3		
<u>Stresses:</u> SigxA =	-123.0	MDs						1 I		1			
	-123,0						- s	2 1	PL	2	1		
SigxB = SigyA =		MPa							PL	2			
		MPa					\rightarrow	≁B€	-		➡ D		
SigyC = Tau =		MPa					Sigx	l	Lt L				
rau =	72,0	MPa						F	L>	= \$			
Stiffener: Bi	F 160x9.0				Stiffer	ner prope	rtv:		Incl. eff.	plate:			
			-		н	=		mm	se	=	415.3	3 mm	
					tw	=	9.0	mm	zp	=	26.2	2 mm	
ZA	ZA.				c	-	22,0		Ae	=	6,764E+3		
K SS → J B Y ← ZD ↑ → H W H W A			r	=	6.0	mm	le	=	1,755E+7	7 mm4			
			в	=	28,3		Wep	=	6,694E+5	5 mm3			
			tf	=	17,6		Wes	=	1.255E+5	5 mm3			
			A	=		mm2		= 142.4	4 <= 307.5		.2)		
1		tfi			g	=		kg/m					
		• ±			ez	-	93.6	-					
1	KCH KB	H T			ly	=	4.475E+6						
					Iz	-	6.670E+4						

lz = 6,670E+4 mm4	
STIFFENER BUCKLING CHECK (DNV-RP-C201): (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 415,3 mm Sigxsd = -123,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 3,0 mm	
UF1s=Nsd/Nks1Rd-2*NSd/N1Rd+(M1Sd+NSd*z)/(Mst1Rd*(1-Nsd/Ne))+u =	
1104,5/1085,0-2*1104,5/2477,4+(0,0+1104,5*0,003)/(40,5*(1-1104,5/2272,8))+0,107 =	0,39 < 1,00 (Eq 7.54)
UF1p=Nsd/Nkp1Rd+(M1Sd+NSd*z)/(Mp1Rd*(1-Nsd/Ne))+u = 1104.5/1294.8+(0.0+1104.5*0.003)/(255.8*(1-1104.5/2272.8))+0.107 =	0,99 < 1,00 (Eq 7.55)
UF2s=Nsd/Nks2Rd+(M2Sd-NSd*z)/(Ms2Rd*(1-Nsd/Ne))+u = 1104.5/1085.0+(0.0-1104.5*0.003)/(39.5*(1-1104.5/2272.8))+0.107 =	0,96 < 1.00 (Eq 7.56)
UF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =	
1104,5/1294,6-2*1104,5/2477,4+(0,0-1104,5*0,003)/(255,6*(1-1104,5/2272,8))+0,107 =	0,04 < 1.00 (Eq 7.57)



							Project: Sensitivitetsstudie stiverkasse					
Plate/Stiff check based on DNV-RP-C201 Version 2.2 Copyright (C) 2004-2014 StruProg AB						ŀ	ification: Bjørnafjorden fase 5 Date: 28.06	2019				
							Time: 10:9	2010				
File: c:\program files (x86)\struprog 2014\stipla dnvrp db							e.drps					
Safety	Forma	at/Material.	:				General:					
Design			•		LRFD		Buckling length Lk = 4000 mm					
		ge Factor:	UF	=	1.00		Mom fact - Field km2 = 24,0					
Materia	I Facto	Dr:	gm	=	1,10		- Support km1 = 12.0					
Plate/S	tiffener		2	Gener	al/General		Continuous stiffener					
Yield st	ress		fyp/fys	=	420/355	MPa						
Youngs	modu	lus	E	=	2,10E+5	MPa						
Geome	try:					_	Figure:					
Stiffene	r span		L	=	4000	mm	у					
Length	of gird	er	Lg	=	16500	mm	Ĺ,x					
Plate th	icknes	s	t	=	12,0	mm						
Stiffene	r spac	ing	s1	=	600	mm						
			s2	=	600	mm						
Lat tors	buckl	length	Lt	=	4000	mm	s1 PL1					
Stress							1 2 3					
SigxA	=	-213.0	MPa									
SigxB	=	-213.0					s2 N PL2					
SigyA	=		MPa									
SigyC	=	0.0	MPa									
Tau	=	72,0	MPa				Sigx					
Ctille	ari Pr	200-44.0				C1.4	l and off sister					
sunen	ar or	300x11,0				H	<u>property:</u> <u>Incl. eff. plate:</u> = 300 mm se = 415.3 mm					
						tw	= 11.0 mm zp = 94.3 mm					
	ZA.	Z.A				C	= 43.0 mm Ae = 9.662E+3 mm2					
125	T	Ĩ				0	- 45,0 mm AC = 9,002E+5 mm2					



STIFFENER BUCKLING CHECK (DNV-RP-C201); (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 415,3 mm Sigxsd = -213,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 7,0 mm	
UF1s=Nsd/Nks1Rd+(M1Sd-NSd*z)/(Ms1Rd*(1-Nsd/Ne))+u = 2530,0/2611,1+(0,0-2530,0*0,007)/(201,7*(1-2530,0/17262,3))+0,107 =	0,97 < 1,00 (Eq 7.50)
UF1p=Nsd/Nkp1Rd-2*NSd/N1Rd+(M1Sd-Nsd*z*)/(Mp1Rd*(1-Nsd/Ne))+u =	
2530,0/3011,4-2*2530,0/3412,8+(0,0-2530,0*0,007)/(539,7*(1-2530,0/17262,3))+0,107 =	-0,57 < 1.00 (Eq 7.51)
UF2s=Nsd/Nks2Rd-2*NSd/NRd+(M2Sd+NSd*z)/(Mst2Rd*(1-Nsd/Ne))+u =	
2530,0/2611,1-2*2530,0/3412,6+(0,0+2530,0*0,007)/(203,1*(1-2530,0/17262,3))+0,107 =	-0,30 < 1,00 (Eq 7.52)
UF2p=Nsd/Nkp2Rd+(M2Sd+NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u = 2530.0/3011,4+(0.0+2530.0*0.007)/(539,7*(1-2530,0/17262,3))+0,107 =	0,99 < 1.00 (Eq 7.53)

1.0



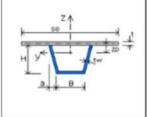
4.3 Trapezoidal profilE

DNVRPS		0204		P	ject: Sensitivitetsstudie stiverkasse	Page: 1/1
Plate/Stiff check based on DNV-RP-C201 Version 2.2 Copyright (C) 2004-2014 StruProg AB					ntification: Bjørnafjorden fase 5 Date: 28.06	2019
					Time: 10:16	
File: c:\program files (x86	i)\struprog	2014\	stipla dnvrp	lb\sti		
Safety Format/Material:					General:	
Design Condition: LRFD					Buckling length Lk = 4000 mm	
lowable Usage Factor:	UF	=	1,00		Mom fact - Field km2 = 24,0	
Material Factor:	gm	=	1,10		- Support km1 = 12,0	
Plate/Stiffener:	-	Gener	al/General		Continuous stiffener	
rield stress	fyp/fys	=	420/420	ИРа		
roungs modulus	E	=	2,10E+5	ИРа		
Geometry:					Figure:	
Stiffener span	L	=	4000	mm	У	
Length of girder	Lg	=	16500	nm	Ĺ,x	
Plate thickness	t	=	12,0	mm		
Stiffener spacing	s1	=	600	mm		
	s2	=	600	mm		
at tors buckl length.	Lt	=	4000	nm	s1 PL1	
Stresses:						
SigxA = -63,0 I	MPa					
SigxB = -63,0 1	MPa				s2 PL2	
SigyA = 0.0 1	MPa					
SigyC = 0.0 1	MPa					
Tau = 72,0 I					Sigx Lt	
					L>=s	
Stiffener: Trapez 115x50	/25x5,0			Stiffer	r property: Incl. eff. plate:	
			1	H	= 115 mm se = 496,2 mm	
			1	3	= 50 mm zp = 13,4 mm	
				3	= 25 mm Ae = 7,330E+3 mm2	
ZΛ			1	w	= 5,0 mm le = 7,588E+6 mm4	
k se				4	= 1376 mm2 Wep = 5,659E+5 mm3	
Concession of the local division of the loca	***			3	= 10,8 kg/m Wes = 7,053E+4 mm3	
	<u></u>			z	= 65,4 mm Web: hw = 110,0 <= 157,1 OK (Eq 9.2)	
				y	= 1,812E+6 mm4	
a B .						
-+*						
		_				
STIFFENER BUCKLING CHI	ECK (DNV-	RP-C20	1): (1 = Suppo	ort, 2 =	ield; s = stiffener, p = plate)	
e = 496,2 mm Sigxsd = -63	3,0 MPa S	igysd =	0.0 MPa p0	= 0,0	0 MPa z* = 2,0 mm	
JF1s=Nsd/Nks1Rd-2*NSd/N1	IRd+(M1Sd	+NSd*z	WinstiRd*(1-	Nsd/N	\\+n =	

or is-isolitics incontrol control control control (institute (institute))+e -	
540,3/840,8-2*540,3/2798,8+(0,0+540,3*0,002)/(26,9*(1-540,3/983,0))+0,217 =	0,76 < 1.00 (Eq 7.54)
UF1p=Nsd/Nkp1Rd+(M1Sd+NSd*z)/(Mp1Rd*(1-Nsd/Ne))+u = 540,3/714,2+(0,0+540,3*0,002)/(216,1*(1-540,3/983,0))+0,217 =	0,98 < 1,00 (Eq 7.55)
UF2s=Nsd/Nks2Rd+(M2Sd-NSd*z)/(Ms2Rd*(1-Nsd/Ne))+u = 540,3/640,8+(0.0-540,3*0,002)/(26,9*(1-540,3/983,0))+0,217 =	0,97 < 1,00 (Eq 7.56)
UF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =	
540,3/714,2-2*540,3/2798,6+(0,0-540,3*0,002)/(216,1*(1-540,3/983,0))+0,217 =	0,58 < 1.00 (Eq 7.57)



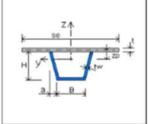
RPS					Project: Sensitivitetsstudie stiverkasse					
eck based	on DNV-RP-	C201		ŀ	fication: Bigmafjorden fase 5	6 2019				
) 2004-201	4 StruProg	AB								
ram files (x8	6)\struprog	2014\	stipla dnvrp	db\s	drps					
at/Material:	:				General:					
			LRFD		Buckling length Lk = 4000 mm					
	UF	=	1,00		Mom fact - Field $km^2 = 24.0$					
	gm	=	1,10		- Support km1 = 12,0					
er:	2	Gener	al/General		Continuous stiffener					
	fyp/fys	=	420/420	MPa						
ulus	E	=	2,10E+5	MPa						
					Figure:					
n	L	=	4000	mm	у					
der	Lg	=	16500	mm	Ĺ_x					
SS	t	=	12,0	mm	·					
cing	s1	=	600	mm						
	s2	=	600	mm						
l length	Lt	=	4000	mm	S1 PL1					
-123.0	MPa									
					s2 PL2					
0.0	MPa									
0.0	MPa									
72,0	MPa				Sigx					
					A					
apez 150x6	0/30x5,0									
				-						
				a	= 30 mm Ae = 7.915E+3 mm2					
	eck based 2) 2004-201- ram files (x8 at/Material/ ition: age Factor: or: er: ulus h der ss cing l length -123,0 0,0 0,0 72,0	eck based on DNV-RP- 2) 2004-2014 StruProg / ram files (x86)(struprog / at/Material: ition: age Factor: UF or: gm rr: UF fyp/fys ulus E n L der Lg ss t cing s1 s2	beeck based on DNV-RP-C201 c) 2004-2014 StruProg AB ram files (x86)\struprog 2014\v at/Material: ition: age Factor: UF or: gm gm = ftp:/fys = n L der Lg ss t cing s1 s2 = il length Lt -123,0 MPa 0,0 MPa 0,0 MPa 72,0 MPa	and the set of the set o	Interview of the section of the secti	Identification: Bjørnafjorden fase 5Date: 28 (f)identification: Bjørnafjorden fase 5Date: 28 (f)Time: 10:at/Material:Buckling lengthLkLkat/Material:General:Buckling lengthLkat REFDage Factor: UF = 1,00or: general/Generalfyprifys = 420/420 MPaJuss E = 2,10E+5 MPaFigure:YOntinuous stiffenerSupport km1 = 12,0continuous stiffenerYSigxIdentification: Bjørnafjorden fase 5Date: 28 (f)Continuous stiffenerSupport km1 = 12,0Continuous stiffenerYIdentification: Bjørnafjorden fase 5Date: 28 (f)On mmSigxIdentification: Bjørnafjorden fase 5Date: 28 (f)				



0x5,0	Stiffene	er proper	ty:		Incl. eff.	plate:		
	н	=	150	mm	se	=	511,4	mm
	в	=	60	mm	zp	=	20,5	mm
	а	=	30	mm	Ae	=	7,915E+3	mm2
	tw	=	5,0	mm	le	=	1,553E+7	mm4
-> ,t	A	=	1779	mm2	Wep	=	7,579E+5	mm3
罰業	g	=	14,0	kg/m	Wes	=	1,146E+5	mm3
-	ez	=	85,1	mm	Web: hv	v = 145,0	<= 157,1	OK (Eq 9.2)
	ly	=	3,994E+6	mm4				

STIFFENER BUCKLING CHECK (DNV-RP-C201): (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 511,4 mm Sigxsd = -123,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 2,0 mm	
UF1s=Nsd/Nks1Rd-2*NSd/N1Rd+(M1Sd+NSd*z)/(Mst1Rd*(1-Nsd/Ne))+u =	
1104,4/1132,5-2*1104,4/3022,2+(0,0+1104,4*0,002)/(43,7*(1-1104,4/2011,1))+0,107 =	0,46 < 1,00 (Eq 7.54)
$UF1p = Nsd/Nkp1Rd + (M1Sd + NSd^2z)/(Mp1Rd^{(1-Nsd/Ne)}) + u = 1104.4/1279.1 + (0.0 + 1104.4^{\circ}0.002)/(289.4^{(1-1104.4/2011.1)}) + 0.107 = 0.00200000000000000000000000000000000$	0,99 < 1.00 (Eq 7.55)
UF2s=Nsd/Nks2Rd+(M2Sd-NSd*z)/(Ms2Rd*(1-Nsd/Ne))+u = 1104.4/1132.5+(0.0-1104.4*0.002)/(43.7*(1-1104.4/2011.1))+0.107 =	0,97 < 1,00 (Eq 7.56)
UF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =	
1104,4/1279,1-2*1104,4/3022,2+(0,0-1104,4*0,002)/(289,4*(1-1104,4/2011,1))+0,107 =	0.22 < 1.00 (Eq 7.57)

DNVRPS							Project: Sensitivitetsstudie stiverkasse						
Plate/Stiff check based on DNV-RP-C201 Version 2.2 Copyright (C) 2004-2014 StruProg AB							Identification: Bjørnafjorden fase 5 Date: 28 Time: 10						
File: c:	\progra	am files (x8	6)\struprog	2014\	stipla dnvrp	db\s	vere.drps						
Safety	Forma	at/Material	:				General:						
Design	Condit	tion:			LRFD		Buckling length Lk = 4000 mm						
Allowat	ole Usa	ge Factor:	UF	=	1,00		Mom fact - Field km2 = 24,0						
Materia	I Facto	DIT:	gm	=	1,10		- Support km1 = 12,0						
Plate/S	tiffener	r.		Gener	ral/General		Continuous stiffener						
Yield st	ress		fyp/fys	=	420/420	MPa							
Youngs	modu	lus	E	=	2,10E+5	MPa							
Geome	etry:						Figure:						
Stiffene	er span	1	L	=	4000	mm	y						
Length	of gird	er	Lg	=	16500		Ĺ,x						
Plate th	nicknes	s	t	=	12,0	mm	· ·						
Stiffene	er spac	ing	s1	=	600	mm							
			s2	=	= 600 m								
Lat tors	buckl	length	Lt	=	4000	mm	s1 PL1						
Stress	es:												
SigxA	=	-218,0	MPa										
SigxB	=	-218,0	MPa				s2 PL2						
SigyA	=	0,0	MPa										
SigyC	=	0,0	MPa				Sigx L II						
Tau	=	72,0	MPa				Sigx Lt L L>= s						
Stiffon	or: Tra	apez 200x1	00/50v8 0			Stiff	er property; Incl. eff. plate;						
ounen						H	= 200 mm se = 567.4 mm						
						в	= 100 mm zp = 45,0 mm						
						a	= 50 mm Ae = 1.078E+4 mm2						
		ZΛ											



St	iffener proper	ty:		Incl. eff. plate:				
н	=	200	mm	se	=	567,4	mm	
в	-	100	mm	zp	=	45,0	mm	
a	-	50	mm	Ae	=	1,078E+4	mm2	
tw	=	8,0	mm	le	=	5,361E+7	mm4	
A	=	3967	mm2	Wep	=	1,192E+6	mm3	
g	-	31,1	kg/m	Wes	=	3,329E+5	mm3	
ez	=	116,2	mm	Web: hw =	192,0	<= 251,3	OK (Eq 9.2)	
ly	=	1,612E+7	mm4					

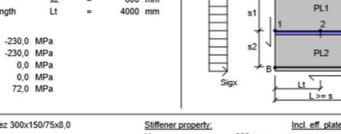
STIFFENER BUCKLING CHECK (DNV-RP-C201); (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 567,4 mm Sigxsd = -218,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 2,0 mm	
UF1s=Nsd/Nks1Rd-2*NSd/N1Rd+(M1Sd+NSd*z)/(Mst1Rd*(1-Nsd/Ne))+u =	
2434,3/2857,8-2*2434,3/4114,4+(0,0+2434,3*0,002)/(127,1*(1-2434,3/8944,5))+0,107 =	-0,10 < 1,00 (Eq 7.54)
$UF1p = Nsd/Nkp1Rd + (M1Sd + NSd^2z)/(Mp1Rd^(1-Nsd/Ne)) + u = 2434.3/2867, 1 + (0,0 + 2434, 3^{\circ}0,002)/(455, 2^{\circ}(1-2434, 3/6944, 5)) + 0,107 = 0.000000000000000000000000000000000$	0,97 < 1,00 (Eq 7.55)
UF2s=Nsd/Nks2Rd+(M2Sd-NSd*z)/(Ms2Rd*(1-Nsd/Ne))+u = 2434,3/2657,6+(0.0-2434,3*0,002)/(127,1*(1-2434,3/6944,5))+0.107 =	0,96 < 1.00 (Eq 7.56)
UF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =	
2434.3/2887,1-2*2434.3/4114,4+(0.0-2434,3*0.002)/(455,2*(1-2434,3/6944,5))+0,107 =	-0.24 < 1.00 (Eq 7.57)

4.4 Plate thickness

DNVRPS Plate/Stiff check based on DNV-RP-C201							Project: Sensitivitetsstudie stiverkasse					
Version 2.2 Copyright (C) 2004-2014 StruProg AB						- t	ification: Bjørnafjorden fase 5 Date: 28.06	2019				
						- 1	Time: 10:17	7				
File: c:	\progra	am files (x8	6)\struprog	2014\	stipla dnvrp	db\s	e.drps					
Safety	Forma	t/Material	-				General:					
Design	Condit	tion:			LRFD		Buckling length Lk = 4000 mm					
Allowab	le Usa	ge Factor:	UF	=	1,00		Mom fact - Field km2 = 24,0					
Materia	I Facto	n:	gm	=	1,10		- Support km1 = 12,0					
Plate/S	tiffener			Gener	al/General		Continuous stiffener					
Yield st	ress		fyp/fys	=	420/420	MPa						
Youngs	modul	lus	E	=	2,10E+5	MPa						
Geome	try:						Figure:					
Stiffene	r span		L	=	4000	mm	у					
Length	of gird	er	Lg	=	16500	mm	L Lx					
Plate th	icknes	s	t	=	8,0	mm						
Stiffene	r spac	ing	s1	=	600	mm						
			s2	=	600	mm						
Lat tors	buckl	length	Lt	=	4000	mm	s1 PL1					
Stresse	es:											
SigxA	=	-230,0	MPa									
SigxB	=	-230,0	MPa				s2 PL2					
SigyA	=	0,0	MPa									
SigyC	=	0,0	MPa									
Tau	=	72.0	MPa				Sigx Lt					

511,2 mm
407.4
107,1 mm
1,011E+4 mm2
1,347E+8 mm4
1,257E+6 mm3
6,840E+5 mm3
= 251,3 NOK (Eq 9.2)
= 2

STIFFENER BUCKLING CHECK (DNV-RP-C201): (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 511,2 mm Sigxsd = -230,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 1,0 mm	
JF1s=Nsd/Nks1Rd-2*NSd/N1Rd+(M1Sd+NSd*2)/(Mst1Rd*(1-Nsd/Ne))+u =	
2487.6/3280.5-2*2487.6/3858.4+(0.0+2487.6*0.001)/(261.2*(1-2487.6/17444.9))+0.107 =	-0,41 < 1,00 (Eq 7.54)
JF1p=Nsd/Nkp1Rd+(M1Sd+NSd*z)/(Mp1Rd*(1-Nsd/Ne))+u = 2487.6/3343.7+(0.0+2487.6^0.001)/(480.1*(1-2487.6/17444.9))+0.107 =	0,86 < 1,00 (Eq 7.55)
JF2s=Nsd/Nks2Rd+(M2Sd-NSd*z)/(Ms2Rd*(1-Nsd/Ne))+u = 2487.6/3280.5+(0.0-2487.6^0.001)/(261,2^(1-2487.6/17444,9))+0.107 =	0,85 < 1,00 (Eq 7.56)
JF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =	
2487.8/3343,7-2*2487.8/3858.4+(0.0-2487.6*0.001)/(480.1*(1-2487.8/17444.9))+0.107 =	-0,44 < 1.00 (Eq 7.57)



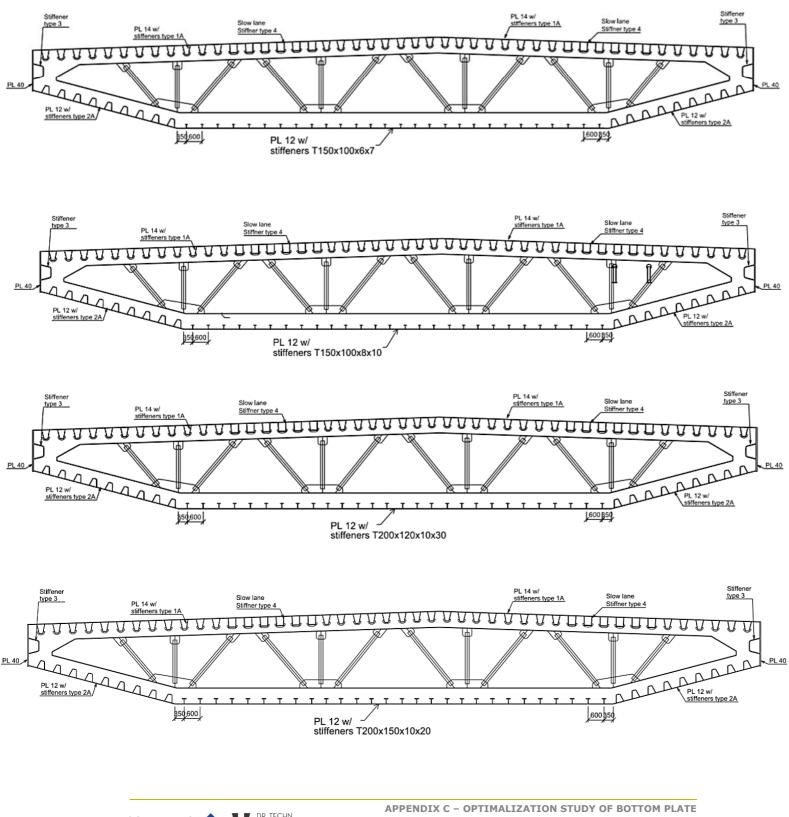
Plate/Stiff check based on DNV-RP-C201						F	Project: Sensitivitetsstudie stiverkasse			
							entification: Bjørnafjorden fase 5 Date: 28.06.	1/1		
						"	Time: 10:31	2013		
File: c:\	progra	am files (x8	6)\struprog	2014	stipla dnvrp	db\st				
Safety Format/Material:							General:			
Design Condition:					LRFD		Buckling length Lk = 4000 mm			
Allowable Usage Factor: UF			=	= 1,00		Mom fact - Field km2 = 24,0				
Material Factor: gm			gm	=	1,10		- Support km1 = 12,0			
Plate/Sti	tiffener		(Gene	ral/General		Continuous stiffener			
Yield str	ress		fyp/fys	=	420/420	MPa				
Youngs modulus E			E	=	= 2,10E+5 M					
Geomet	try:						Figure:			
Stiffener	r span		L	=	4000	mm	у			
Length o	of gird	er	Lg	=	16500	mm	Ĺ→x			
Plate thickness t			=	8,0	mm					
Stiffener spacing s1		s1	=	600	mm					
			s2	=	600	mm				
Lat tors buckl length Lt		=	4000	mm	s1 PL1					
<u>Stresse</u> SigxA	=	-135.0	MDa							
SigxA		-135,0					s2 V PL2			
Sigxa	=		MPa							
SigyA	=		MPa							
Tau	-		MPa				Sigx Lt L			
lau	-	12,0	mPa				L>=s			
Stiffene	er: Tra	pez 175x5	0/25x8.0			Stiffe	er property; Incl. eff. plate;			
			0100 AND 1250	-		н	= 175 mm se = 389,7 mm			
						в	= 50 mm zp = 49,3 mm			
						а	= 25 mm Ae = 6,216E+3 mm2			
		ZA				tw	= 8,0 mm le = 2,413E+7 mm4			
k-	5	e	, k			A	= 3099 mm2 Wep = 4,899E+5 mm3			
-						g	= 24,3 kg/m Wes = 1,860E+5 mm3			
н	y*		tw			ez	= 94.8 mm Web: hw = 167,0 <= 251,3 OK (Eq 9.2)			
	1		4			ly	= 8.942E+6 mm4			

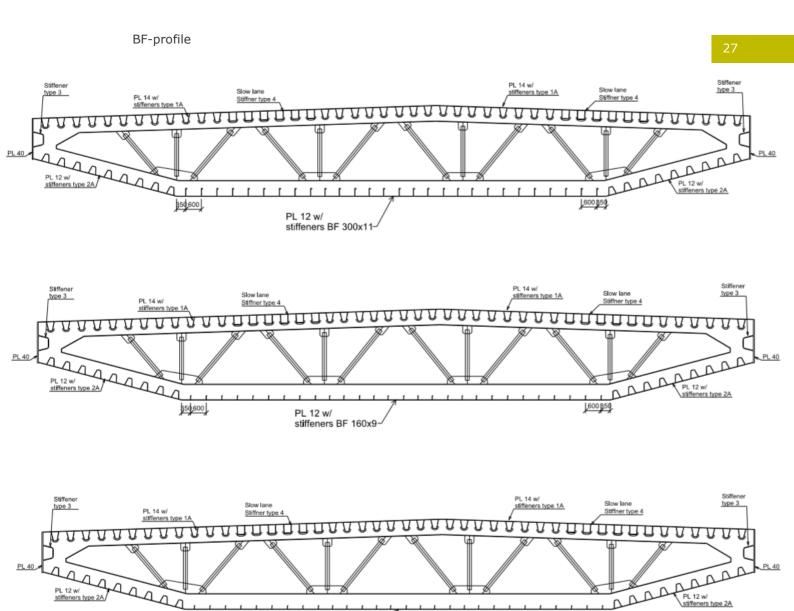
STIFFENER BUCKLING CHECK (DNV-RP-C201); (1 = Support, 2 = field; s = stiffener, p = plate)	
se = 389,7 mm Sigxsd = -135,0 MPa Sigysd = 0,0 MPa p0 = 0,000 MPa z* = 2,0 mm	
UF1s=Nsd/Nks1Rd-2*NSd/N1Rd+(M1Sd+NSd*z)/(Mst1Rd*(1-Nsd/Ne))+u =	
1066.4/1389.8-2*1066.4/2373.5+(0.0+1066.4*0.002)/(71.0*(1-1066.4/3125.4))+0.107 =	0,02 < 1,00 (Eq 7.54)
UF1p=Nsd/Nkp1Rd+(M1Sd+NSd*z)'(Mp1Rd*(1-Nsd/Ne))+u = 1068.4/1481.8+(0.0+1068.4*0.002)'(187.0*(1-1068.4/3125.4))+0.107 =	0,84 < 1.00 (Eq 7.55)
UF2s=Nsd/Nks2Rd+(M2Sd-NSd*z)/(Ms2Rd*(1-Nsd/Ne))+u = 1068,4/1389,6+(0,0-1068,4*0,002)/(71,0*(1-1068,4/3125,4))+0,107 =	0,83 < 1,00 (Eq 7.56)
UF2p=Nsd/Nkp2Rd-2*NSd/NRd+(M2Sd-NSd*z)/(Mp2Rd*(1-Nsd/Ne))+u =	
1068,4/1481,8-2*1068,4/2373,5+(0,0-1068,4*0,002)/(187,0*(1-1068,4/3125,4))+0,107 =	-0,09 < 1,00 (Eq 7.57)



²⁶ 5 CROSS-SECTION DRAWINGS

T-profile



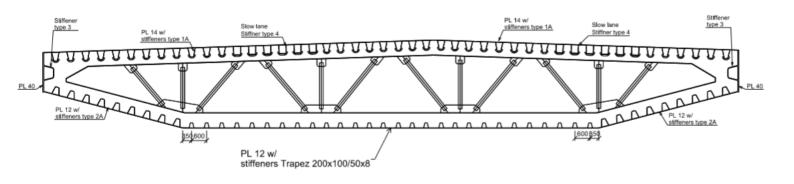


Trapezoidal profile

350,600

PL 12 w/ stiffeners BF 140x7





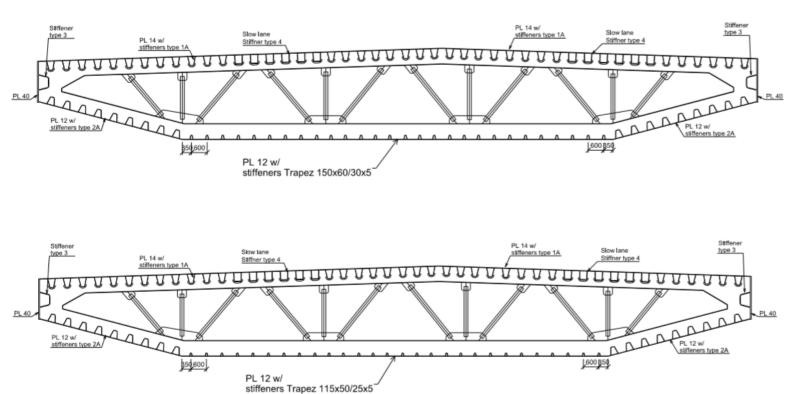
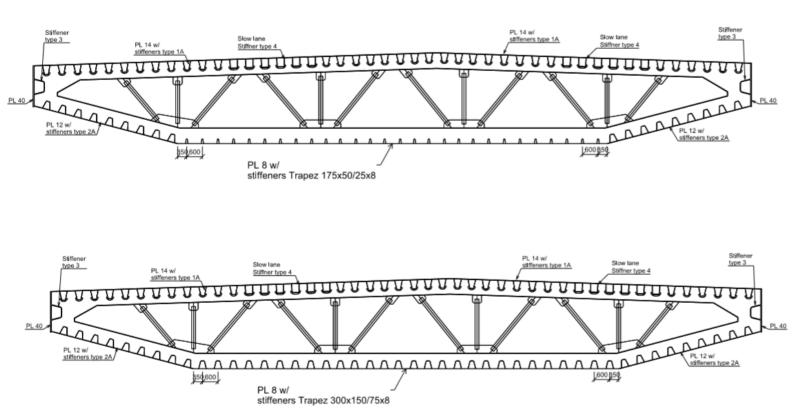
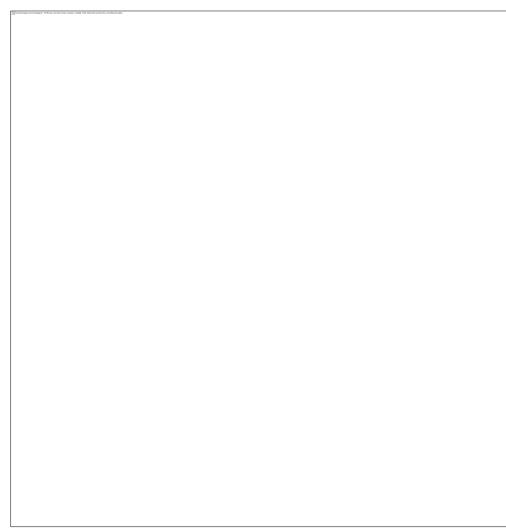


Plate thickness



6 LONG HAND CALCULATIONS

6.1 Bending moment and change in axial stess



6.2 Shear stress

Norconsult 💸 📕 OLAV OLSEN

3:

6.3 Reduction in bending moment



7 REFERENCES

- [1] Håndbok N400 , «Bruprosjektering,» Statens vegvesen Vegdirektoratet, 2015.
- [2] SBJ-32-C4-SVV-90-BA-001, «Design Basis Bjørnafjorden floating bridges,» Statens Vegvesen, 2018.
- [3] NS-EN 1993-1-1:2005+A1:2014+NA:2015, «Eurocode 3: Design of steel structures -Part 1-1: General rules and rules for buildings,» Standard Norge, 2005.

