Stretto di Messina

Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia
e il Continente Organismo di Diritto Pubblico
(Legge n° 1158 del 17 dicembre 1971, modificata dal D.Lgs. n°114 del 24 aprile 2003)

EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.

IMPREGILO S.p.A. (MANDATARIA)
SOCIETÀ ITALIANA PER CONDOTTE D’ACQUA S.p.A. (MANDANTE)
COOPERATIVA MURATORI E CEMENTISTI - C.M.C. DI RAVENNA SOC. COOP. A.R.L. (MANDANTE)
SACYR S.A.U. (MANDANTE)
ISHIKAWAJIMA - HARIMA HEAVY INDUSTRIES CO. LTD (MANDANTE)
A.C.I. S.C.P.A. - CONSORZIO STABILE (MANDANTE)

IL PROGETTISTA	IL CONTRAENTE GENERALE	STRETTO DI MESSINA	STRETTO DI MESSINA
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Unità Funzionale	OPERA D’ATTRAVERSAMENTO	PS0017_F0
Tipo di sistema	SOVRASTRUTTURE	
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INDICE

1 Introduction

This report presents design calculations for the tower base anchorage.

The design is based on that shown in the Tender Design.

In this project phase it was found advantageous to introduce the following changes to the tender design:

- Multi-strand post-tensioning tendons replace the anchor bolts in the tower base anchorage to simplify and reduce the reinforcing in the tower foundation.

Calculations are typically based on the global IBDAS model version 3.3f.

1.1 Outline

This report is organized into the following sections:

- Section 1 includes this introduction and outline;
- Section 2 provides a list of reference materials, including design specifications, design codes, reference drawings and complementary reports;
- Section 3 provides details of the materials used in the tower design;
- Section 4 provides a reference to the reports describing the design principles used in the tower design;
- Section 5 provides design calculations for the three tower base anchorage components: anchorage tendons, tower leg stiffening and base plate. To allow for easy cross referencing between tower design reports, the calculations are presented in the same order as the components are described in CG.10.00-P-RX-D-P-SV-T4-00-00-00-00-01 “Specialist Technical Design Report, Towers;”

2 Design References

2.1 Design Specifications

CG.10.00-P-RG-D-P-GE-00-00-00-00-00-02 - “Design Basis, Structural, Annex,” COWI 2010

GCG.F.05.03 “Design Development – Requirements and Guidelines,” Stretto di Messina, 2004 October 22.

GCG.G.03.02 “Structural Steel Works and Protective Coatings,” Stretto di Messina, 2004 July 30.

2.2 Design Codes

“Norme tecniche per le costruzioni,” 2008 (NTC08).

EN 1991 Eurocode 1: Actions on Structures – Part 2: Traffic loads on bridges

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-1: General rules and rules for buildings

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-5: Plated structural elements

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-8: Design of joints

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-9: Fatigue

EN 1993 Eurocode 3: Design of Steel Structures – Part 2: Steel Bridges

Rete Ferroviaria Italia - Istruzione No. 44F “Verifiche a fatica dei ponti ferroviari”

2.3 Drawings

The reference tower design drawings for this report are listed in Table 2-1.

Drawing Title	Drawing Number
Tower Sicilia - General Arrangement	CG.10.00-P-AX-D-P-SV-T4-TS-00-00-00-01_0
Typical - Leg - Cross Section & Vertical Joints	CG.10.00-P-WX-D-P-SV-T4-TO-00-00-00-01_0
Tower Sicilia - Leg - Sections & Plate Thicknesses	CG.10.00-P-WX-D-P-SV-T4-TS-00-00-00-01_0
Typical - Leg - Cross Diaphragms	CG.10.00-P-AX-D-P-SV-T4-TO-00-D0-00-01_0
Typical - Leg - Cross Diaphragms, Details	CG.10.00-P-BX-D-P-SV-T4-TO-00-D0-00-01_0
Typical - Leg - Horizontal Joints	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-01_0
Typical - Leg - Horizontal Joints, Details	CG.10.00-P-BX-D-P-SV-T4-TO-00-00-00-01_0
Typical - Cross Beam no. 1	CG.10.00-P-AX-D-P-SV-T4-TO-T0-00-00-01_0
Typical - Cross Beam no. 2	CG.10.00-P-AX-D-P-SV-T4-TO-T0-00-00-02_0

Typical - Cross Beam no. 3	CG.10.00-P-AX-D-P-SV-T4-TO-T0-00-00-03_0
Typical - Cross Beams - Details	CG.10.00-P-BX-D-P-SV-T4-TO-T0-00-00-01_0
Typical - Cross Beam Connection to Tower leg	CG.10.00-P-WX-D-P-SV-T4-TO-T0-00-00-02_0
Typical - Connection from Girder	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-03_0
Typical - Base Section 1	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-04_0
Typical - Base Section 2	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-05_0
Typical - Base Section, Details	CG.10.00-P-BX-D-P-SV-T4-TO-00-00-00-02_0
Typical - Top Section	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-06_0
Typical - Tuned Mass Dampers - Support Structure	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-07_0
Typical - Tuned Mass Dampers	CG.10.00-P-AX-D-P-SV-T4-TO-00-00-00-08_0
Typical - Leg - Steelwork Modifications 1	CG.10.00-P-BX-D-P-SV-T4-TO-00-00-00-04_0
Typical - Leg - Steelwork Modifications 2	CG.10.00-P-BX-D-P-SV-T4-TO-00-00-00-05_0
Typical - Cross Beams - Steelwork Modifications	CG.10.00-P-BX-D-P-SV-T4-TO-T0-00-00-06_0
Tower Calabria - General Arrangement	CG.10.00-P-AX-D-P-SV-T4-TC-00-00-00-01_0
Tower Calabria - Leg - Sections & Plate Thicknesses	CG.10.00-P-WX-D-P-SV-T4-TC-00-00-00-01_0

Table 2-1: Reference tower drawings.

2.4 Complementary Reports

The tower design reports listed in Table 2-2 provide supplementary information about the tower design principles and verifications.

Report Title	Report Number
Specialist Technical Design Report, Towers	CG.10.00-P-RX-D-P-SV-T4-00-00-00-00-01
General Design Principles	CG.10.00-P-RG-D-P-SV-T4-00-00-00-00-01
Design Report - Tower Legs	CG.10.00-P-CL-D-P-SV-T4-00-00-00-00-01
Design Report - Cross Beams	CG.10.00-P-CL-D-P-SV-T4-00-00-00-00-02

Table 2-2: Reference tower design reports.

3 Materials

The mechanical properties of the tower construction materials are described in this section.

3.1 Structural Steel

Tower structural components are generally fabricated from Grade S460 ML structural steel with the exception of: the hot-rolled circular hollow sections comprising the cross beam internal bracing members, the tower base plate and the base anchorage stiffening plates, which are fabricated from Grade S355 ML structural steel. All structural steels shall be produced in accordance with EN 10025-4. The steels are assumed to have the mechanical properties listed in Table 3-1, in accordance with NTC08 Section 11.3.4.1. As an exception to the standard requirements of NTC08 and EN 10025-4 the mechanical properties of the steel shall not vary with material thickness for thicknesses up to 110 mm for S460ML steel and up to 150 mm for S355ML steel. The feasibility of the production of steel with the required properties has been confirmed.

Grade	Yield Strength, f_{yk} (MPa)	Tensile Strength, f_{tk} (MPa)
S 355 ML	355	470
S 460 ML	460	540

Table 3-1: Structural steel mechanical properties for thicknesses up to 110 mm for S460ML steel and up to 150 mm for S355ML steel.

All structural steel is also assumed to have the following properties, in accordance with NTC08 Section 11.3.4.1:

- Elastic modulus: $E = 210{,}000$ MPa
- Poisson's ratio: $\nu = 0.3$
- Shear modulus: $G = 80{,}770$ MPa
- Coefficient of thermal expansion: $\alpha = 12 \times 10^{-6} / °C$
- Density: $\rho = 7{,}850$ kg/m^3

The material partial factors (safety coefficients) used to verify structural steel elements are in accordance with NTC08 Sections 4.2.4.1.1, 4.2.4.1.4 and are listed in Table 3-2.

Verification	Partial Factor
Resistance of Class 1, 2, 3 and 4 sections	$\gamma_{M0} = 1.05$
Resistance to instability of members in road and rail bridges	$\gamma_{M1} = 1.10$
Resistance to fracture of sections under tension (weakened by holes)	$\gamma_{M2} = 1.25$
Fatigue resistance (useful fatigue life criterion with significant failure consequences)	$\gamma_{mf} = 1.35$

Table 3-2: Material partial factors for structural steel.

3.2 Post-tensioning Strand

All post-tensioning strands shall conform to the requirements of EN 10138-3. Post-tensioning strands are assumed to have the following mechanical properties:

- Nominal Yield Strength, $f_{py} = 1636$ MPa
- Ultimate Strength, $f_{pk} = 1860$ MPa
- Elastic modulus: $E = 195000$ MPa

Post-tensioning strands are proportioned considering a partial safety factor on their effective tension at the ULS/SILS of 1.1.

3.3 Welding Consumables

Welding consumables shall comply with the requirements of EN 1993-1-8 Section 4.2.

Welding procedures shall be selected so as to not reduce the properties of the thermo-mechanically processed plates.

The material partial factor, $\gamma_{M2} = 1.25$, used to verify welded connections and splices is in accordance with NTC08 Section 4.2.8.1.1.

4 Design Principles

The design principles are primarily described in CG.10.00-P-RG-D-P-SV-T4-00-00-00-00-01 “General Design Principles.”

Summaries and discussions of verification results are provided in CG.10.00-P-RX-D-P-SV-T4-00-00-00-00-01 “Specialist Technical Design Report, Towers.”

5 Tower Base

BASE ANCHORAGE LOAD PATHS

① COMPRESSIVE TOWER LEG STRESSES

COMPRESSIVE STRESSES ARE CARRIED TO THE BASE ANCHORAGE THROUGH THE CONTINUOUS TOWER LEG PLATES & LONGITUDINAL STIFFENERS. IN THE LOWER 1.5 m OF THE TOWER THESE COMPRESSIVE STRESSES ARE SPREAD THROUGH THE ANCHORAGE & BASE PL STIFFENERS TO THE TOP OF THE BASE PL. THE STIFFENERS ALLOW THE LOAD TO BE SPREAD MORE UNIFORMALLY TO THE BASE PL. THE 150 mm THICK BASE PL THEN SPREADS THE COMPRESSIVE STRESSES APPROXIMATELY UNIFORMLY TO THE UNDERLYING GROUT PAD & TOWER FOUNDATION.

② TENSILE TOWER LEG STRESSES

TENSILE STRESSES ARE CARRIED TO THE THE BASE ANCHORAGE THROUGH THE CONTINUOUS TOWER LEG PLATES AND LONGITUDINAL STIFFENERS. HOWEVER, NEAR THE TOWER BASE THE TENSILE STRESSES MUST CONCENTRATE IN THE MAIN TOWER LEG PLATES BECAUSE ONLY THESE PLATES ARE ANCHORED TO THE TOWER FOUNDATION. IN THE LOWER 1.5 m OF THE TOWER LEG THE TENSILE STRESS ARE SPREAD OUTWARDS THROUGH THE ANCHORAGE STIFFENERS IN SHEA TO THE ANCHORAGE TENDONS. THE ANCHORAGE STIFFENERS TRANSFER THE SHEAR FORCE TO THE ANCHORAGE PIPES WHICH BEAR ON THE UNDER SIDE OF THE ANCHORAGE TENDON BEARING PL. THE ANCHORAGE TENDONS TRANSFER THE TENSILE FORCE TO THE TOWER FOUNDATION.

THIS LOAD PATH REQUIRES THAT THE MAIN PLs ALONE BE CAPABLE OF CARRYING ALL OF THE TENSILE STRESSES WITH NO CONTRIBUTION FROM THE LONGITUDINA STIFFENERS. CONFIRM...

THE MAXIMUM TENSILE STRESS ANYWHERE @ THE TOWER BASE UNDER THE GOVERNING LOAD COMBINATIONS IS 197 MPa → FOR SIMPLICITY ASSUME 200 MPa.

AT THE TOWER BASE LONGITUDINAL STIFFENERS REPRESENT A MAXIMUM OF 32% OF THE TOTAL PANEL AREA. SO A STRESS OF 200 MPa ON THE TOTAL PANEL AREA BECOMES $\frac{200}{1-0.32} = 294$ MPa, WHICH IS STILL $< \frac{f_y}{\gamma_{M0}}$

THIS CONFIRMS THAT THE TENSILE FORCE CAN BE CARRIED THROUGH THE MAIN TOWER PLATES ALONE.

THE PROPORTIONING OF THE ANCHORAGE STIFFENERS WAS STRONGLY GOVERNED BY THE COMPRESSIVE TOWER LEG STRESSES & SO THEY HAVE MORE THAN ENOUGH CAPACITY TO CARRY THE TENSILE STRESSES TO THE ANCHORAGE TENDONS.

③ TOWER LEG SHEAR STRESSES.

TOWER LEG SHEAR STRESSES ARE TRANSFERRED TO THE TOWER FOUNDATION THROUGH FRICTION B/W THE BASE PL AND THE FOUNDATION. AXIAL LOAD IS SO DOMINANT IN THE TOWER LEGS THAT THE SHEAR FORCES CAN BE TRANSFERRED WITH EVEN SMALL FRICTION COEFFICIENTS,

SICILIA TOWER

ENVELOPE OF ALL ULS COMBINATIONS AND LEGS

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Main Span					
	Plate A	LS1		-54.8	25.2
	Plate B	LS2	+	-58.3	25.8
		LS2	-	-57.0	24.5
		LS3	+	-55.5	22.0
		LS3	-	-54.0	20.2
	Plate C	LS4	+	-52.2	17.9
		LS4	-	-50.4	15.7
		LS5	+	-50.2	15.2
		LS5	-	-47.5	11.9
		LS6	+	-50.4	14.3
		LS6	-	-46.9	11.9
	Plate D	LS7	+	-37.9	9.4
		LS7	-	-35.8	8.2
		LS8	+	-35.8	8.0
		LS9	-	-32.8	5.8
		LS9	+	-34.0	6.4
		LS9	-	-32.8	5.8
	Plate E	LS26	+	-62.8	26.3
		LS26	-	-61.7	25.6
		LS27	+	-56.1	20.7
		LS27	-	-55.1	19.9
		LS28	+	-49.4	14.3
		LS28	-	-48.4	13.5
	Plate F	LS29	+	-32.8	6.4
		LS29	-	-32.0	5.8
	Plate H	LS19	+	-18.6	2.4
		LS19	-	-17.5	1.7
		LS20	+	-21.2	4.5
		LS20	-	-19.9	3.7
	Plate G	LS18	+	-17.5	1.2
		LS18	-	-17.2	1.0
Side Span					
	Plate A	LS17		-52.2	8.3
	Plate B	LS12	+	-53.0	7.0
		LS12	-	-54.7	7.7
		LS13	+	-48.9	3.5
		LS13	-	-51.1	4.3
	Plate C	LS14	+	-44.4	0.0
		LS14	-	-47.1	0.8
		LS15	+	-45.7	0.7
		LS15	-	-44.2	0.0
		LS16	+	-48.3	3.8
		LS16	-	-46.6	3.1
	Plate D	LS11	+	-37.0	5.1
		LS11	-	-35.7	4.5
		LS10	+	-35.3	5.6
		LS10	-	-34.0	5.1
		LS9	+	-34.0	6.4
		LS9	-	-32.8	5.8
	Plate E	LS33	+	-57.3	6.3
		LS33	-	-58.5	6.9
		LS32	+	-50.1	2.4
		LS32	-	-51.2	2.9
		LS31	+	-42.5	-2.3
		LS31	-	-43.6	-1.7
	Plate F	LS30	+	-27.0	-5.0
		LS30	-	-27.7	-4.6
	Plate H	LS23	+	-17.9	-1.1
		LS23	-	-17.4	-1.3
		LS24	+	-20.5	0.8
		LS24	-	-19.8	0.6
	Plate G	LS22	+	-14.6	-4.5
		LS22	-	-14.4	-4.5

ENVELOPE OF ALL SILS COMBINATIONS AND LEGS

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Main Span					
	Plate A	LS1		-50.4	22.7
	Plate B	LS2	+	-53.8	23.2
		LS2	-	-52.5	21.7
		LS3	+	-51.1	19.5
		LS3	-	-49.6	17.5
	Plate C	LS4	+	-48.0	15.5
		LS4	-	-46.3	13.0
		LS5	+	-46.2	13.0
		LS5	-	-43.5	10.1
		LS6	+	-49.1	14.7
		LS6	-	-45.2	12.0
	Plate D	LS7	+	-37.6	10.3
		LS7	-	-35.3	8.8
		LS8	+	-35.8	9.0
		LS9	-	-33.0	6.9
		LS9	+	-34.4	7.6
		LS9	-	-33.0	6.9
	Plate E	LS26	+	-57.8	23.5
		LS26	-	-56.7	22.5
		LS27	+	-51.5	18.0
		LS27	-	-50.5	17.1
		LS28	+	-45.2	11.8
		LS28	-	-44.2	10.8
	Plate F	LS29	+	-29.9	4.6
		LS29	-	-29.1	3.9
	Plate H	LS19	+	-17.7	2.2
		LS19	-	-16.5	1.4
		LS20	+	-20.6	4.6
		LS20	-	-19.2	3.7
	Plate G	LS18	+	-15.8	0.1
		LS18	-	-15.5	-0.1
Side Span					
	Plate A	LS17		-54.0	9.4
	Plate B	LS12	+	-54.9	8.4
		LS12	-	-56.7	8.8
		LS13	+	-50.9	5.2
		LS13	-	-53.2	5.8
	Plate C	LS14	+	-46.4	1.8
		LS14	-	-49.2	2.7
		LS15	+	-48.2	3.4
		LS15	-	-46.4	2.5
		LS16	+	-50.7	6.7
		LS16	-	-48.8	5.7
	Plate D	LS11	+	-38.3	7.0
		LS11	-	-36.8	6.2
		LS10	+	-36.2	7.2
		LS10	-	-34.7	6.4
		LS9	+	-34.4	7.6
		LS9	-	-33.0	6.9
	Plate E	LS33	+	-59.4	7.9
		LS33	-	-60.8	8.1
		LS32	+	-52.2	4.1
		LS32	-	-53.5	4.3
		LS31	+	-44.6	-0.4
		LS31	-	-45.8	-0.2
	Plate F	LS30	+	-28.6	-3.4
		LS30	-	-29.4	-3.3
	Plate H	LS23	+	-18.3	-0.5
		LS23	-	-17.7	-0.8
		LS24	+	-21.2	1.8
		LS24	-	-20.4	1.4
	Plate G	LS22	+	-14.8	-4.0
		LS22	-	-15.0	-4.0

ENVELOPE OF ALL ULS COMB FOR FREE STANDING TOWER

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Main Span					
	Plate A	LS1		-21.2	13.5
	Plate B	LS2	+	-23.5	15.2
		LS2	-	-22.1	14.2
		LS3	+	-22.2	13.8
		LS3	-	-20.7	12.8
	Plate C	LS4	+	-20.8	12.3
		LS4	-	-19.2	11.3
		LS5	+	-19.7	11.2
		LS5	-	-17.7	9.8
		LS6	+	-18.9	10.4
		LS6	-	-16.3	8.4
	Plate D	LS7	+	-11.8	5.4
		LS7	-	-9.9	4.6
		LS8	+	-10.9	5.0
		LS9	-	-9.2	4.1
		LS9	+	-10.3	4.7
		LS9	-	-9.2	4.1
	Plate E	LS26	+	-24.7	15.5
		LS26	-	-23.2	14.5
		LS27	+	-21.6	12.8
		LS27	-	-20.2	11.8
		LS28	+	-18.3	10.0
		LS28	-	-17.0	9.0
	Plate F	LS29	+	-11.1	5.3
		LS29	-	-10.1	4.6
	Plate H	LS19	+	-6.6	2.9
		LS19	-	-5.7	2.2
		LS20	+	-7.4	3.5
		LS20	-	-6.2	2.6
	Plate G	LS18	+	-5.6	2.0
		LS18	-	-5.2	1.6
Side Span					
	Plate A	LS17		-20.4	12.8
	Plate B	LS12	+	-22.5	14.2
		LS12	-	-21.3	13.5
		LS13	+	-21.1	12.7
		LS13	-	-20.0	12.1
	Plate C	LS14	+	-19.6	11.2
		LS14	-	-18.5	10.7
		LS15	+	-18.1	9.7
		LS15	-	-17.1	9.2
		LS16	+	-16.8	8.2
		LS16	-	-15.8	7.9
	Plate D	LS11	+	-11.2	4.8
		LS11	-	-10.1	4.5
		LS10	+	-10.6	4.7
		LS10	-	-9.6	4.3
		LS9	+	-10.3	4.7
		LS9	-	-9.2	4.1
	Plate E	LS33	+	-23.6	14.4
		LS33	-	-22.3	13.6
		LS32	+	-20.6	11.8
		LS32	-	-19.3	11.0
		LS31	+	-17.3	9.0
		LS31	-	-16.2	8.2
	Plate F	LS30	+	-10.4	4.6
		LS30	-	-9.6	4.0
	Plate H	LS23	+	-5.9	2.2
		LS23	-	-5.4	1.9
		LS24	+	-6.4	2.6
		LS24	-	-6.0	2.4
	Plate G	LS22	+	-5.2	1.6
		LS22	-	-4.9	1.2

ENVELOPE OF ALL ULS COMB FOR FREE STANDING TOWER w/ TIE BACK

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Main Span					
	Plate A	LS1		-0.5	22.7
	Plate B	LS2	+	-2.8	24.7
		LS2	-	-0.6	23.0
		LS3	+	-3.8	22.4
		LS3	-	-1.4	20.5
	Plate C	LS4	+	-4.9	20.0
		LS4	-	-2.2	17.9
		LS5	+	-6.5	18.1
		LS5	-	-3.0	15.2
		LS6	+	-8.1	16.2
		LS6	-	-4.2	13.8
	Plate D	LS7	+	-8.4	8.8
		LS7	-	-6.5	7.9
		LS8	+	-9.3	6.8
		LS9	-	-9.2	4.1
		LS9	+	-10.7	4.6
		LS9	-	-9.2	4.1
	Plate E	LS26	+	-2.6	25.5
		LS26	-	-0.5	24.0
		LS27	+	-2.9	21.4
		LS27	-	-1.0	19.9
		LS28	+	-3.5	16.8
		LS28	-	-1.6	15.3
	Plate F	LS29	+	-2.9	9.1
		LS29	-	-1.6	8.1
	Plate H	LS19	+	-2.9	4.8
		LS19	-	-1.6	3.8
		LS20	+	-3.6	5.6
		LS20	-	-2.1	4.7
	Plate G	LS18	+	-1.7	3.8
		LS18	-	-1.3	3.3
Side Span					
	Plate A	LS17		-30.5	-7.3
	Plate B	LS12	+	-32.7	-6.1
		LS12	-	-31.7	-6.7
		LS13	+	-30.4	-5.4
		LS13	-	-29.3	-5.9
	Plate C	LS14	+	-27.8	-4.5
		LS14	-	-26.7	-5.1
		LS15	+	-25.2	-3.7
		LS15	-	-24.1	-4.2
		LS16	+	-23.8	-1.8
		LS16	-	-21.7	-3.0
	Plate D	LS11	+	-14.8	1.2
		LS11	-	-13.6	1.0
		LS10	+	-12.8	2.7
		LS10	-	-11.5	2.4
		LS9	+	-10.7	4.6
		LS9	-	-9.2	4.1
	Plate E	LS33	+	-34.6	-7.1
		LS33	-	-33.4	-7.8
		LS32	+	-29.9	-6.3
		LS32	-	-28.8	-7.0
		LS31	+	-25.0	-5.4
		LS31	-	-23.9	-6.2
	Plate F	LS30	+	-14.7	-3.4
		LS30	-	-14.0	-3.8
	Plate H	LS23	+	-8.2	-1.3
		LS23	-	-7.5	-1.8
		LS24	+	-9.2	-0.7
		LS24	-	-8.2	-1.2
	Plate G	LS22	+	-7.4	-2.1
		LS22	-	-7.0	-2.4

ENVELOPE OF ALL ULS COMB FOR
FREE STANDING TOWER after Main Cable

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Main Span					
	Plate A	LS1		-15.8	19.6
	Plate B	LS2	+	-17.7	19.8
		LS2	-	-16.5	18.7
		LS3	+	-17.9	16.7
		LS3	-	-16.4	15.3
	Plate C	LS4	+	-18.1	13.4
		LS4	-	-16.1	11.8
		LS5	+	-18.6	10.9
		LS5	-	-16.2	8.5
		LS6	+	-19.5	9.0
		LS6	-	-16.5	5.4
	Plate D	LS7	+	-16.6	3.9
		LS7	-	-14.5	1.1
		LS8	+	-16.9	2.1
		LS9	-	-15.5	-2.4
		LS9	+	-17.6	-0.1
		LS9	-	-15.5	-2.4
	Plate E	LS26	+	-19.2	20.4
		LS26	-	-18.2	19.6
		LS27	+	-18.1	16.0
		LS27	-	-17.1	15.2
		LS28	+	-17.1	11.0
		LS28	-	-16.2	10.3
	Plate F	LS29	+	-11.7	4.7
		LS29	-	-11.0	4.1
	Plate H	LS19	+	-7.8	1.5
		LS19	-	-6.9	0.7
		LS20	+	-8.6	2.5
		LS20	-	-7.4	0.9
	Plate G	LS18	+	-7.2	0.9
		LS18	-	-7.0	0.8
Side Span					
	Plate A	LS17		-39.9	-11.6
	Plate B	LS12	+	-40.6	-12.8
		LS12	-	-41.7	-12.5
		LS13	+	-37.4	-13.1
		LS13	-	-38.8	-12.7
	Plate C	LS14	+	-33.9	-13.4
		LS14	-	-35.5	-12.7
		LS15	+	-33.1	-11.3
		LS15	-	-32.4	-12.3
		LS16	+	-32.8	-8.7
		LS16	-	-30.2	-11.6
	Plate D	LS11	+	-22.3	-3.4
		LS11	-	-19.8	-6.2
		LS10	+	-20.0	-1.9
		LS10	-	-17.6	-4.6
		LS9	+	-17.6	-0.1
		LS9	-	-15.5	-2.4
	Plate E	LS33	+	-43.9	-14.2
		LS33	-	-44.6	-14.0
		LS32	+	-38.3	-13.7
		LS32	-	-39.1	-13.6
		LS31	+	-32.5	-13.5
		LS31	-	-33.2	-13.3
	Plate F	LS30	+	-19.5	-9.5
		LS30	-	-20.0	-9.4
	Plate H	LS23	+	-12.1	-4.5
		LS23	-	-11.0	-5.8
		LS24	+	-13.4	-3.7
		LS24	-	-11.9	-5.2
	Plate G	LS22	+	-10.6	-6.1
		LS22	-	-10.6	-6.1

OVERALL MAXIMUM FORCES

	Stiff	Max Compr Force (MN/m)	Governing Case	Max Tensile Force (MN/m)	Governing Case
Main Span					
Plate A	LS1	-54.8	ULS-Completed Bridge	25.2	ULS-Completed Bridge
Plate B	LS2	-58.3	ULS-Completed Bridge	25.8	ULS-Completed Bridge
	LS3	-55.5	ULS-Completed Bridge	22.4	Freestanding Tower with Tie-Back
Plate C	LS4	-52.2	ULS-Completed Bridge	20.0	Freestanding Tower with Tie-Back
	LS5	-50.2	ULS-Completed Bridge	18.1	Freestanding Tower with Tie-Back
	LS6	-50.4	ULS-Completed Bridge	16.2	Freestanding Tower with Tie-Back
Plate D	LS7	-37.9	ULS-Completed Bridge	10.3	SILS-Completed Bridge
	LS8	-35.8	SILS-Completed Bridge	9.0	SILS-Completed Bridge
	LS9	-34.4	SILS-Completed Bridge	7.6	SILS-Completed Bridge
Plate E	LS26	-62.8	ULS-Completed Bridge	26.3	ULS-Completed Bridge
	LS27	-56.1	ULS-Completed Bridge	21.4	Freestanding Tower with Tie-Back
	LS28	-49.4	ULS-Completed Bridge	16.8	Freestanding Tower with Tie-Back
Plate F	LS29	-32.8	ULS-Completed Bridge	9.1	Freestanding Tower with Tie-Back
Plate H	LS19	-18.6	ULS-Completed Bridge	4.8	Freestanding Tower with Tie-Back
	LS20	-21.2	ULS-Completed Bridge	5.6	Freestanding Tower with Tie-Back
Plate G	LS18	-17.5	ULS-Completed Bridge	3.8	Freestanding Tower with Tie-Back
Side Span					
Plate A	LS17	-54.0	SILS-Completed Bridge	12.8	Freestanding Tower
Plate B	LS12	-56.7	SILS-Completed Bridge	14.2	Freestanding Tower
	LS13	-53.2	SILS-Completed Bridge	12.7	Freestanding Tower
Plate C	LS14	-49.2	SILS-Completed Bridge	11.2	Freestanding Tower
	LS15	-48.2	SILS-Completed Bridge	9.7	Freestanding Tower
	LS16	-50.7	SILS-Completed Bridge	8.2	Freestanding Tower
Plate D	LS11	-38.3	SILS-Completed Bridge	7.0	SILS-Completed Bridge
	LS10	-36.2	SILS-Completed Bridge	7.2	SILS-Completed Bridge
	LS9	-34.4	SILS-Completed Bridge	7.6	SILS-Completed Bridge
Plate E	LS33	-60.8	SILS-Completed Bridge	14.4	Freestanding Tower
	LS32	-53.5	SILS-Completed Bridge	11.8	Freestanding Tower
	LS31	-45.8	SILS-Completed Bridge	9.0	Freestanding Tower
Plate F	LS30	-29.4	SILS-Completed Bridge	4.6	Freestanding Tower
Plate H	LS23	-18.3	SILS-Completed Bridge	2.2	Freestanding Tower
	LS24	-21.2	SILS-Completed Bridge	2.6	Freestanding Tower
Plate G	LS22	-15.0	SILS-Completed Bridge	1.6	Freestanding Tower

		Area (mm^2)	f_{pk} (MPa)	T_r (MN)	
Strand Propertie	Conventional	140	1860	0.154	=0.65 x fpu x A / 1.10
	Super	150	1860	0.165	=0.65 x fpu x A / 1.10
	Dyform	165	1820	0.177	=0.65 x fpu x A / 1.10

Tendons on Plates A, E, F, G and H are routed longitudinally and connect the corresponding anchors on the main and side span sides of the tower leg.

Tendons on Plates B, C and D are routed transversally and connect the corresponding anchors on the east and west sides of the tower leg.

	Tributary Width (m)	Tributary Area (m^2)	Tensile Force (MN)	Tensile Stress (MPa)	Number of Strands Required			Number of Tendons	Req'd Strands/ Tendon	Provided Strands/ Tendon	Tendon Size
					Conventional	Super	Dyform				
Main Span											
Plate A	2	0.256	50.5	196.9	328	306	284	6	52	52	55
Plate B	1.2915	0.178	33.3	187.1	217	202	188	4	51	52	55
	1.25	0.174	28.0	160.9	182	170	158	4	43	43	43
Plate C	1.25	0.174	25.0	143.6	162	152	141	4	38	38	43
	1.25	0.174	22.6	129.7	147	137	127	4	35	35	37
	1.2155	0.171	19.7	115.8	128	120	111	4	30	30	31
Plate D	1.2	0.132	12.4	93.5	80	75	70	4	19	19	19
	1.4	0.147	12.6	85.7	82	77	71	4	20	20	22
	1.6	0.162	12.2	75.4	79	74	69	4	19	20	22
Plate E	1	0.153	26.3	172.3	171	160	148	4	38	38	43
	1.1665	0.170	24.9	147.0	162	151	140	4	38	38	43
	1.333	0.170	22.4	132.2	146	136	126	4	34	34	37
Plate F	1.333	0.136	12.1	89.1	79	73	68	4	19	19	19
Plate H	1.4125	0.086	6.8	79.2	44	41	39	4	11	11	12
	1.25	0.079	7.0	89.2	46	43	40	4	11	11	12
Plate G	1.4	0.086	5.3	61.5	34	32	30	4	9	9	12
Side Span											
Plate A	2	0.256	25.5	99.6	166	155	144	6	26	52	55
Plate B	1.2915	0.178	18.3	102.6	119	111	103	4	28	52	55
	1.25	0.174	15.9	91.3	103	96	90	4	25	29	31
Plate C	1.25	0.174	14.0	80.3	91	85	79	4	22	22	22
	1.25	0.174	12.1	69.4	79	73	68	4	19	20	22
	1.2155	0.171	10.0	58.6	65	61	56	4	16	18	19
Plate D	1.2	0.132	8.4	63.4	54	51	47	4	13	15	19
	1.4	0.147	10.1	68.3	65	61	57	4	16	17	19
	1.6	0.162	12.2	75.4	79	74	69	4	19	20	22
Plate E	1	0.153	14.4	94.3	94	87	81	4	22	38	43
	1.1665	0.170	13.8	81.4	90	84	78	4	21	38	43
	1.333	0.170	12.0	70.5	78	73	67	4	19	34	37
Plate F	1.333	0.136	6.1	44.8	40	37	34	4	10	19	19
Plate H	1.4125	0.086	3.1	35.9	20	19	17	4	5	11	12
	1.25	0.079	3.2	41.0	21	20	18	4	5	11	12
Plate G	1.4	0.086	2.2	25.7	14	13	12	4	4	9	12

	Base Plate Width (m)	Externally Applied Comp. Stress (MPa)	Stressing Force (MN)	Total Compression (MN/m)	Compressive Stress at U/S of Baseplate (MPa)
Main Span					
Plate A	1.625	-34	11.6	-90	-55
Plate B	1.575	-37	11.6	-94	-60
	1.575	-35	9.6	-86	-55
Plate C	1.575	-33	8.5	-79	-50
	1.575	-32	7.8	-75	-48
	1.575	-32	6.7	-72	-46
Plate D	1.495	-25	4.2	-52	-35
	1.495	-24	4.5	-49	-32
	1.495	-23	4.5	-46	-30
Plate E	1.575	-40	8.5	-97	-61
	1.575	-36	8.5	-85	-54
	1.575	-31	7.6	-72	-46
Plate F	1.575	-21	4.2	-45	-29
Plate H	1.395	-13	2.5	-26	-18
	1.395	-15	2.5	-29	-21
Plate G	1.395	-13	2.0	-23	-17
Side Span					
Plate A	1.625	-33	11.6	-89	-55
Plate B	1.575	-36	11.6	-93	-59
	1.575	-34	6.5	-74	-47
Plate C	1.575	-31	4.9	-65	-41
	1.575	-31	4.5	-62	-40
	1.575	-32	4.0	-64	-41
Plate D	1.495	-26	3.3	-49	-33
	1.495	-24	3.8	-47	-31
	1.495	-23	4.5	-46	-30
Plate E	1.575	-39	8.5	-95	-60
	1.575	-34	8.5	-83	-52
	1.575	-29	7.6	-69	-44
Plate F	1.575	-19	4.2	-42	-27
Plate H	1.395	-13	2.5	-25	-18
	1.395	-15	2.5	-29	-21
Plate G	1.395	-11	2.0	-21	-15

Tendon Requirements at Plate Intersections

Stiffener	w1	t1	Stress (MPa)	T (MN)	Total (MN)	Strands Required	Number of Tendons	eq'd Strands Tendon	vided Stran Tendon	Tendon Size
Plate A, B and E										
LS1	1000	100	196.9	19.7	40.8	247	5	50	55	55
LS26	500	100	172.3	8.6						
LS2	666.5	100	187.1	12.5						
Plate F, G and H										
LS29	666.5	70	89.1	4.2	8.5	52	4	13	14	19
LS18	600	45	61.5	1.7						
LS19	750	45	79.2	2.7						
Plate C, D and H										
LS6	590.5	100	115.8	6.8	13.1	80	4	20	21	22
LS20	587.5	45	89.2	2.4						
LS7	600	70	93.5	3.9						

Plate A, B and E										
LS17	1000	100	99.6	10.0	21.5	130	5	27	55	55
LS33	500	100	94.3	4.7						
LS12	666.5	100	102.6	6.8						
Plate F, G and H										
LS30	666.5	70	44.8	2.1	4.0	24	4	7	14	19
LS22	600	45	25.7	0.7						
LS23	750	45	35.9	1.2						
Plate C, D and H										
LS16	590.5	100	58.6	3.5	7.2	44	4	11	12	22
LS24	587.5	45	41.0	1.1						
LS11	600	70	63.4	2.7						

CALABRIA TOWER

ENVELOPE OF ALL ULS COMBINATIONS AND LEGS

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Side Span					
	Plate A	LS1		-55.1	5.4
	Plate B	LS2	+	-56.9	5.1
		LS2	-	-55.6	3.8
		LS3	+	-53.9	3.0
		LS3	-	-52.2	1.1
	Plate C	LS4	+	-43.0	0.7
		LS4	-	-41.3	-1.4
		LS5	+	-43.0	1.6
		LS5	-	-40.0	-0.4
		LS6	+	-44.9	3.8
		LS6	-	-41.9	2.2
	Plate D	LS7	+	-43.1	5.8
		LS7	-	-40.9	4.5
		LS8	+	-40.7	6.2
		LS9	-	-37.3	6.0
		LS9	+	-38.8	6.8
		LS9	-	-37.3	6.0
	Plate E	LS26	+	-52.0	3.6
		LS26	-	-51.2	2.9
		LS27	+	-46.5	1.2
		LS27	-	-45.7	0.6
		LS28	+	-40.8	-1.6
		LS28	-	-40.0	-2.2
	Plate F	LS29	+	-21.7	-2.6
		LS29	-	-21.2	-2.9
	Plate H	LS19	+	-18.1	-0.9
		LS19	-	-17.2	-1.4
		LS20	+	-20.7	1.0
		LS20	-	-19.5	0.3
	Plate G	LS18	+	-13.8	-3.1
		LS18	-	-13.7	-3.2
Main Span					
	Plate A	LS17		-52.8	23.9
	Plate B	LS12	+	-53.8	22.7
		LS12	-	-55.0	23.3
		LS13	+	-51.0	18.6
		LS13	-	-52.5	19.4
	Plate C	LS14	+	-40.8	12.3
		LS14	-	-42.3	13.0
		LS15	+	-40.6	9.4
		LS15	-	-40.3	9.9
		LS16	+	-42.9	10.7
		LS16	-	-41.4	9.9
	Plate D	LS11	+	-42.3	9.4
		LS11	-	-40.7	8.6
		LS10	+	-40.3	8.1
		LS10	-	-38.8	7.3
		LS9	+	-38.8	6.8
		LS9	-	-37.3	6.0
	Plate E	LS33	+	-49.6	20.0
		LS33	-	-50.3	20.4
		LS32	+	-44.6	15.5
		LS32	-	-45.3	15.9
		LS31	+	-39.6	10.4
		LS31	-	-40.3	10.8
	Plate F	LS30	+	-21.3	3.4
		LS30	-	-21.8	3.7
	Plate H	LS23	+	-17.4	1.6
		LS23	-	-17.0	1.4
		LS24	+	-20.0	3.6
		LS24	-	-19.4	3.3
	Plate G	LS22	+	-14.0	0.6
		LS22	-	-14.1	0.7

ENVELOPE OF ALL SILS COMBINATIONS AND LEGS

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Side Span					
	Plate A	LS1		-55.3	5.8
	Plate B	LS2	+	-57.0	5.3
		LS2	-	-55.9	4.0
		LS3	+	-53.7	2.9
		LS3	-	-52.4	1.3
	Plate C	LS4	+	-43.3	2.0
		LS4	-	-41.4	-0.7
		LS5	+	-44.5	4.1
		LS5	-	-41.5	1.5
		LS6	+	-46.4	6.6
		LS6	-	-43.4	4.2
	Plate D	LS7	+	-44.3	7.8
		LS7	-	-41.8	6.2
		LS8	+	-41.6	7.8
		LS9	-	-37.5	7.1
		LS9	+	-39.2	8.1
		LS9	-	-37.5	7.1
	Plate E	LS26	+	-52.0	4.0
		LS26	-	-51.4	3.1
		LS27	+	-46.3	1.6
		LS27	-	-45.7	0.8
		LS28	+	-40.4	-1.3
		LS28	-	-39.8	-2.0
	Plate F	LS29	+	-21.3	-2.4
		LS29	-	-21.0	-2.9
	Plate H	LS19	+	-18.3	-0.3
		LS19	-	-17.4	-1.0
		LS20	+	-21.2	1.9
		LS20	-	-20.0	1.0
	Plate G	LS18	+	-13.5	-3.0
		LS18	-	-13.4	-3.1
Main Span					
	Plate A	LS17		-48.6	21.0
	Plate B	LS12	+	-49.3	19.6
		LS12	-	-50.6	20.3
		LS13	+	-46.6	15.5
		LS13	-	-48.3	16.3
	Plate C	LS14	+	-37.2	9.6
		LS14	-	-38.8	10.4
		LS15	+	-39.0	9.5
		LS15	-	-37.4	8.6
		LS16	+	-41.9	11.2
		LS16	-	-40.1	10.2
	Plate D	LS11	+	-42.0	10.5
		LS11	-	-40.1	9.4
		LS10	+	-40.3	9.3
		LS10	-	-38.5	8.3
		LS9	+	-39.2	8.1
		LS9	-	-37.5	7.1
	Plate E	LS33	+	-45.5	17.1
		LS33	-	-46.3	17.5
		LS32	+	-40.8	12.7
		LS32	-	-41.6	13.2
		LS31	+	-36.1	7.7
		LS31	-	-36.8	8.2
	Plate F	LS30	+	-19.4	1.9
		LS30	-	-19.8	2.1
	Plate H	LS23	+	-16.6	1.5
		LS23	-	-16.1	1.2
		LS24	+	-19.5	3.8
		LS24	-	-18.7	3.3
	Plate G	LS22	+	-12.6	-0.5
		LS22	-	-12.8	-0.4

ENVELOPE OF ALL ULS COMB FOR FREE STANDING TOWER

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Side Span					
	Plate A	LS1		-24.3	15.8
	Plate B	LS2	+	-25.5	16.7
		LS2	-	-23.9	15.7
		LS3	+	-24.0	15.2
		LS3	-	-22.4	14.1
	Plate C	LS4	+	-19.0	11.5
		LS4	-	-17.5	10.5
		LS5	+	-17.9	10.3
		LS5	-	-16.1	9.1
		LS6	+	-17.2	9.5
		LS6	-	-14.8	7.8
	Plate D	LS7	+	-13.6	6.3
		LS7	-	-10.7	4.8
		LS8	+	-12.1	5.5
		LS9	-	-9.6	4.3
		LS9	+	-11.4	5.1
		LS9	-	-9.6	4.3
	Plate E	LS26	+	-19.6	12.5
		LS26	-	-18.4	11.7
		LS27	+	-17.1	10.4
		LS27	-	-16.0	9.6
		LS28	+	-14.5	8.1
		LS28	-	-13.5	7.3
	Plate F	LS29	+	-8.9	4.4
		LS29	-	-8.2	3.8
	Plate H	LS19	+	-6.8	3.1
		LS19	-	-5.9	2.4
		LS20	+	-7.7	3.7
		LS20	-	-6.5	2.8
	Plate G	LS18	+	-5.2	1.9
		LS18	-	-4.8	1.5
Main Span					
	Plate A	LS17		-23.5	14.9
	Plate B	LS12	+	-24.4	15.6
		LS12	-	-23.1	14.9
		LS13	+	-22.9	14.0
		LS13	-	-21.6	13.4
	Plate C	LS14	+	-18.0	10.5
		LS14	-	-17.0	10.0
		LS15	+	-16.6	9.0
		LS15	-	-15.6	8.6
		LS16	+	-15.3	7.7
		LS16	-	-14.4	7.3
	Plate D	LS11	+	-12.7	5.4
		LS11	-	-10.9	4.7
		LS10	+	-11.5	5.2
		LS10	-	-10.1	4.5
		LS9	+	-11.4	5.1
		LS9	-	-9.6	4.3
	Plate E	LS33	+	-18.8	11.7
		LS33	-	-17.7	11.0
		LS32	+	-16.3	9.6
		LS32	-	-15.3	8.9
		LS31	+	-13.8	7.3
		LS31	-	-12.8	6.7
	Plate F	LS30	+	-8.4	3.8
		LS30	-	-7.7	3.4
	Plate H	LS23	+	-6.1	2.4
		LS23	-	-5.6	2.1
		LS24	+	-6.7	2.8
		LS24	-	-6.2	2.6
	Plate G	LS22	+	-4.8	1.5
		LS22	-	-4.5	1.2

ENVELOPE OF ALL ULS COMB FOR FREE STANDING TOWER w/ TIE BACK

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Side Span					
	Plate A	LS1		-31.6	-5.2
	Plate B	LS2	+	-32.7	-3.2
		LS2	-	-31.0	-4.4
		LS3	+	-30.6	-2.6
		LS3	-	-28.8	-3.9
	Plate C	LS4	+	-24.0	-1.6
		LS4	-	-22.3	-2.7
		LS5	+	-22.5	-0.5
		LS5	-	-20.2	-2.2
		LS6	+	-21.1	0.6
		LS6	-	-18.3	-1.7
	Plate D	LS7	+	-16.6	2.6
		LS7	-	-14.1	1.4
		LS8	+	-14.2	3.6
		LS9	-	-9.7	4.3
		LS9	+	-11.6	4.9
		LS9	-	-9.7	4.3
	Plate E	LS26	+	-25.2	-3.1
		LS26	-	-24.0	-4.0
		LS27	+	-21.9	-2.8
		LS27	-	-20.7	-3.6
		LS28	+	-18.4	-2.5
		LS28	-	-17.2	-3.3
	Plate F	LS29	+	-11.2	-1.6
		LS29	-	-10.3	-2.2
	Plate H	LS19	+	-8.3	-0.4
		LS19	-	-7.3	-1.3
		LS20	+	-9.3	0.2
		LS20	-	-7.9	-0.9
	Plate G	LS18	+	-6.4	-1.3
		LS18	-	-5.9	-1.7
Main Span					
	Plate A	LS17		-2.7	22.3
	Plate B	LS12	+	-4.5	22.7
		LS12	-	-3.2	21.8
		LS13	+	-5.1	20.3
		LS13	-	-3.9	19.6
	Plate C	LS14	+	-4.9	15.1
		LS14	-	-3.9	14.7
		LS15	+	-5.4	13.0
		LS15	-	-4.5	12.7
		LS16	+	-6.6	11.6
		LS16	-	-5.3	10.9
	Plate D	LS11	+	-8.9	8.4
		LS11	-	-7.3	7.9
		LS10	+	-10.0	6.6
		LS10	-	-8.3	6.2
		LS9	+	-11.6	4.9
		LS9	-	-9.7	4.3
	Plate E	LS33	+	-3.3	17.2
		LS33	-	-2.1	16.4
		LS32	+	-3.2	14.3
		LS32	-	-2.2	13.5
		LS31	+	-3.3	11.0
		LS31	-	-2.3	10.3
	Plate F	LS30	+	-2.5	5.9
		LS30	-	-1.8	5.4
	Plate H	LS23	+	-2.7	3.8
		LS23	-	-2.0	3.4
		LS24	+	-3.5	4.6
		LS24	-	-2.6	4.1
	Plate G	LS22	+	-1.6	2.7
		LS22	-	-1.3	2.4

ENVELOPE OF ALL ULS COMB FOR
FREE STANDING TOWER after Main Cable

		Stiff	side	Max Compr Force (MN/m)	Max Tensile Force (MN/m)
Side Span					
	Plate A	LS1		-41.4	-11.4
	Plate B	LS2	+	-41.0	-11.2
		LS2	-	-40.2	-12.4
		LS3	+	-38.2	-11.5
		LS3	-	-37.2	-13.0
	Plate C	LS4	+	-30.1	-10.0
		LS4	-	-28.8	-11.5
		LS5	+	-28.5	-8.6
		LS5	-	-26.1	-11.8
		LS6	+	-28.2	-6.6
		LS6	-	-24.1	-10.6
	Plate D	LS7	+	-24.8	-3.5
		LS7	-	-21.3	-7.1
		LS8	+	-22.2	-2.1
		LS9	-	-17.0	-3.4
		LS9	+	-19.7	-0.5
		LS9	-	-17.0	-3.4
	Plate E	LS26	+	-32.2	-9.4
		LS26	-	-31.7	-10.0
		LS27	+	-28.3	-9.2
		LS27	-	-27.8	-9.8
		LS28	+	-24.1	-9.2
		LS28	-	-23.7	-9.8
	Plate F	LS29	+	-15.4	-6.8
		LS29	-	-14.6	-7.2
	Plate H	LS19	+	-11.9	-4.2
		LS19	-	-10.3	-5.8
		LS20	+	-13.3	-3.4
		LS20	-	-11.4	-5.3
	Plate G	LS18	+	-9.6	-5.0
		LS18	-	-9.3	-5.3
Main Span					
	Plate A	LS17		-19.1	18.8
	Plate B	LS12	+	-18.6	17.2
		LS12	-	-19.9	17.6
		LS13	+	-18.2	14.1
		LS13	-	-19.8	14.6
	Plate C	LS14	+	-15.0	9.1
		LS14	-	-16.5	9.7
		LS15	+	-15.5	6.6
		LS15	-	-16.5	7.2
		LS16	+	-17.3	5.9
		LS16	-	-16.8	5.0
	Plate D	LS11	+	-18.8	2.8
		LS11	-	-16.5	0.2
		LS10	+	-19.0	1.3
		LS10	-	-16.5	-1.4
		LS9	+	-19.7	-0.5
		LS9	-	-17.0	-3.4
	Plate E	LS33	+	-15.1	13.1
		LS33	-	-15.8	13.2
		LS32	+	-14.1	10.1
		LS32	-	-14.8	10.2
		LS31	+	-13.2	6.7
		LS31	-	-13.8	6.8
	Plate F	LS30	+	-9.1	2.6
		LS30	-	-9.5	2.7
	Plate H	LS23	+	-7.7	0.7
		LS23	-	-7.8	0.6
		LS24	+	-8.8	1.6
		LS24	-	-8.4	1.0
	Plate G	LS22	+	-6.4	0.3
		LS22	-	-6.6	0.3

OVERALL MAXIMUM FORCES

	Stiff	Max Compr Force (MN/m)	Governing Case	Max Tensile Force (MN/m)	Governing Case
Side Span					
Plate A	LS1	-55.3	SILS-Completed Bridge	15.8	Freestanding Tower
Plate B	LS2	-57.0	SILS-Completed Bridge	16.7	Freestanding Tower
	LS3	-53.9	ULS-Completed Bridge	15.2	Freestanding Tower
Plate C	LS4	-43.3	SILS-Completed Bridge	11.5	Freestanding Tower
	LS5	-44.5	SILS-Completed Bridge	10.3	Freestanding Tower
	LS6	-46.4	SILS-Completed Bridge	9.5	Freestanding Tower
Plate D	LS7	-44.3	SILS-Completed Bridge	7.8	SILS-Completed Bridge
	LS8	-41.6	SILS-Completed Bridge	7.8	SILS-Completed Bridge
	LS9	-39.2	SILS-Completed Bridge	8.1	SILS-Completed Bridge
Plate E	LS26	-52.0	SILS-Completed Bridge	12.5	Freestanding Tower
	LS27	-46.5	ULS-Completed Bridge	10.4	Freestanding Tower
	LS28	-40.8	ULS-Completed Bridge	8.1	Freestanding Tower
Plate F	LS29	-21.7	ULS-Completed Bridge	4.4	Freestanding Tower
Plate H	LS19	-18.3	SILS-Completed Bridge	3.1	Freestanding Tower
	LS20	-21.2	SILS-Completed Bridge	3.7	Freestanding Tower
Plate G	LS18	-13.8	ULS-Completed Bridge	1.9	Freestanding Tower
Main Span					
Plate A	LS17	-52.8	ULS-Completed Bridge	23.9	ULS-Completed Bridge
Plate B	LS12	-55.0	ULS-Completed Bridge	23.3	ULS-Completed Bridge
	LS13	-52.5	ULS-Completed Bridge	20.3	Freestanding Tower with Tie-Back
Plate C	LS14	-42.3	ULS-Completed Bridge	15.1	Freestanding Tower with Tie-Back
	LS15	-40.6	ULS-Completed Bridge	13.0	Freestanding Tower with Tie-Back
	LS16	-42.9	ULS-Completed Bridge	11.6	Freestanding Tower with Tie-Back
Plate D	LS11	-42.3	ULS-Completed Bridge	10.5	SILS-Completed Bridge
	LS10	-40.3	SILS-Completed Bridge	9.3	SILS-Completed Bridge
	LS9	-39.2	SILS-Completed Bridge	8.1	SILS-Completed Bridge
Plate E	LS33	-50.3	ULS-Completed Bridge	20.4	ULS-Completed Bridge
	LS32	-45.3	ULS-Completed Bridge	15.9	ULS-Completed Bridge
	LS31	-40.3	ULS-Completed Bridge	11.0	Freestanding Tower with Tie-Back
Plate F	LS30	-21.8	ULS-Completed Bridge	5.9	Freestanding Tower with Tie-Back
Plate H	LS23	-17.4	ULS-Completed Bridge	3.8	Freestanding Tower with Tie-Back
	LS24	-20.0	ULS-Completed Bridge	4.6	Freestanding Tower with Tie-Back
Plate G	LS22	-14.1	ULS-Completed Bridge	2.7	Freestanding Tower with Tie-Back

	Tributary Width (m)	Tributary Area (m^2)	Tensile Force (MN)	Tensile Stress (MPa)	Number of Strands Required			Number of Tendons	Strands/ Tendon	Provided Strands/ Tendon	Tendon Size
					Conventional	Super	Dyform				
Side Span											
Plate A	2	0.256	31.5	122.9	205	191	178	6	32	52	55
Plate B	1.2915	0.175	21.6	123.2	140	131	122	4	33	52	55
	1.25	0.171	19.0	111.0	123	115	107	4	29	29	31
Plate C	1.25	0.171	14.4	84.0	93	87	81	4	22	22	22
	1.25	0.171	12.9	75.6	84	78	73	4	20	20	22
	1.2155	0.167	11.6	69.1	75	70	65	4	18	18	19
Plate D	1.2	0.142	9.4	66.2	61	57	53	4	15	15	19
	1.4	0.158	10.9	68.8	71	66	61	4	17	17	19
	1.6	0.174	13.0	74.6	84	79	73	4	20	20	22
Plate E	1	0.127	12.5	98.1	81	76	70	4	19	38	43
	1.1665	0.141	12.1	85.7	79	74	68	4	19	38	43
	1.333	0.132	10.8	81.4	70	65	61	4	17	34	37
Plate F	1.333	0.092	5.8	63.6	38	35	33	4	9	19	19
Plate H	1.4125	0.079	4.3	54.4	28	26	24	4	7	11	12
	1.25	0.073	4.7	64.2	30	28	26	4	8	11	12
Plate G	1.4	0.069	2.7	38.3	17	16	15	4	5	9	12
Main Span											
Plate A	2	0.256	47.9	186.7	311	290	270	6	49	52	55
Plate B	1.2915	0.175	30.1	172.2	196	183	170	4	46	52	55
	1.25	0.171	25.4	148.7	165	154	143	4	39	43	43
Plate C	1.25	0.171	18.9	110.6	123	115	107	4	29	38	43
	1.25	0.171	16.3	95.3	106	99	92	4	25	35	37
	1.2155	0.167	14.1	84.3	92	86	80	4	22	30	31
Plate D	1.2	0.142	12.5	88.4	82	76	71	4	20	19	19
	1.4	0.158	13.0	82.4	85	79	73	4	20	20	22
	1.6	0.174	13.0	74.6	84	79	73	4	20	20	22
Plate E	1	0.127	20.4	160.6	133	124	115	4	31	38	43
	1.1665	0.141	18.6	131.3	121	113	105	4	29	38	43
	1.333	0.132	14.7	111.2	96	89	83	4	23	34	37
Plate F	1.333	0.092	7.9	86.2	51	48	45	4	12	19	19
Plate H	1.4125	0.079	5.4	68.1	35	33	30	4	9	11	12
	1.25	0.073	5.8	79.5	38	35	33	4	9	11	12
Plate G	1.4	0.069	3.7	53.9	24	23	21	4	6	9	12

	Base Plate Width (m)	Externally Applied Comp. Stress (MPa)	Stressing Force (MN)	Total Compression (MN/m)	Compressive Stress at U/S of Baseplate (MPa)
Side Span					
Plate A	1.625	-34	11.6	-90	-55
Plate B	1.575	-36	11.6	-93	-59
	1.575	-34	6.5	-75	-47
Plate C	1.575	-27	4.9	-59	-37
	1.575	-28	4.5	-59	-37
	1.575	-29	4.0	-60	-38
Plate D	1.495	-30	3.3	-55	-37
	1.495	-28	3.8	-52	-35
	1.495	-26	4.5	-50	-34
Plate E	1.575	-33	8.5	-86	-55
	1.575	-30	8.5	-76	-48
	1.575	-26	7.6	-64	-40
Plate F	1.575	-14	4.2	-34	-22
Plate H	1.395	-13	2.5	-25	-18
	1.395	-15	2.5	-29	-21
Plate G	1.395	-10	2.0	-20	-14
Main Span					
Plate A	1.625	-33	11.6	-88	-54
Plate B	1.575	-35	11.6	-91	-58
	1.575	-33	9.6	-83	-53
Plate C	1.575	-27	8.5	-69	-44
	1.575	-26	7.8	-66	-42
	1.575	-27	6.7	-65	-41
Plate D	1.495	-28	4.2	-56	-38
	1.495	-27	4.5	-53	-35
	1.495	-26	4.5	-50	-34
Plate E	1.575	-32	8.5	-84	-53
	1.575	-29	8.5	-74	-47
	1.575	-26	7.6	-63	-40
Plate F	1.575	-14	4.2	-34	-22
Plate H	1.395	-12	2.5	-24	-17
	1.395	-14	2.5	-28	-20
Plate G	1.395	-10	2.0	-20	-14

Tendon Requirements at Plate Intersections

Stiffener	w1	t1	Stress (MPa)	T (MN)	Total (MN)	Strands Required	Number of Tendons	eq'd Strands Tendon	vided Stran Tendon	Tendon Size
Plate A, B and E										
LS1	1000	100	122.9	12.3	25.4	154	5	31	55	55
LS26	500	100	98.1	4.9						
LS2	666.5	100	123.2	8.2						
Plate F, G and H										
LS29	666.5	70	63.6	3.0	5.8	35	4	9	14	19
LS18	600	45	38.3	1.0						
LS19	750	45	54.4	1.8						
Plate C, D and H										
LS6	590.5	100	69.1	4.1	8.6	52	4	13	15	22
LS20	587.5	45	64.2	1.7						
LS7	600	70	66.2	2.8						

Plate A, B and E										
LS17	1000	100	186.7	18.7	38.2	232	5	47	55	55
LS33	500	100	160.6	8.0						
LS12	666.5	100	172.2	11.5						
Plate F, G and H										
LS30	666.5	70	86.2	4.0	7.8	47	4	12	14	19
LS22	600	45	53.9	1.5						
LS23	750	45	68.1	2.3						
Plate C, D and H										
LS16	590.5	100	84.3	5.0	10.8	65	4	17	21	22
LS24	587.5	45	79.5	2.1						
LS11	600	70	88.4	3.7						

1913 - Messina Strait Bridge - Base Anchorage

Tower Leg Stiffening Plate Design

Tendon Anchor Pipes

Range of the number of strands in the tendons: $n_s := (55 \quad 43 \quad 37 \quad 31 \quad 27 \quad 22 \quad 19 \quad 12)^T$

Strand area: $A_s := 150 \cdot mm^2$

Strand characteristic strength: $f_{pk} := 1860 \cdot MPa$

Tendon areas: $A_{t_i} := n_{s_i} \cdot A_s$

$A_t^T = (8250 \quad 6450 \quad 5550 \quad 4650 \quad 4050 \quad 3300 \quad 2850 \quad 1800)\,mm^2$

Tendon ultimate strength: $T_{tu_i} := A_{t_i} \cdot f_{pk}$

$T_{tu}^T = (15.345 \quad 11.997 \quad 10.323 \quad 8.649 \quad 7.533 \quad 6.138 \quad 5.301 \quad 3.348)\,MN$

Assume tendons will be jacked to 80% of their ultimate load. Design the anchor pipes for 90% of their ultimate load.

Design compression: $P_{d_i} := 0.9 \cdot T_{tu_i}$

$P_d^T = (13.81 \quad 10.797 \quad 9.291 \quad 7.784 \quad 6.78 \quad 5.524 \quad 4.771 \quad 3.013)\,MN$

Pipe yield strength: $f_y := 460 \cdot MPa$

Material partial factor considering buckling: $\gamma_{M0} := 1.05$

Pipe outside diameters: $d_o := (350 \quad 325 \quad 300 \quad 275 \quad 275 \quad 250 \quad 225 \quad 200)^T \cdot mm$

Assuming no stability effects, determine the pipe thickness required:

Required pipe area: $A_{p_i} := \dfrac{P_{d_i} \cdot \gamma_{M0}}{f_y}$

$A_p^T = (31524 \quad 24646 \quad 21207 \quad 17768 \quad 15475 \quad 12610 \quad 10890 \quad 6878)\,mm^2$

Approximate pipe thickness:

$$t_{p_i} := \frac{1}{2}\cdot\left[d_{o_i} - \left[\frac{4}{\pi}\cdot\left[\frac{\pi}{4}\cdot\left(d_{o_i}\right)^2 - A_{p_i}\right]\right]^{0.5}\right]$$

$$t_p^{\,T} = (32 \quad 26 \quad 25 \quad 22 \quad 19 \quad 17 \quad 17 \quad 12)\,\text{mm}$$

Trial pipe thickness:

$$t_p := (35 \quad 30 \quad 30 \quad 25 \quad 25 \quad 20 \quad 20 \quad 15)^T\cdot\text{mm}$$

Compute section class:

Limiting d/t ratios:

Class 1 - $dt_{max1} := 50\cdot\frac{235\cdot\text{MPa}}{f_y}$ $\quad dt_{max1} = 25.543$

Class 2 - $dt_{max2} := 70\cdot\frac{235\cdot\text{MPa}}{f_y}$ $\quad dt_{max2} = 35.761$

Class 3 - $dt_{max3} := 90\cdot\frac{235\cdot\text{MPa}}{f_y}$ $\quad dt_{max3} = 45.978$

Actual d/t ratios:

$$dt_i := \frac{d_{o_i}}{t_{p_i}}$$

$$dt^T = (10 \quad 10.833 \quad 10 \quad 11 \quad 11 \quad 12.5 \quad 11.25 \quad 13.333)$$

All pipes are Class 1.

Pipe inner diameter:

$$d_{i_i} := d_{o_i} - 2\cdot t_{p_i}$$

$$d_i^{\,T} = (280 \quad 265 \quad 240 \quad 225 \quad 225 \quad 210 \quad 185 \quad 170)\,\text{mm}$$

Pipe area:

$$A_{p_i} := \left(\frac{\pi}{4}\right)\cdot\left[\left(d_{o_i}\right)^2 - \left(d_{i_i}\right)^2\right]$$

$$A_p^{\,T} = (34636 \quad 27803 \quad 25447 \quad 19635 \quad 19635 \quad 14451 \quad 12881 \quad 8718)\,\text{mm}^2$$

Pipe inertia:

$$I_{p_i} := \frac{\pi}{64}\cdot\left[\left(d_{o_i}\right)^4 - \left(d_{i_i}\right)^4\right]$$

$$I_p^{\,T} = \left(4.35\times10^8 \quad 3.06\times10^8 \quad 2.35\times10^8 \quad 1.55\times10^8 \quad 1.55\times10^8 \quad 9.63\times10^7 \quad 6.83\times10^7 \quad 3.75\times10^7\right)\text{mm}^4$$

Pipe radii of gyration: $i_{p_i} := \sqrt{\dfrac{I_{p_i}}{A_{p_i}}}$

$$i_p^T = (112 \quad 105 \quad 96 \quad 89 \quad 89 \quad 82 \quad 73 \quad 66)\,\mathrm{mm}$$

Conservatively assume an unbraced length of: $L_{cr} := 2\cdot m$

This is conservative because the compressive load being applied is internal and any deformation occurring at the onset of buckling will result in either a restoring force or a reduction of the load inducing buckling. If the computed buckling reduction factor is small, ignore overall buckling of the tendon anchor pipes.

Slenderness parameters: $\lambda_1 := 93.9\cdot\sqrt{\dfrac{235\cdot MPa}{f_y}}$ [EN 1993-1-1 Section 6.3.1.3]

$$\lambda_1 = 67.115$$

$$\lambda_{bar_i} := \frac{L_{cr}}{i_{p_i}\cdot\lambda_1}$$

$$\lambda_{bar}^T = (0.266 \quad 0.284 \quad 0.31 \quad 0.335 \quad 0.335 \quad 0.365 \quad 0.409 \quad 0.454)$$

Assume pipe are hot-rolled or cold rolled and heat treated allowing the use of buckling curve a_o.

Imperfection factor: $\alpha := 0.13$

Buckling reduction factor: $\Phi_i := 0.5\cdot\left[1 + \alpha\cdot\left(\lambda_{bar_i} - 0.2\right) + \left(\lambda_{bar_i}\right)^2\right]$

$$\Phi^T = (0.54 \quad 0.546 \quad 0.555 \quad 0.565 \quad 0.565 \quad 0.577 \quad 0.597 \quad 0.62)$$

$$\chi_i := \min\left[1, \left[\Phi_i + \sqrt{\left(\Phi_i\right)^2 - \left(\lambda_{bar_i}\right)^2}\right]^{-1}\right]$$

$$\chi^T = (0.991 \quad 0.988 \quad 0.984 \quad 0.981 \quad 0.981 \quad 0.976 \quad 0.969 \quad 0.96)$$

With buckling reduction factors of approximately 1.0, overall buckling of the pipes is not a problem. Use their gross cross sectional areas.

Determine the size of the welds required to connect the anchor pipe to the base plate and anchor plate.

Assume that the stiffener and anchor plate can be machined to bear directly on the top of the base plate. With this arrangement welds have to be provided to carry 25% of the load to be transferred (EN 1993-1-8 Section 6.2.7.1).

Material partial factor: $\gamma_{M0} := 1.05$

Welds will be governed by the lower strength base plate material: $f_y := 355 \cdot \text{MPa}$

Actual pipe stress during jacking:

$$\sigma_{c_i} := \frac{0.8 \cdot T_{tu_i}}{A_{p_i}}$$

$$\sigma_c^{\,T} = (354 \quad 345 \quad 325 \quad 352 \quad 307 \quad 340 \quad 329 \quad 307)\,\text{MPa}$$

Compressive stress limit based on the base plate strength:

$$\sigma_{cmax} := \frac{f_y}{\gamma_{M0}}$$

$$\sigma_{cmax} = 338.095\,\text{MPa}$$

Design the welds for 25% of the larger of the actual stress during jacking and the compressive stress limit.

$$F_{W_i} := 0.25 \cdot A_{p_i} \cdot \max\left(\sigma_{c_i}, \sigma_{cmax}\right)$$

$$F_W^{\,T} = (3.07 \quad 2.4 \quad 2.15 \quad 1.73 \quad 1.66 \quad 1.23 \quad 1.09 \quad 0.74)\,\text{MN}$$

Assume the weld length is the pipe circumference.

Weld demand per unit length:

$$F_{w_i} := \frac{F_{W_i}}{\pi \cdot d_{o_i}}$$

$$F_w^{\,T} = (2.791 \quad 2.35 \quad 2.282 \quad 2.002 \quad 1.921 \quad 1.563 \quad 1.54 \quad 1.173)\,\frac{\text{MN}}{\text{m}}$$

Base metal tensile strength: $f_u := 470 \cdot \text{MPa}$

Material partial factor: $\gamma_{M2} := 1.25$

Normal stress limit:

$$\sigma_{perp.max} := 0.9 \cdot \frac{f_u}{\gamma_{M2}}$$

$$\sigma_{perp.max} = 338.4\,\text{MPa}$$

Required preparation depth $s_{r_i} := \dfrac{F_{w_i}}{\sigma_{perp.max}}$

d_{pipe} (mm)	s (mm)
350	8.2
325	6.9
300	6.7
275	5.9
275	5.7
250	4.6
225	4.6
200	3.5

$$\frac{s_r}{t_p} = \begin{pmatrix} 0.236 \\ 0.231 \\ 0.225 \\ 0.237 \\ 0.227 \\ 0.231 \\ 0.228 \\ 0.231 \end{pmatrix}$$

The partial penetration weld doesn't seem well suited to the top and bottom of the pipe. Therefore, specifiy equivalent fillet welds.

Determine the size of equivalent fillet welds.

Correlation factor: $\beta_w := 0.9$ for Grade S355 steel

von Mises stress limit: $\sigma_{vm.max} := \dfrac{f_u}{\beta_w \cdot \gamma_{M2}}$

$\sigma_{vm.max} = 417.778\,\text{MPa}$

von Mises stress: $\sigma_{vm_i} := \left[\left(\dfrac{F_{w_i}}{\sqrt{2}}\right)^2 + 3\cdot\left(\dfrac{F_{w_i}}{\sqrt{2}}\right)^2\right]^{0.5}$

Required fillet weld throat: $a_{r_i} := \dfrac{\sigma_{vm_i}}{\sigma_{vm.max}}$

$$\frac{a_r}{t_p} = \begin{pmatrix} 0.27 \\ 0.265 \\ 0.258 \\ 0.271 \\ 0.26 \\ 0.265 \\ 0.261 \\ 0.265 \end{pmatrix}$$

d_{pipe} (mm)	a (mm)
350	9.4
325	8.0
300	7.7
275	6.8
275	6.5
250	5.3
225	5.2
200	4.0

Specify fillets as having a throat thickness equal to one quarter of the pipe thickness.

BASE PLATE STIFFENER,
THICKNESS TO MATCH THAT OF
OPPOSTE LONGITUDINAL
STIFFENER, TYP

1913 - Messina Strait Bridge - Base Plate Capacities

Base plate thickness =	0.15 m
Base plate area =	0.15 m^2/m
Base plate plastic modulus =	0.005625 m^3/m
Base plate yield strength =	355 MPa
Material partial factor =	1.05
Base plate design stress =	338 MPa

Cantilever Spans

Span (m)	0.1			0.2			0.225			0.25		
Bearing Pressure (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)
10	9	7	15	36	13	42	45	15	52	56	17	63
15	13	10	22	53	20	64	68	23	78	83	25	94
20	18	13	29	71	27	85	90	30	104	111	33	125
25	22	17	36	89	33	106	113	38	130	139	42	157
30	27	20	44	107	40	127	135	45	156	167	50	188
35	31	23	51	124	47	148	158	53	182	194	58	219
40	36	27	58	142	53	170	180	60	208	222	67	250
45	40	30	66	160	60	191	203	68	234	250	75	282
50	44	33	73	178	67	212	225	75	260	278	83	313
55	49	37	80	196	73	233	248	83	286	306	92	344
60	53	40	87	213	80	254	270	90	312	333	100	376
65	58	43	95	231	87	276	293	98	338	361	108	407
70	62	47	102	249	93	297	315	105	364	389	117	438

Span (m)	0.3			0.4			0.5		
Bearing Pressure (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)
10	80	20	87	142	27	150	222	33	230
15	120	30	131	213	40	224	333	50	344
20	160	40	174	284	53	299	444	67	459
25	200	50	218	356	67	374	556	83	574
30	240	60	262	427	80	449	667	100	689
35	280	70	305	498	93	523	778	117	804
40	320	80	349	569	107	598	889	133	918
45	360	90	392	640	120	673	1000	150	1033
50	400	100	436	711	133	748	1111	167	1148
55	440	110	479	782	147	822	1222	183	1263
60	480	120	523	853	160	897	1333	200	1378
65	520	130	567	924	173	972	1444	217	1492
70	560	140	610	996	187	1047	1556	233	1607

Continuous Spans

Span (m)	0.1			0.2			0.3			0.4		
Bearing Pressure (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)
10	2	3	6	7	7	14	16	10	24	28	13	37
15	3	5	9	11	10	20	24	15	35	43	20	55
20	4	7	12	14	13	27	32	20	47	57	27	73
25	4	8	15	18	17	34	40	25	59	71	33	92
30	5	10	18	21	20	41	48	30	71	85	40	110
35	6	12	21	25	23	47	56	35	83	100	47	128
40	7	13	24	28	27	54	64	40	94	114	53	147
45	8	15	27	32	30	61	72	45	106	128	60	165
50	9	17	30	36	33	68	80	50	118	142	67	183
55	10	18	33	39	37	75	88	55	130	156	73	202
60	11	20	36	43	40	81	96	60	141	171	80	220
65	12	22	39	46	43	88	104	65	153	185	87	238
70	12	23	42	50	47	95	112	70	165	199	93	256

Span (m)	0.5			0.55			0.6			0.65		
Bearing Pressure (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)
10	44	17	53	54	18	62	64	20	73	75	22	84
15	67	25	79	81	28	94	96	30	109	113	33	126
20	89	33	106	108	37	125	128	40	146	150	43	168
25	111	42	132	134	46	156	160	50	182	188	54	210
30	133	50	159	161	55	187	192	60	218	225	65	252
35	156	58	185	188	64	219	224	70	255	263	76	294
40	178	67	212	215	73	250	256	80	291	300	87	336
45	200	75	238	242	83	281	288	90	327	338	98	378
50	222	83	265	269	92	312	320	100	364	376	108	420
55	244	92	291	296	101	343	352	110	400	413	119	462
60	267	100	318	323	110	375	384	120	437	451	130	504
65	289	108	344	350	119	406	416	130	473	488	141	546
70	311	117	371	376	128	437	448	140	509	526	152	588

Span (m)	0.7			0.75			0.8			0.85		
Bearing Pressure (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)	σ_b (MPa)	τ (MPa)	von Mises (MPa)
10	87	23	96	100	25	109	114	27	123	128	28	138
15	131	35	144	150	38	163	171	40	184	193	43	206
20	174	47	192	200	50	218	228	53	246	257	57	275
25	218	58	240	250	63	272	284	67	307	321	71	344
30	261	70	288	300	75	327	341	80	368	385	85	413
35	305	82	336	350	88	381	398	93	430	450	99	481
40	348	93	384	400	100	436	455	107	491	514	113	550
45	392	105	432	450	113	490	512	120	553	578	128	619
50	436	117	480	500	125	545	569	133	614	642	142	688
55	479	128	528	550	138	599	626	147	675	706	156	756
60	523	140	576	600	150	654	683	160	737	771	170	825
65	566	152	624	650	163	708	740	173	798	835	184	894
70	610	163	672	700	175	763	796	187	860	899	198	963

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1913 - Messina Strait Bridge - Base Anchorage Design

Von Mises Stresses on Vertical Stiffeners

Plate slenderness:
$$\lambda_p(h,b,f_y) := \frac{\frac{h}{b}}{28.4\cdot\sqrt{\frac{235\cdot MPa}{f_y}}\cdot\sqrt{0.85}}$$

Reduction factor:
$$\rho\left(h,b,f_y\right) := \frac{\lambda_p(h,b,f_y) - 0.055\cdot 2}{\lambda_p(h,b,f_y)^2}$$

Shear stress:
$$\alpha(Vo,y,b,h) := -\frac{6\cdot Vo\cdot y}{b\cdot h^3}\cdot(y-h)$$

Bending compressive stress:
$$\sigma_b(Mo,y,b,h) := \frac{12\cdot Mo\cdot(y-0.5\cdot h)}{b\cdot h^3}$$

von Mises Stress:
$$\sigma_{vm}(Mo,Vo,y,b,h) := \sqrt{\sigma_b(Mo,y,b,h)^2 + 3\cdot\alpha(Vo,y,b,h)^2}$$

von Mises Stress amplified:
$$\sigma_{vm\_amp}(Mo,Vo,y,b,h,f_y) := \sqrt{\left(\frac{\sigma_b(Mo,y,b,h)}{\rho\left(h,b,f_y\right)}\right)^2 + 3\cdot\alpha(Vo,y,b,h)^2}$$

Yield strength: $f_y := 355\cdot MPa$

Case 1

Stiffener thickness: $b := 30 \cdot mm$

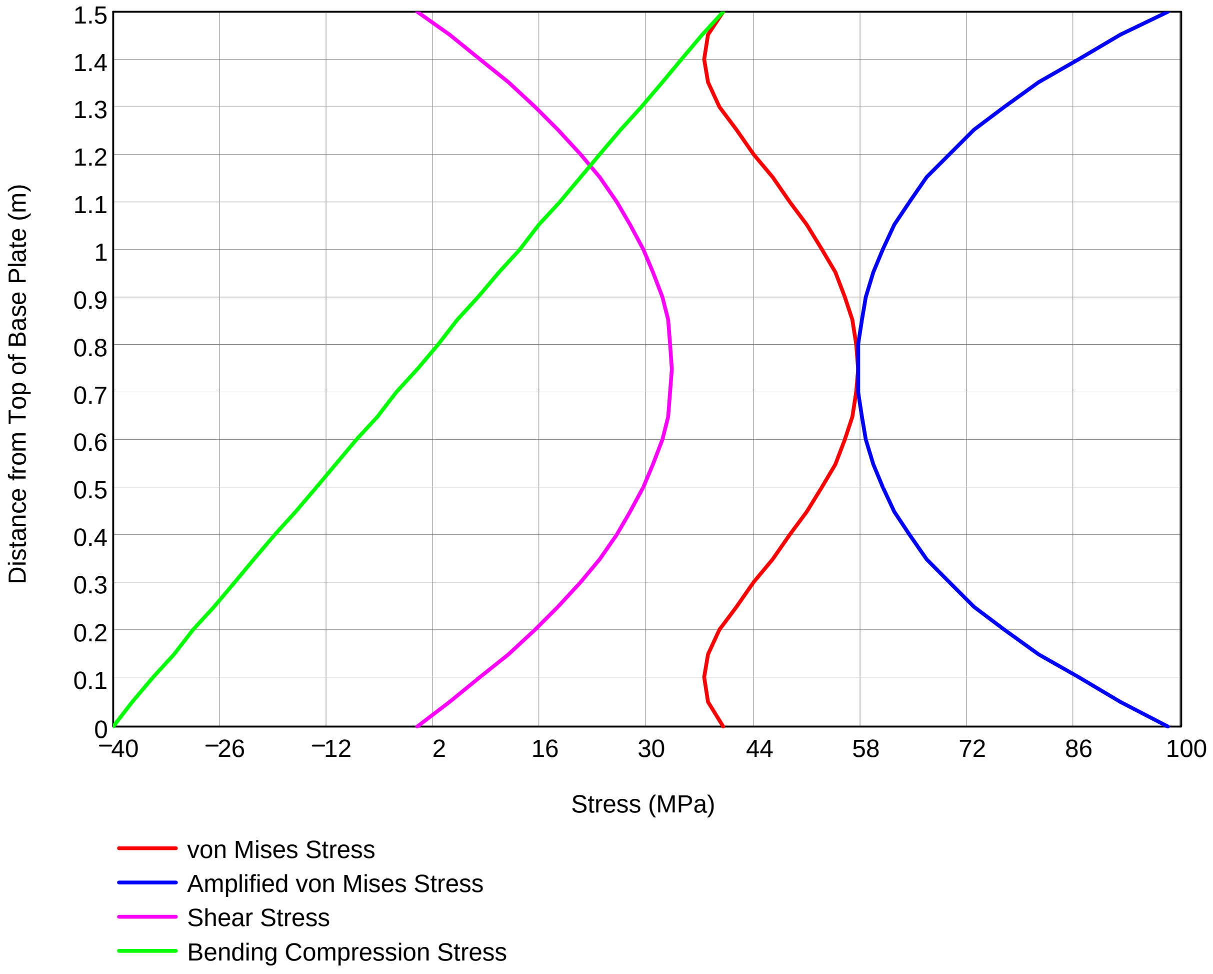
Stiffener depth: $h := 1500 \cdot mm$

Shear force: $Vo := 1 \cdot MN$

Moment as a fraction of shear force: $Mo := Vo \cdot 0.45 \cdot m$

Range variable to cycle through stiffener depth: $y := 0 \cdot m, 0.05 \cdot m .. 1.5 \cdot m$

Reduction factor: $\rho\left(h, b, f_y\right) = 0.406$



Case 2

Stiffener thickness: $b := 40 \cdot mm$

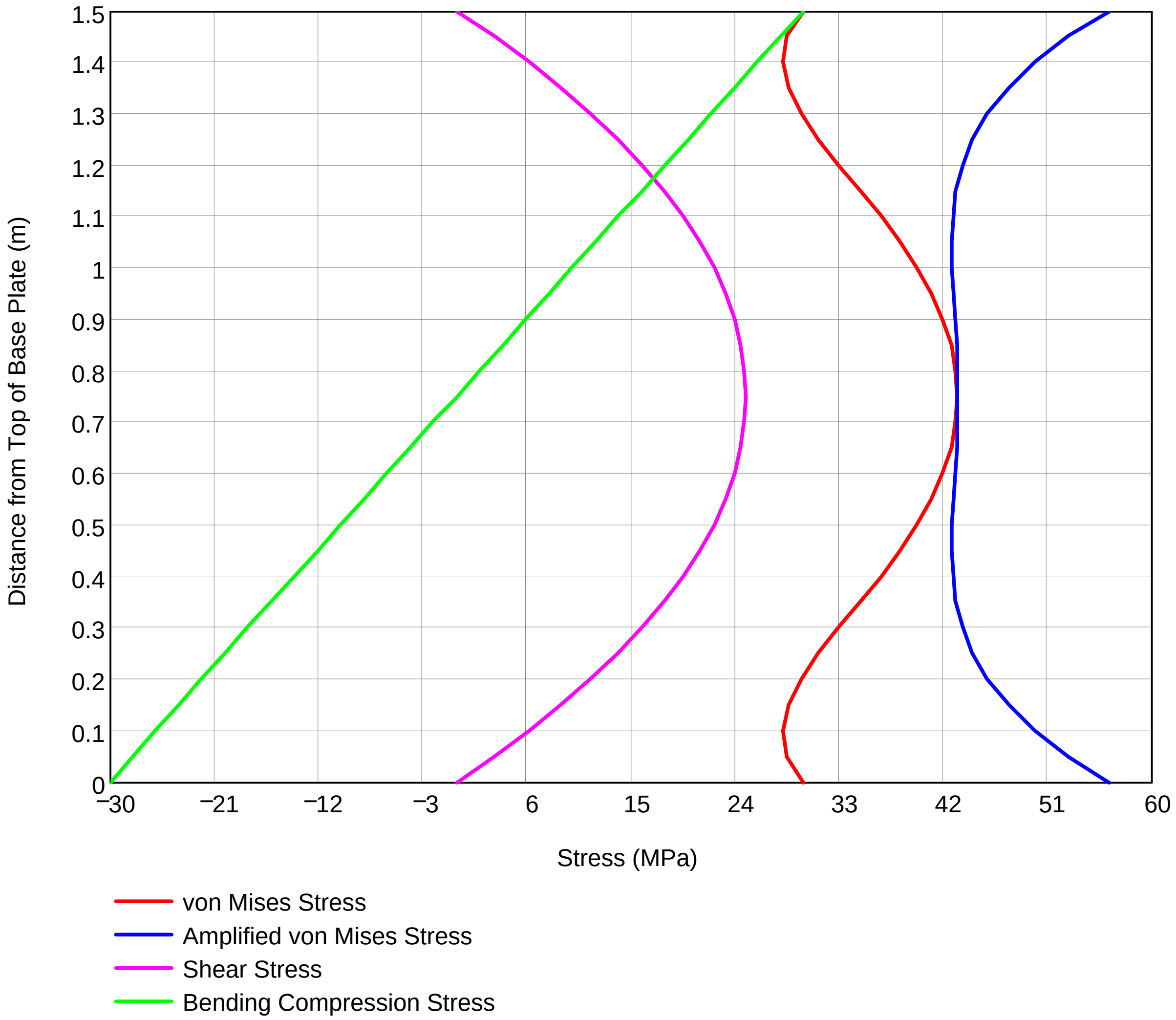
Stiffener depth: $h := 1500 \cdot mm$

Shear force: $Vo := 1 \cdot MN$

Moment as a fraction of shear force: $Mo := Vo \cdot 0.45 \cdot m$

Range variable to cycle through stiffener depth: $y := 0 \cdot m, 0.05 \cdot m .. 1.5 \cdot m$

Reduction factor: $\rho\left(h, b, f_y\right) = 0.533$



Case 3

Stiffener thickness: $b := 50\cdot mm$

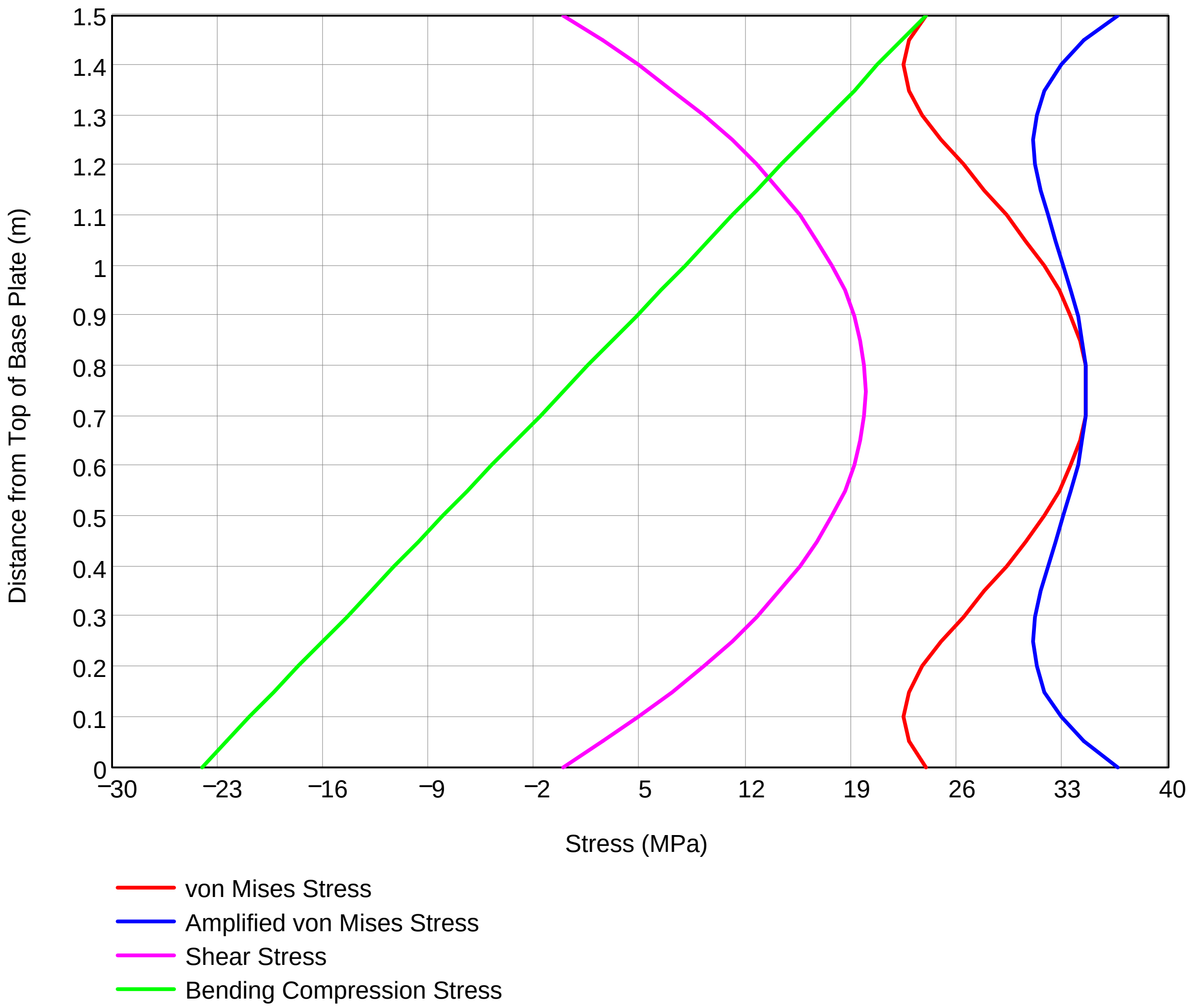
Stiffener depth: $h := 1500\cdot mm$

Shear force: $Vo := 1\cdot MN$

Moment as a fraction of shear force: $Mo := Vo\cdot 0.45\cdot m$

Range variable to cycle through stiffener depth: $y := 0\cdot m, 0.05\cdot m .. 1.5\cdot m$

Reduction factor: $\rho\left(h, b, f_y\right) = 0.655$ $\qquad \dfrac{0.45}{\rho\left(h, b, f_y\right)} = 0.687$



Case 4

Stiffener thickness: $b := 53 \cdot mm$

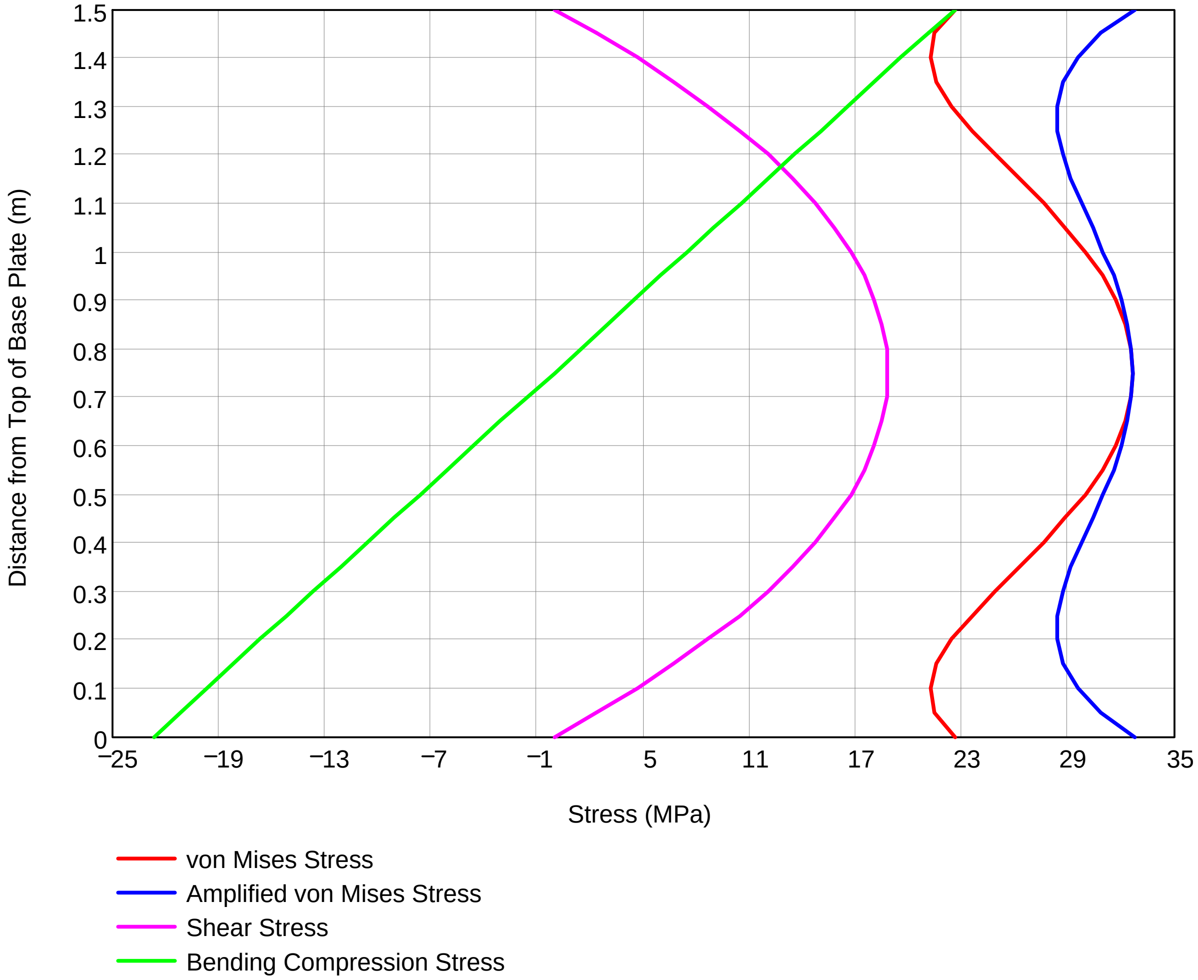
Stiffener depth: $h := 1500 \cdot mm$

Shear force: $Vo := 1 \cdot MN$

Moment as a fraction of shear force: $Mo := Vo \cdot 0.45 \cdot m$

Range variable to cycle through stiffener depth: $y := 0 \cdot m, 0.05 \cdot m \,..\, 1.5 \cdot m$

Reduction factor: $\rho\left(h, b, f_y\right) = 0.69$ $\quad \dfrac{0.45}{\rho\left(h, b, f_y\right)} = 0.652$



Case 5

Stiffener thickness: $b := 60 \cdot mm$

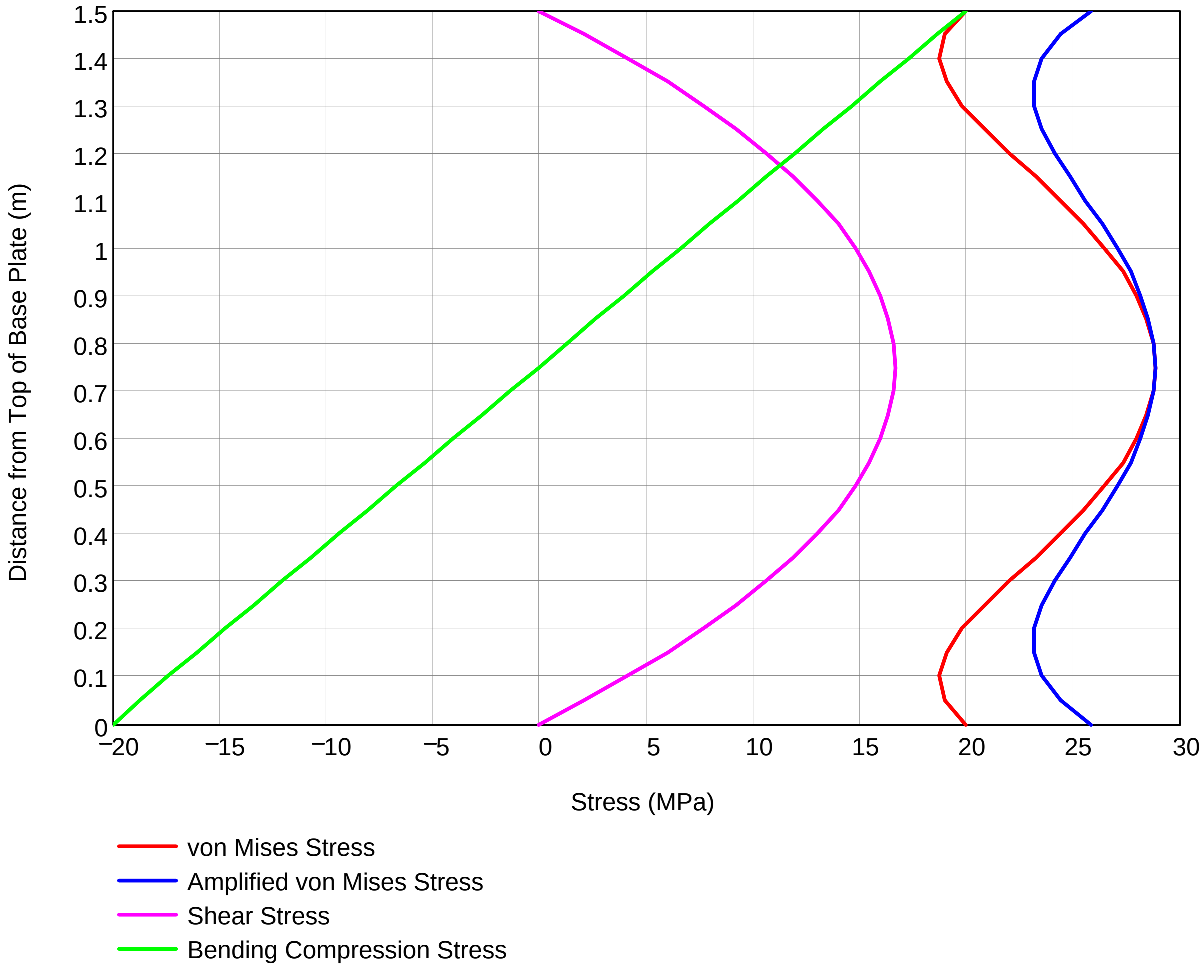
Stiffener depth: $h := 1500 \cdot mm$

Shear force: $Vo := 1 \cdot MN$

Moment as a fraction of shear force: $Mo := Vo \cdot 0.45 \cdot m$

Range variable to cycle through stiffener depth: $y := 0 \cdot m, 0.05 \cdot m .. 1.5 \cdot m$

Reduction factor: $\rho\left(h, b, f_y\right) = 0.772$ $\qquad \dfrac{0.45}{\rho\left(h, b, f_y\right)} = 0.583$



Case 6

Stiffener thickness: $b := 70 \cdot mm$

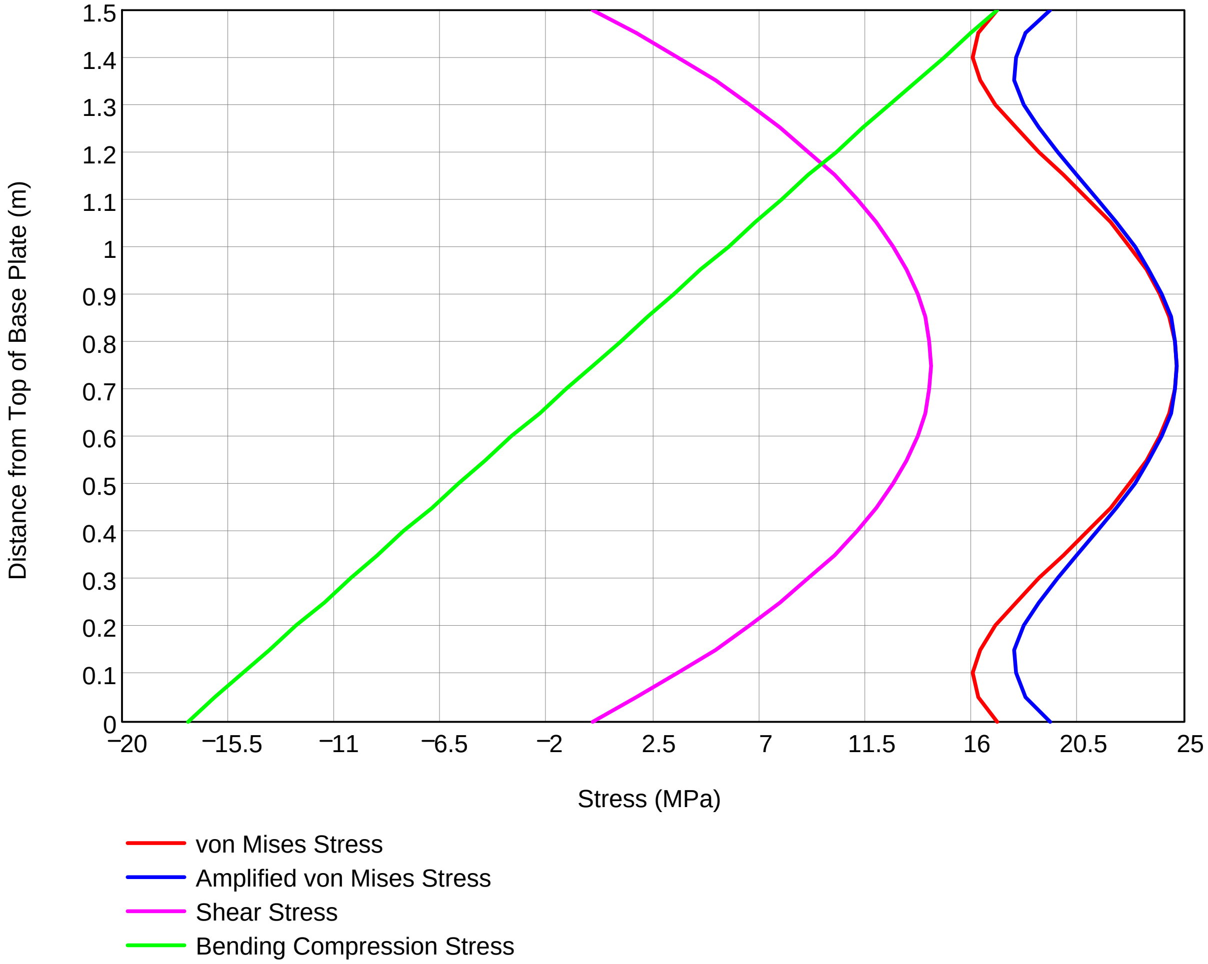
Stiffener depth: $h := 1500 \cdot mm$

Shear force: $Vo := 1 \cdot MN$

Moment as a fraction of shear force: $Mo := Vo \cdot 0.45 \cdot m$

Range variable to cycle through stiffener depth: $y := 0 \cdot m, 0.05 \cdot m .. 1.5 \cdot m$

Reduction factor: $\rho\left(h, b, f_y\right) = 0.885$ $\qquad \dfrac{0.45}{\rho\left(h, b, f_y\right)} = 0.508$



1913 - Messina Strait Bridge - Vertical Stiffener Capacities

Base plate width carried = 0.6 m
Length tributary to tower leg plate = 0.15 m
Stiffener plate yield strength = 355 MPa
Material partial factor = 1.1
Design stress = 323 MPa
Nominal depth = 1.5 m

Stiffener thickness = 0.03 m
λ_{p_bar} = 2.35
ρ = 0.41
Effective depth = 1.055 m
Gross stiffener area = 0.045 m^2
Gross stiffener elastic modulus = 0.01125 m^3
Reduced stiffener elastic modulus = 0.00556 m^3

Tributary Width (m)	0.2				0.3				0.4			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	48	27	69	118	72	40	104	177	96	53	139	236
15	72	40	104	177	108	60	156	266	144	80	208	355
20	96	53	139	236	144	80	208	355	192	107	277	473
25	120	67	173	295	180	100	260	443	240	133	346	591
30	144	80	208	355	216	120	312	532	288	160	416	709
35	168	93	242	414	252	140	364	621	336	187	485	827
40	192	107	277	473	288	160	416	709	384	213	554	946
45	216	120	312	532	324	180	468	798	432	240	624	1064
50	240	133	346	591	360	200	520	886	480	267	693	1182
55	264	147	381	650	396	220	572	975	528	293	762	1300
60	288	160	416	709	432	240	624	1064	576	320	831	1418
65	312	173	450	768	468	260	675	1152	624	347	901	1537
70	336	187	485	827	504	280	727	1241	672	373	970	1655

Tributary Width (m)	0.45				0.5				0.55			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	108	60	156	266	120	67	173	295	132	73	191	325
15	162	90	234	399	180	100	260	443	198	110	286	488
20	216	120	312	532	240	133	346	591	264	147	381	650
25	270	150	390	665	300	167	433	739	330	183	476	813
30	324	180	468	798	360	200	520	886	396	220	572	975
35	378	210	546	931	420	233	606	1034	462	257	667	1138
40	432	240	624	1064	480	267	693	1182	528	293	762	1300
45	486	270	701	1197	540	300	779	1330	594	330	857	1463
50	540	300	779	1330	600	333	866	1477	660	367	953	1625
55	594	330	857	1463	660	367	953	1625	726	403	1048	1788
60	648	360	935	1596	720	400	1039	1773	792	440	1143	1950
65	702	390	1013	1729	780	433	1126	1921	858	477	1238	2113
70	756	420	1091	1862	840	467	1212	2068	924	513	1334	2275

Tributary Width (m)	0.6				0.7				0.8			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	144	80	208	355	168	93	242	414	192	107	277	473
15	216	120	312	532	252	140	364	621	288	160	416	709
20	288	160	416	709	336	187	485	827	384	213	554	946
25	360	200	520	886	420	233	606	1034	480	267	693	1182
30	432	240	624	1064	504	280	727	1241	576	320	831	1418
35	504	280	727	1241	588	327	849	1448	672	373	970	1655
40	576	320	831	1418	672	373	970	1655	768	427	1109	1891
45	648	360	935	1596	756	420	1091	1862	864	480	1247	2128
50	720	400	1039	1773	840	467	1212	2068	960	533	1386	2364
55	792	440	1143	1950	924	513	1334	2275	1056	587	1524	2600
60	864	480	1247	2128	1008	560	1455	2482	1152	640	1663	2837
65	936	520	1351	2305	1092	607	1576	2689	1248	693	1801	3073
70	1008	560	1455	2482	1176	653	1697	2896	1344	747	1940	3310

Tributary Width (m)	0.9			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	216	120	312	532
15	324	180	468	798
20	432	240	624	1064
25	540	300	779	1330
30	648	360	935	1596
35	756	420	1091	1862
40	864	480	1247	2128
45	972	540	1403	2394
50	1080	600	1559	2659
55	1188	660	1715	2925
60	1296	720	1871	3191
65	1404	780	2026	3457
70	1512	840	2182	3723

Stiffener thickness = 0.04 m
λ_{p_bar} = 1.76
ρ = 0.53
Effective depth = 1.149 m
Gross stiffener area = 0.06 m^2
Gross stiffener elastic modulus = 0.015 m^3
Reduced stiffener elastic modulus = 0.00881 m^3

Tributary Width (m)	0.2				0.3				0.4			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	36	20	52	68	54	30	78	101	72	40	104	135
15	54	30	78	101	81	45	117	152	108	60	156	203
20	72	40	104	135	108	60	156	203	144	80	208	270
25	90	50	130	169	135	75	195	253	180	100	260	338
30	108	60	156	203	162	90	234	304	216	120	312	406
35	126	70	182	237	189	105	273	355	252	140	364	473
40	144	80	208	270	216	120	312	406	288	160	416	541
45	162	90	234	304	243	135	351	456	324	180	468	608
50	180	100	260	338	270	150	390	507	360	200	520	676
55	198	110	286	372	297	165	429	558	396	220	572	744
60	216	120	312	406	324	180	468	608	432	240	624	811
65	234	130	338	439	351	195	507	659	468	260	675	879
70	252	140	364	473	378	210	546	710	504	280	727	946

Tributary Width (m)	0.45				0.5				0.55			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	81	45	117	152	90	50	130	169	99	55	143	186
15	122	68	175	228	135	75	195	253	149	83	214	279
20	162	90	234	304	180	100	260	338	198	110	286	372
25	203	113	292	380	225	125	325	422	248	138	357	465
30	243	135	351	456	270	150	390	507	297	165	429	558
35	284	158	409	532	315	175	455	591	347	193	500	651
40	324	180	468	608	360	200	520	676	396	220	572	744
45	365	203	526	684	405	225	585	760	446	248	643	836
50	405	225	585	760	450	250	650	845	495	275	714	929
55	446	248	643	836	495	275	714	929	545	303	786	1022
60	486	270	701	913	540	300	779	1014	594	330	857	1115
65	527	293	760	989	585	325	844	1098	644	358	929	1208
70	567	315	818	1065	630	350	909	1183	693	385	1000	1301

Tributary Width (m)	0.6				0.7				0.8			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	108	60	156	203	126	70	182	237	144	80	208	270
15	162	90	234	304	189	105	273	355	216	120	312	406
20	216	120	312	406	252	140	364	473	288	160	416	541
25	270	150	390	507	315	175	455	591	360	200	520	676
30	324	180	468	608	378	210	546	710	432	240	624	811
35	378	210	546	710	441	245	637	828	504	280	727	946
40	432	240	624	811	504	280	727	946	576	320	831	1082
45	486	270	701	913	567	315	818	1065	648	360	935	1217
50	540	300	779	1014	630	350	909	1183	720	400	1039	1352
55	594	330	857	1115	693	385	1000	1301	792	440	1143	1487
60	648	360	935	1217	756	420	1091	1419	864	480	1247	1622
65	702	390	1013	1318	819	455	1182	1538	936	520	1351	1757
70	756	420	1091	1419	882	490	1273	1656	1008	560	1455	1893

Tributary Width (m)	0.9			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	162	90	234	304
15	243	135	351	456
20	324	180	468	608
25	405	225	585	760
30	486	270	701	913
35	567	315	818	1065
40	648	360	935	1217
45	729	405	1052	1369
50	810	450	1169	1521
55	891	495	1286	1673
60	972	540	1403	1825
65	1053	585	1520	1977
70	1134	630	1637	2129

Stiffener thickness = 0.05 m
λ_{p_bar} = 1.41
ρ = 0.65
Effective depth = 1.241 m
Gross stiffener area = 0.075 m^2
Gross stiffener elastic modulus = 0.01875 m^3
Reduced stiffener elastic modulus = 0.01283 m^3

Tributary Width (m)	0.2				0.3				0.413			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	29	16	42	44	43	24	62	66	59	33	86	91
15	43	24	62	66	65	36	94	99	89	50	129	136
20	58	32	83	88	86	48	125	132	119	66	172	182
25	72	40	104	110	108	60	156	165	149	83	215	227
30	86	48	125	132	130	72	187	198	178	99	258	273
35	101	56	145	154	151	84	218	231	208	116	300	318
40	115	64	166	176	173	96	249	264	238	132	343	363
45	130	72	187	198	194	108	281	297	268	149	386	409
50	144	80	208	220	216	120	312	330	297	165	429	454
55	158	88	229	242	238	132	343	363	327	182	472	500
60	173	96	249	264	259	144	374	396	357	198	515	545
65	187	104	270	286	281	156	405	429	387	215	558	591
70	202	112	291	308	302	168	436	462	416	231	601	636

Tributary Width (m)	0.45				0.5				0.55			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	65	36	94	99	72	40	104	110	79	44	114	121
15	97	54	140	148	108	60	156	165	119	66	171	181
20	130	72	187	198	144	80	208	220	158	88	229	242
25	162	90	234	247	180	100	260	275	198	110	286	302
30	194	108	281	297	216	120	312	330	238	132	343	363
35	227	126	327	346	252	140	364	385	277	154	400	423
40	259	144	374	396	288	160	416	440	317	176	457	484
45	292	162	421	445	324	180	468	495	356	198	514	544
50	324	180	468	495	360	200	520	550	396	220	572	605
55	356	198	514	544	396	220	572	605	436	242	629	665
60	389	216	561	594	432	240	624	660	475	264	686	726
65	421	234	608	643	468	260	675	715	515	286	743	786
70	454	252	655	693	504	280	727	770	554	308	800	847

Tributary Width (m)	0.6				0.7				0.8			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	86	48	125	132	101	56	145	154	115	64	166	176
15	130	72	187	198	151	84	218	231	173	96	249	264
20	173	96	249	264	202	112	291	308	230	128	333	352
25	216	120	312	330	252	140	364	385	288	160	416	440
30	259	144	374	396	302	168	436	462	346	192	499	528
35	302	168	436	462	353	196	509	539	403	224	582	616
40	346	192	499	528	403	224	582	616	461	256	665	704
45	389	216	561	594	454	252	655	693	518	288	748	792
50	432	240	624	660	504	280	727	770	576	320	831	880
55	475	264	686	726	554	308	800	847	634	352	915	968
60	518	288	748	792	605	336	873	924	691	384	998	1056
65	562	312	811	858	655	364	946	1001	749	416	1081	1144
70	605	336	873	924	706	392	1018	1078	806	448	1164	1232

Tributary Width (m)	0.9			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	130	72	187	198
15	194	108	281	297
20	259	144	374	396
25	324	180	468	495
30	389	216	561	594
35	454	252	655	693
40	518	288	748	792
45	583	324	842	891
50	648	360	935	990
55	713	396	1029	1089
60	778	432	1122	1188
65	842	468	1216	1287
70	907	504	1309	1386

Stiffener thickness = 0.06 m
λ_{p_bar} = 1.17
ρ = 0.77
Effective depth = 1.329 m
Gross stiffener area = 0.09 m^2
Gross stiffener elastic modulus = 0.0225 m^3
Reduced stiffener elastic modulus = 0.01767 m^3

Tributary Width (m)	0.2				0.3				0.4			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	24	13	35	35	36	20	52	52	48	27	69	69
15	36	20	52	52	54	30	78	78	72	40	104	104
20	48	27	69	69	72	40	104	104	96	53	139	139
25	60	33	87	87	90	50	130	130	120	67	173	173
30	72	40	104	104	108	60	156	156	144	80	208	208
35	84	47	121	121	126	70	182	182	168	93	242	242
40	96	53	139	139	144	80	208	208	192	107	277	277
45	108	60	156	156	162	90	234	234	216	120	312	312
50	120	67	173	173	180	100	260	260	240	133	346	346
55	132	73	191	191	198	110	286	286	264	147	381	381
60	144	80	208	208	216	120	312	312	288	160	416	416
65	156	87	225	225	234	130	338	338	312	173	450	450
70	168	93	242	242	252	140	364	364	336	187	485	485

Tributary Width (m)	0.47				0.5				0.55			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	56	31	81	81	60	33	87	87	66	37	95	95
15	85	47	122	122	90	50	130	130	99	55	143	143
20	113	63	163	163	120	67	173	173	132	73	191	191
25	141	78	204	204	150	83	217	217	165	92	238	238
30	169	94	244	244	180	100	260	260	198	110	286	286
35	197	110	285	285	210	117	303	303	231	128	333	333
40	226	125	326	326	240	133	346	346	264	147	381	381
45	254	141	366	366	270	150	390	390	297	165	429	429
50	282	157	407	407	300	167	433	433	330	183	476	476
55	310	172	448	448	330	183	476	476	363	202	524	524
60	338	188	488	488	360	200	520	520	396	220	572	572
65	367	204	529	529	390	217	563	563	429	238	619	619
70	395	219	570	570	420	233	606	606	462	257	667	667

Tributary Width (m)	0.6				0.7				0.8			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	72	40	104	104	84	47	121	121	96	53	139	139
15	108	60	156	156	126	70	182	182	144	80	208	208
20	144	80	208	208	168	93	242	242	192	107	277	277
25	180	100	260	260	210	117	303	303	240	133	346	346
30	216	120	312	312	252	140	364	364	288	160	416	416
35	252	140	364	364	294	163	424	424	336	187	485	485
40	288	160	416	416	336	187	485	485	384	213	554	554
45	324	180	468	468	378	210	546	546	432	240	624	624
50	360	200	520	520	420	233	606	606	480	267	693	693
55	396	220	572	572	462	257	667	667	528	293	762	762
60	432	240	624	624	504	280	727	727	576	320	831	831
65	468	260	675	675	546	303	788	788	624	347	901	901
70	504	280	727	727	588	327	849	849	672	373	970	970

Tributary Width (m)	0.9			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	108	60	156	156
15	162	90	234	234
20	216	120	312	312
25	270	150	390	390
30	324	180	468	468
35	378	210	546	546
40	432	240	624	624
45	486	270	701	701
50	540	300	779	779
55	594	330	857	857
60	648	360	935	935
65	702	390	1013	1013
70	756	420	1091	1091

Stiffener thickness = 0.07 m
λ_{p_bar} = 1.01
ρ = 0.89
Effective depth = 1.414 m
Gross stiffener area = 0.105 m^2
Gross stiffener elastic modulus = 0.02625 m^3
Reduced stiffener elastic modulus = 0.02333 m^3

Tributary Width (m)	0.2				0.3				0.4			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	21	11	30	30	31	17	45	45	41	23	59	59
15	31	17	45	45	46	26	67	67	62	34	89	89
20	41	23	59	59	62	34	89	89	82	46	119	119
25	51	29	74	74	77	43	111	111	103	57	148	148
30	62	34	89	89	93	51	134	134	123	69	178	178
35	72	40	104	104	108	60	156	156	144	80	208	208
40	82	46	119	119	123	69	178	178	165	91	238	238
45	93	51	134	134	139	77	200	200	185	103	267	267
50	103	57	148	148	154	86	223	223	206	114	297	297
55	113	63	163	163	170	94	245	245	226	126	327	327
60	123	69	178	178	185	103	267	267	247	137	356	356
65	134	74	193	193	201	111	289	289	267	149	386	386
70	144	80	208	208	216	120	312	312	288	160	416	416

Tributary Width (m)	0.47				0.5				0.55			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	48	27	70	70	51	29	74	74	57	31	82	82
15	73	40	105	105	77	43	111	111	85	47	122	122
20	97	54	140	140	103	57	148	148	113	63	163	163
25	121	67	174	174	129	71	186	186	141	79	204	204
30	145	81	209	209	154	86	223	223	170	94	245	245
35	169	94	244	244	180	100	260	260	198	110	286	286
40	193	107	279	279	206	114	297	297	226	126	327	327
45	218	121	314	314	231	129	334	334	255	141	367	367
50	242	134	349	349	257	143	371	371	283	157	408	408
55	266	148	384	384	283	157	408	408	311	173	449	449
60	290	161	419	419	309	171	445	445	339	189	490	490
65	314	175	454	454	334	186	482	482	368	204	531	531
70	338	188	488	488	360	200	520	520	396	220	572	572

Tributary Width (m)	0.68				0.76				0.8			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	70	39	101	101	78	43	113	113	82	46	119	119
15	105	58	151	151	117	65	169	169	123	69	178	178
20	140	78	202	202	156	87	226	226	165	91	238	238
25	175	97	252	252	195	109	282	282	206	114	297	297
30	210	117	303	303	235	130	338	338	247	137	356	356
35	245	136	353	353	274	152	395	395	288	160	416	416
40	280	155	404	404	313	174	451	451	329	183	475	475
45	315	175	454	454	352	195	508	508	370	206	534	534
50	350	194	505	505	391	217	564	564	411	229	594	594
55	385	214	555	555	430	239	621	621	453	251	653	653
60	420	233	606	606	469	261	677	677	494	274	713	713
65	455	253	656	656	508	282	733	733	535	297	772	772
70	490	272	707	707	547	304	790	790	576	320	831	831

Tributary Width (m)	0.9			
Bearing Pressure (MPa)	σ_b (MPa)	τ_{avg} (MPa)	Max von Mises (MPa)	Max Amplified von Mises (MPa)
10	93	51	134	134
15	139	77	200	200
20	185	103	267	267
25	231	129	334	334
30	278	154	401	401
35	324	180	468	468
40	370	206	534	534
45	417	231	601	601
50	463	257	668	668
55	509	283	735	735
60	555	309	802	802
65	602	334	868	868
70	648	360	935	935

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ALL OTHER ⅊ TENDONS ARE SMALLER THAN 52 STRANDS, BUT HAVE THE SAME 50 mm THICK STIFFENERS. ⅊C HAS 50 mm STIFFENERS ALSO.

THERE CERTAINLY DOESN'T APPEAR TO BE AN ISSUE. AS A WORST CASE SCENARIO CHECK IF THE SMALLEST 40 mm STIFFENER CAN CARRY THE SHEAR FROM A 52 STRAND TENDON.

$V_r = 0.04(323) = 12.9\ \text{MN} \therefore \underline{\text{OK}}$

FOR A 55 STRAND TENDON: $V = 55(150)(1209)\times10^{-6}$

$= 9.97\ \text{MN}.$ ✓

IN THE FINAL DRAWING REVISION THE FIN STIFFENERS (ALSO KNOWN AS BASE PLATE STIFFENERS) HAVE BEEN MODIFIED TO HAVE THE SAME THICKNESSES AS THE TOWER LEG LONGITUDINAL STIFFENERS OPPOSITE THEM. THE FIN STIFFENERS HAVE ALSO BEEN INCREASED IN HEIGHT TO 2.5 M. THESE MODIFICATIONS WERE MADE SO AS TO MORE GRADUALLY INTRODUCE TOWER LEG FORCES INTO THE STIFFENERS AND TO MINIMIZE POTENTIAL ECCENTRICITIES OF TOWER BASE TENSILE FORCE LINES OF ACTION TO THE LINES OF ACTION OF THE RESISTING ANCHORAGE TENDONS. ECCENTRICITIES ARE MINIMIZED BY BETTER BALANCING THE AMOUNT OF THE STEEL (STIFFENING) PLACED ON EITHER SIDE OF THE TOWER LEG MAIN PLATES. CHANGES HAVE BEEN MADE IN RESPONSE TO A REVIEW COMMENT RECEIVED FROM THE PMC.

IN ALL CASES, THIS CHANGE RESULTS IN AN INCREASE OF THE FIN STIFFENER CAPACITY AND NO FUTHER DESIGN CHECKS ARE NECESSARY.

Stiffener Welds

Using Fillet Welds

Determine the corresponding normal and shear stress components on the welds connecting the stiffeners to the anchor pipes and tower leg plates.

$$\sigma_{perp}(Mo,y,b,h) := \frac{\sigma_b(Mo,y,b,h)\cdot b}{\sqrt{2}\cdot 2}$$

Stresses are expressed as MN/m and must be divided by the weld throat to produce the actual stress.

$$\alpha_{perp}(Mo,y,b,h) := \frac{\sigma_b(Mo,y,b,h)\cdot b}{\sqrt{2}\cdot 2}$$

$$\alpha_{ptr}(Vo,y,b,h) := \alpha(Vo,y,b,h)\cdot\frac{b}{2}$$

von Mises weld stress:

$$\sigma_{vm.weld}(Mo,Vo,y,b,h) := \left[\sigma_{perp}(Mo,y,b,h)^2 + 3\cdot\left(\alpha_{perp}(Mo,y,b,h)^2 + \alpha_{ptr}(Vo,y,b,h)^2\right)\right]^{0.5}$$

Limit stresses:

Correlation factor: $\beta_w := 0.9$ for Grade S355 steel

Base metal tensile strength: $f_u := 470\cdot MPa$

Material partial factor: $\gamma_{M2} := 1.25$

von Mises stress limit: $\sigma_{vm.max} := \dfrac{f_u}{\beta_w\cdot\gamma_{M2}}$

$$\sigma_{vm.max} = 417.778\,MPa$$

Normal stress limit: $\sigma_{perp.max} := 0.9\cdot\dfrac{f_u}{\gamma_{M2}}$

$$\sigma_{perp.max} = 338.4\,MPa$$

Required weld throat for von Mises stresses:

$$a_{vm}(Mo, Vo, y, b, h) := \frac{\sigma_{vm.weld}(Mo, Vo, y, b, h)}{\sigma_{vm.max}}$$

Required weld throat for normal stresses:

$$a_n(Mo, y, b, h) := \frac{\sigma_{perp}(Mo, y, b, h)}{\sigma_{perp.max}}$$

Governing weld throat:

$$a_r\left(Mo, Vo, y_{vm}, y_n, b, h\right) := \max\left(a_{vm}\left(Mo, Vo, y_{vm}, b, h\right), a_n\left(Mo, y_n, b, h\right)\right)$$

Bearing pressure:

$$i := 1 .. 7$$

$$\sigma_{bp_i} := 5\cdot(i + 1)\cdot MPa$$

Tributary width:

$$j := 1 .. 17$$

$$w_{arib_j} := (0.05\cdot j + 0.15)\cdot m$$

The bearing pressure on the first 150 mm of base plate width outside of the tower leg plate is assumed to be carried directly through the base plate into the tower leg plate (i.e, does not load the stiffener), the bearing pressures on the outer 600 mm of the base plate width is carried by the stiffener. The distribution of weld demands over the depth of the stiffener depends on the ratio of shear force to the moment, which is relatively constant over the tower base, but not on the tributary width or bearing pressure, so the depth of the maximum normal stress and von Mises stress in the weld will be the same at each location.

Shear force:

$$vo_{i,j} := \sigma_{bp_i}\cdot w_{arib_j}\cdot 0.6\cdot m$$

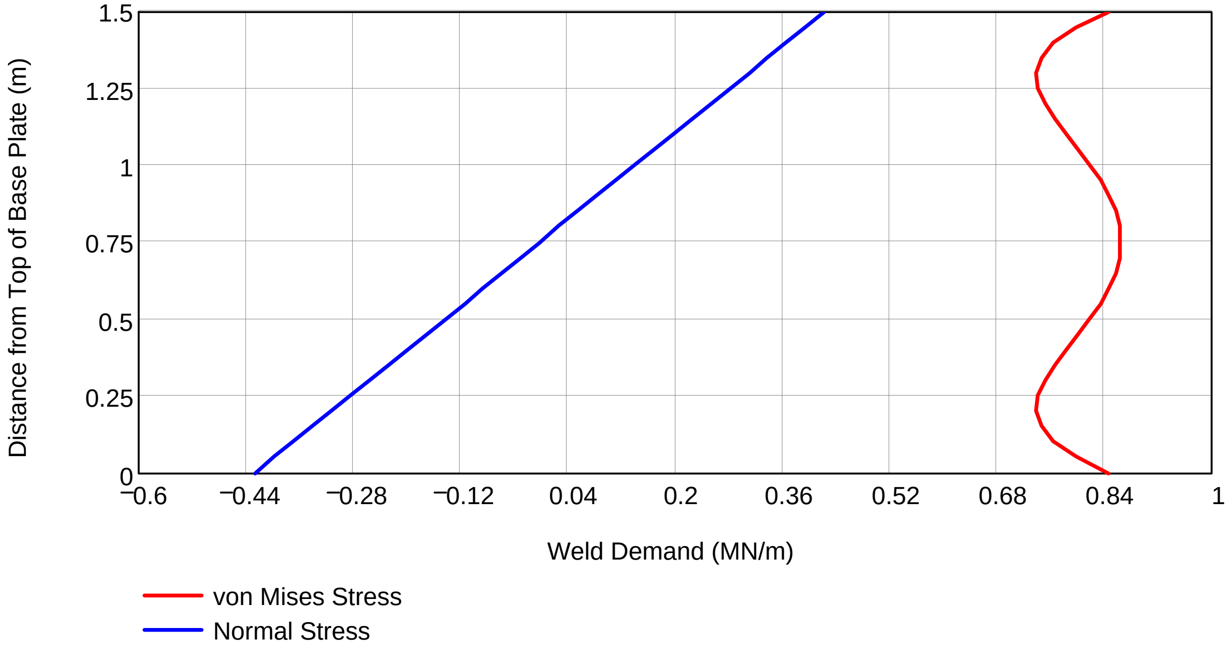
Moment as a function of shear force:

$$mo_{i,j} := vo_{i,j}\cdot 0.45\cdot m$$

Range variable to cycle through stiffener depth:

$$y := 0\cdot m, 0.05\cdot m .. 1.5\cdot m$$

The normal and von Mises stress distributions are as shown in the figure below.



The maximum normal stress occurs at the top and bottom of the stiffener and the maximum von Mises stress occurs at mid-depth. Produce a table with the required weld throat as a function of the bearing stress and the tributary width. Use a partial penetartion groove weld for combinations of pressure and tributary width below the bold line.

$$a_{fillet_{i,j}} := a_r\left(mo_{i,j}, vo_{i,j}, 750\cdot mm, h, 30\cdot mm, h\right)$$

$$a_{fillet.vm_{i,j}} := \frac{\sigma_{vm.weld}\left(mo_{i,j}, vo_{i,j}, 750\cdot mm, 30\cdot mm, h\right)}{\sigma_{vm.max}}$$

$$a_{fillet.n_{i,j}} := \frac{\sigma_{perp}\left(mo_{i,j}, 1500\cdot mm, 30\cdot mm, h\right)}{\sigma_{perp.max}}$$

Required Vertical Stiffener Fillet Weld Throat Sizes

Pressure	Tributary Width (m)											
(MPa)	*0.20*	*0.25*	*0.30*	*0.35*	*0.40*	*0.45*	*0.50*	*0.55*	*0.60*	*0.65*	*0.70*	*0.75*
10	2.5	3.1	3.7	4.4	5.0	5.6	6.2	6.8	7.5	8.1	8.7	9.3
15	3.7	4.7	5.6	6.5	7.5	8.4	9.3	10.3	11.2	12.1	13.1	14.0
20	5.0	6.2	7.5	8.7	10.0	11.2	12.4	13.7	14.9	16.2	17.4	18.7
25	6.2	7.8	9.3	10.9	12.4	14.0	15.5	17.1	18.7	20.2	21.8	23.3
30	7.5	9.3	11.2	13.1	14.9	16.8	18.7	20.5	22.4	24.3	26.1	28.0
35	8.7	10.9	13.1	15.2	17.4	19.6	21.8	23.9	26.1	28.3	30.5	32.6
40	10.0	12.4	14.9	17.4	19.9	22.4	24.9	27.4	29.9	32.3	34.8	37.3

Using Partial Penetration Groove Welds

Determine the corresponding normal and shear stress components on the welds connecting the stiffeners to the anchor pipes and tower leg plates.

$$\sigma_{perp}(Mo, y, b, h) := \frac{\sigma_b(Mo, y, b, h) \cdot b}{2}$$

Stresses are expressed as MN/m and must be divided by the weld depth to produce the actual stress.

$$\alpha_{ptr}(Vo, y, b, h) := \alpha(Vo, y, b, h) \cdot \frac{b}{2}$$

von Mises weld stress:

$$\sigma_{vm.weld}(Mo, Vo, y, b, h) := \left(\sigma_{perp}(Mo, y, b, h)^2 + 3 \cdot \alpha_{ptr}(Vo, y, b, h)^2\right)^{0.5}$$

Limit stresses are as determine for fillet welds.

Required weld throat for von Mises stresses: $s_{vm}(Mo, Vo, y, b, h) := \dfrac{\sigma_{vm.weld}(Mo, Vo, y, b, h)}{\sigma_{vm.max}}$

Required weld throat for normal stresses: $s_n(Mo, y, b, h) := \dfrac{\sigma_{perp}(Mo, y, b, h)}{\sigma_{perp.max}}$

Governing weld throat: $s_r\left(Mo, Vo, y_{vm}, y_n, b, h\right) := \max\left(s_{vm}\left(Mo, Vo, y_{vm}, b, h\right), s_n\left(Mo, y_n, b, h\right)\right)$

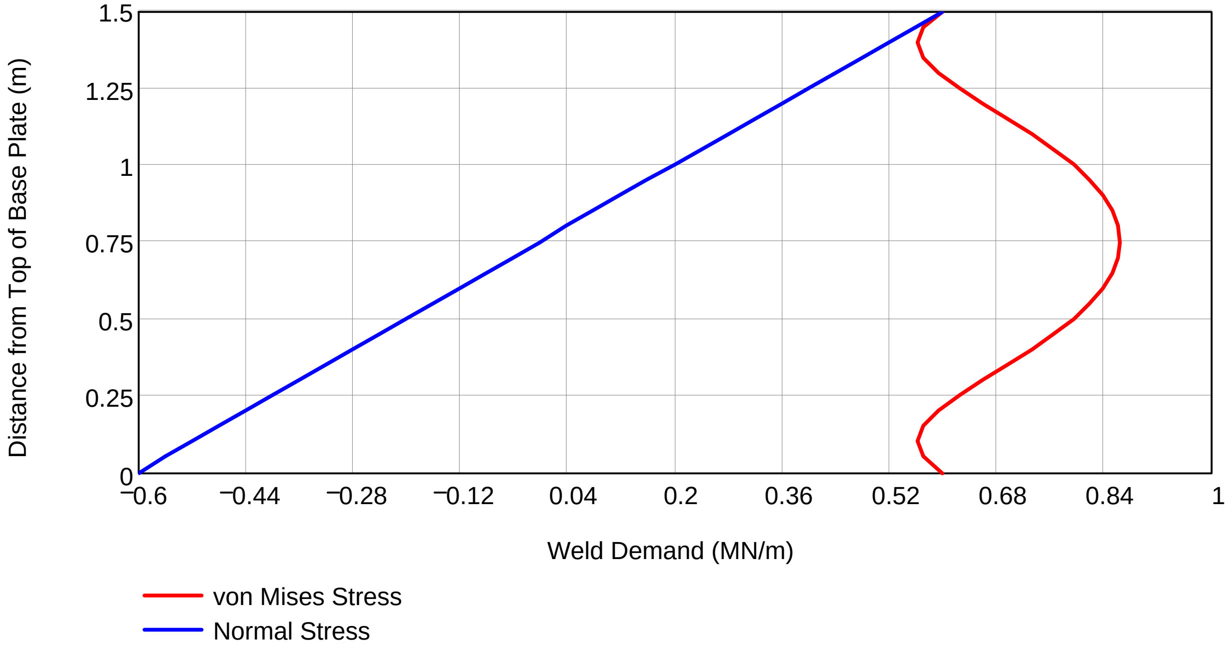
The bearing pressure on the first 150 mm of base plate width outside of the tower leg plate is assumed to be carried directly through the base plate into the tower leg plate (i.e, does not load the stiffener), the bearing pressures on the outer 600 mm of the base plate width is carried by the stiffener. The distribution of weld demands over the depth of the stiffener depends on the ratio of shear force to the moment, which is relatively constant over the tower base, but not on the tributary width or bearing pressure, so the depth of the maximum normal stress and von Mises stress in the weld will be the same at each location.

Shear force: $vo_{i,j} := \sigma_{bp_i} \cdot w_{arib_j} \cdot 0.6 \cdot m$

Moment as a function of shear force: $mo_{i,j} := vo_{i,j} \cdot 0.45 \cdot m$

Range variable to cycle through stiffener depth: $y := 0 \cdot m, 0.05 \cdot m .. 1.5 \cdot m$

The normal and von Mises stress distributions are as shown in the figure below.



The maximum normal stress occurs at the top and bottom of the stiffener and the maximum von Mises stress occurs at mid-depth. The von Mises stresses at the top and bottom of the stiffener are less severe than for fillets because of the lack of a shears tress component on the throat caused by the flexural stresses. Produce a table with the required weld depth as a function of the bearing stress and the tributary width.

$$s_{pp_{i,j}} := s_r\left(mo_{i,j}, vo_{i,j}, 750\cdot mm, h, 30\cdot mm, h\right)$$

$$s_{pp.vm_{i,j}} := \frac{\sigma_{vm.weld}\left(mo_{i,j}, vo_{i,j}, 750\cdot mm, 30\cdot mm, h\right)}{\sigma_{vm.max}}$$

$$s_{pp.n_{i,j}} := \frac{\sigma_{perp}\left(mo_{i,j}, 1500\cdot mm, 30\cdot mm, h\right)}{\sigma_{perp.max}}$$

Pressure	**Tributary Width (m)**											
(MPa)	***0.20***	***0.25***	***0.30***	***0.35***	***0.40***	***0.45***	***0.50***	***0.55***	***0.60***	***0.65***	***0.70***	***0.75***
10	2.5	3.1	3.7	4.4	5.0	5.6	6.2	6.8	7.5	8.1	8.7	9.3
15	3.7	4.7	5.6	6.5	7.5	8.4	9.3	10.3	11.2	12.1	13.1	14.0
20	5.0	6.2	7.5	8.7	10.0	11.2	12.4	13.7	14.9	16.2	17.4	18.7
25	6.2	7.8	9.3	10.9	12.4	14.0	15.5	17.1	18.7	20.2	21.8	23.3
30	7.5	9.3	11.2	13.1	14.9	16.8	18.7	20.5	22.4	24.3	26.1	28.0
35	8.7	10.9	13.1	15.2	17.4	19.6	21.8	23.9	26.1	28.3	30.5	32.6
40	10.0	12.4	14.9	17.4	19.9	22.4	24.9	27.4	29.9	32.3	34.8	37.3

Determine the Z-steel requirement for the tower leg plates to accommodate welds between them and the anchorage stiffeners (EN 1993-1-10 Section 3).

The effective weld depth is a function of the preparation depth required for the stiffener being connected. The preparation depth has been specified as a function of the stiffener thickness and tower leg plate to which it is connecting.

For plates A, B, C and E:

$a_{stiff.A} := (70\ \ 80)^{T} \cdot mm$

$a_{eff.A} := 0.4 a_{stiff.A}$

$a_{eff.A}{}^{T} = (28\ \ 32)\,mm$

$a_{stiff.BC} := (50\ \ 80\ \ 100)^{T} \cdot mm$

$a_{eff.BC} := 0.4 a_{stiff.BC}$

$a_{eff.BC}{}^{T} = (20\ \ 32\ \ 40)\,mm$

$a_{stiff.E} := (50\ \ 60\ \ 70)^{T} \cdot mm$

$a_{eff.E} := 0.4 a_{stiff.E}$

$a_{eff.E}{}^{T} = (20\ \ 24\ \ 28)\,mm$

For plates D, F, G and H:

$a_{stiff.D} := 50 \cdot mm$

$a_{eff.D} := 0.3 a_{stiff.D}$

$a_{eff.D} = 15\,mm$

$a_{stiff.F} := (40\ \ 50)^{T} \cdot mm$

$a_{eff.F} := 0.3 a_{stiff.F}$

$a_{eff.F}{}^{T} = (12\ \ 15)\,mm$

$a_{stiff.G} := 40 \cdot mm$

$a_{eff.G} := 0.3 a_{stiff.G}$

$a_{eff.G} = 12\,mm$

$a_{stiff.H} := (40\ \ 60)^{T} \cdot mm$

$a_{eff.H} := 0.3 a_{stiff.H}$

$a_{eff.H}{}^{T} = (12\ \ 18)\,mm$

Tower leg plate thicknesses are:

$s_{pl.ABCE} := 100 \cdot mm$

$s_{pl.DF} := 70 \cdot mm$

$s_{pl.GH} := 45 \cdot mm$

Factor Z_a is a function of the effective weld depths calculated above.

$$Z_a(a) := \text{if}(a < 7\cdot\text{mm}, 0, \text{if}(a < 10\cdot\text{mm}, 3, \text{if}(a < 20\cdot\text{mm}, 6, \text{if}(a < 30\cdot\text{mm}, 9, \text{if}(a < 40\cdot\text{mm}, 12, 15)))))$$

Plate A: $Z_{a.A} := \max\left(Z_a\left(a_{eff.A_1}\right), Z_a\left(a_{eff.A_2}\right)\right)$ $\quad Z_{a.A} = 12$

Plate B/C: $Z_{a.BC} := \max\left(Z_a\left(a_{eff.BC_1}\right), Z_a\left(a_{eff.BC_2}\right), Z_a\left(a_{eff.BC_3}\right)\right)$ $\quad Z_{a.BC} = 15$

Plate D: $Z_{a.D} := Z_a\left(a_{eff.D}\right)$ $\quad Z_{a.D} = 6$

Plate E: $Z_{a.E} := \max\left(Z_a\left(a_{eff.E_1}\right), Z_a\left(a_{eff.E_2}\right), Z_a\left(a_{eff.E_3}\right)\right)$ $\quad Z_{a.E} = 9$

Plate F: $Z_{a.F} := \max\left(Z_a\left(a_{eff.F_1}\right), Z_a\left(a_{eff.F_2}\right)\right)$ $\quad Z_{a.F} = 6$

Plate G: $Z_{a.G} := Z_a\left(a_{eff.G}\right)$ $\quad Z_{a.G} = 6$

Plate H: $Z_{a.H} := \max\left(Z_a\left(a_{eff.H_1}\right), Z_a\left(a_{eff.H_2}\right)\right)$ $\quad Z_{a.H} = 6$

Factor Z_b is a function of the weld type being applied:

For all plates: $Z_b := 3$

Factor Z_c is a function of the tower leg plate thickness being connected to.

$$Z_c(s) := \text{if}(s < 20\cdot\text{mm}, 4, \text{if}(s < 30\cdot\text{mm}, 6, \text{if}(s < 40\cdot\text{mm}, 8, \text{if}(s < 50\cdot\text{mm}, 10, \text{if}(s < 60\cdot\text{mm}, 12, 15)))))$$

Plates A, B, C and E: $Z_{c.ABCE} := Z_c\left(s_{pl.ABCE}\right)$ $\quad Z_{c.ABCE} = 15$

Plates D and E: $Z_{c.DF} := Z_c\left(s_{pl.DF}\right)$ $\quad Z_{c.DF} = 15$

Plates G and H: $Z_{c.GH} := Z_c\left(s_{pl.GH}\right)$ $\quad Z_{c.GH} = 10$

Factor Z_d is a function of the restraint to weld shrinkage. The weld sequence for attaching the stiffeners can be such that there is no restraint.

For all plates: $Z_d := 0$

Factor Z_e is a function of the influence of preheating.

If all connections are made with preheating greater than 100 deg C.: $Z_e := -8$

Sum the Z values for each plate:

Plate A: $Z_{Ed.A} := Z_{a.A} + Z_b + Z_{c.ABCE} + Z_d + Z_e$ $Z_{Ed.A} = 22$

Plates B &C: $Z_{Ed.BC} := Z_{a.BC} + Z_b + Z_{c.ABCE} + Z_d + Z_e$ $Z_{Ed.BC} = 25$

Plates D: $Z_{Ed.D} := Z_{a.D} + Z_b + Z_{c.DF} + Z_d + Z_e$ $Z_{Ed.D} = 16$

Plates E: $Z_{Ed.E} := Z_{a.E} + Z_b + Z_{c.ABCE} + Z_d + Z_e$ $Z_{Ed.E} = 19$

Plates F: $Z_{Ed.F} := Z_{a.F} + Z_b + Z_{c.DF} + Z_d + Z_e$ $Z_{Ed.F} = 16$

Plates G: $Z_{Ed.G} := Z_{a.G} + Z_b + Z_{c.GH} + Z_d + Z_e$ $Z_{Ed.G} = 11$

Plates H: $Z_{Ed.H} := Z_{a.H} + Z_b + Z_{c.GH} + Z_d + Z_e$ $Z_{Ed.H} = 11$

If the plates are not preheated: $Z_e := 0$

Sum the Z values for each plate:

Plate A: $Z_{Ed.A} := Z_{a.A} + Z_b + Z_{c.ABCE} + Z_d + Z_e$ $Z_{Ed.A} = 30$

Plates B &C: $Z_{Ed.BC} := Z_{a.BC} + Z_b + Z_{c.ABCE} + Z_d + Z_e$ $Z_{Ed.BC} = 33$

Plates D: $Z_{Ed.D} := Z_{a.D} + Z_b + Z_{c.DF} + Z_d + Z_e$ $Z_{Ed.D} = 24$

Plates E: $Z_{Ed.E} := Z_{a.E} + Z_b + Z_{c.ABCE} + Z_d + Z_e$ $Z_{Ed.E} = 27$

Plates F: $Z_{Ed.F} := Z_{a.F} + Z_b + Z_{c.DF} + Z_d + Z_e$ $Z_{Ed.F} = 24$

Plates G: $Z_{Ed.G} := Z_{a.G} + Z_b + Z_{c.GH} + Z_d + Z_e$ $Z_{Ed.G} = 19$

Plates H: $Z_{Ed.H} := Z_{a.H} + Z_b + Z_{c.GH} + Z_d + Z_e$ $Z_{Ed.H} = 19$

Determine the size of the welds required to connect the stiffeners to the base plate.

Assume that the stiffener and anchor plate can be machined to bear directly on the top of the base plate. With this arrangement welds have to be provided to carry 25% of the load to be transferred (EN 1993-1-8 Section 6.2.7.1).

Material partial factor: $\gamma_{M0} := 1.05$

Assume the plates are loaded to the compressive stress limit: $\sigma_{cmax} := \frac{f_y}{\gamma_{M0}}$

$\sigma_{cmax} = 338.095\,\text{MPa}$

Consider stiffener plate thicknesses: $i := 1..7$

$a_{stiff_i} := (10 \cdot i + 30) \cdot \text{mm}$

Design force for each fillet line: $F_{w_i} := \frac{a_{stiff_i} \cdot \sigma_{cmax}}{8}$

Try using fillet welds.

Weld stresses: $\sigma_{vm_i} := \left[\left(\frac{F_{w_i}}{\sqrt{2}}\right)^2 + 3 \cdot \left(\frac{F_{w_i}}{\sqrt{2}}\right)^2\right]^{0.5}$ $\sigma_{perp_i} := \frac{F_{w_i}}{\sqrt{2}}$

Required throat size: $a_{r_i} := \max\left(\frac{\sigma_{vm_i}}{\sigma_{vm.max}}, \frac{\sigma_{vm_i}}{\sigma_{perp.max}}\right)$

t_{stiff} (mm)	a (mm)
40	7.1
50	8.8
60	10.6
70	12.4
80	14.1
90	15.9
100	17.7

Some of the fillets are larger than desired, therefore use partial penetration welds.

There is not shear stress on the weld throat, therefore the von Mises stress is the same as the perpendicular stress.

Required preparation depth $s_{r_i} := \frac{F_{w_i}}{\sigma_{perp.max}}$

Use all PP welds, specified as t $_{stiff}$/8.

t_{stiff} (mm)	s (mm)
40	5.0
50	6.2
60	7.5
70	8.7
80	10.0
90	11.2
100	12.5

34

30

STIFFENER	P (MPa)	w_{trib} (m)	s (mm)	s/t_{stiff}
LS 29	21			
ANCHOR		0.47	s = 12	0.30
FIN		0.39	s = 10	0.25
LS 18	13			
FIN		0.45	s = 8	0.2
ANCHOR		0.60	s = 11	0.28
INTERSECT^N		0.40	s = 8	0.2
LS 19	13			
FIN		0.55	s = 10	0.25
ANCHOR		0.475	s = 8	0.20
LS 20	15			
FIN		0.47	s = 9	0.23
ANCHOR		0.47	s = 9	0.23

RATHER THAN SPECIFYING A DIFFERENT WELD @ EACH STIFFENER, SPECIFY WELDS AS A FUNCTION OF THE STIFFENER THICKNESS.

FOR PLATES A, B, C & E THE REQ'D WELD SIZE VARIES B/W 0.3 & 0.4 × t_{stiff} (GENERALLY) ∴ USE $s = 0.4t$

FOR PLATES D, F, G & H THE REQ'D WELD SIZE VARIES B/W 0.2 & 0.3 × t_{stiff} ∴ USE $s = 0.3t$

SHEAR CAPACITY OF TOWER BASE

CONSERVATIVE ASSESS THE UTILIZATION RATIO FOR SHEAR @ THE TOWER BASE USING THE FOLLOWING PARAMETERS:

MINIMUM DEAD LOAD AXIAL FORCE = 1347 MN COMP. (CALABRI

MAXIMUM SEISMIC (TH) SHEAR FORCE = 134.6 MN (SILS - SICILIA

MAXIMUM NON-SEISMIC SHEAR FORCE IN THE SEISMIC COMBINATION = 18.5 MN (ULS-SICIL

TOTAL SHEAR FORCE = 153 MN.

MAXIMUM RSA SEISMIC COMBINATION = 172 MN (SILS - SICILIA
SHEAR FORCE

SO, CHECK UR BASED ON P = 1347 MN & V = 172 MN & IGNORE THE ADDITIONAL COMPRESSION FROM THE ANCHORAGE TENDONS.

CHECK USING EN 1993-2 § A.3.3.

$$V_{Rd} = \frac{\mu_K}{\gamma_\mu} N_{Ed} + V_{pd}$$

$N_{Ed} = 1347$ MN.
$V_{pd} = 0$
$\mu_K = 0.6$
$\gamma_\mu = 1.2$

$$V_{Rd} = \frac{0.6\,(1347)}{1.2} + 0$$

$$= 674 \text{ MN} \longrightarrow UR = \frac{172}{674} = 0.26.$$

ACCEPTABLE FRICTION COEFFICIENT, $\mu = \frac{1.2\,(172)}{1347}$

$$= 0.15$$

∴ CLEARLY NO PROBLEM.