Appendices

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Appendix 1

Capacity of Bearings and Shear Keys

- FIND TRANSVERSE CAPACITIES OF BEARINGS GIVEN THE VERTICAL & LONGIT. LOADS OF THE MAX. TRANSVERSE & MAX UPLIFT CASES. BY INSP. THESE ARE 2 CONTROLLING CASES.

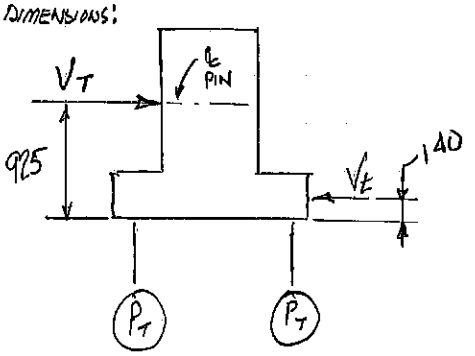
GIVEN:

BOLT FORCE AFTER LOSSES: 2510 kN (2789 kN LOAD WITH 10% LOSSES PER MARWAN)

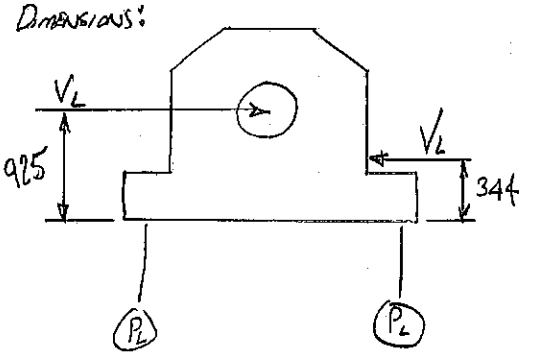
$\mu_{s,\ CONCRETE} = 0.67$

$\mu_{s,\ STEEL} = 0.50$ (CLASS B COATING)

TRANSVERSE DIMENSIONS:

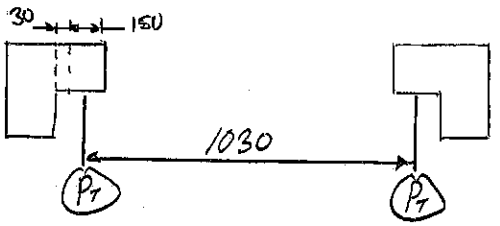


LONGIT. DIMENSIONS:



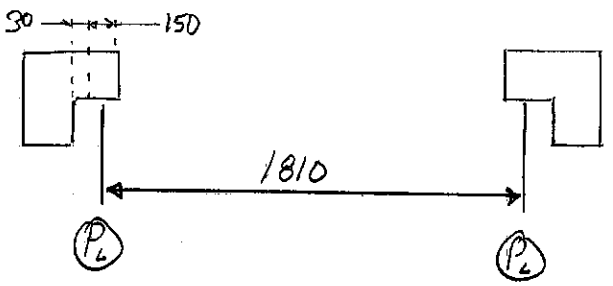
ASSUME P_T & P_L ARE AT MIDPOINT OF CONTACT AREA BETWEEN BRG. BTM. HOUSING & HOLD DOWN

TRANSV:



$$P_T = \frac{V_T(925-140)}{1030} = \frac{785}{1030} V_T$$

LONGIT.

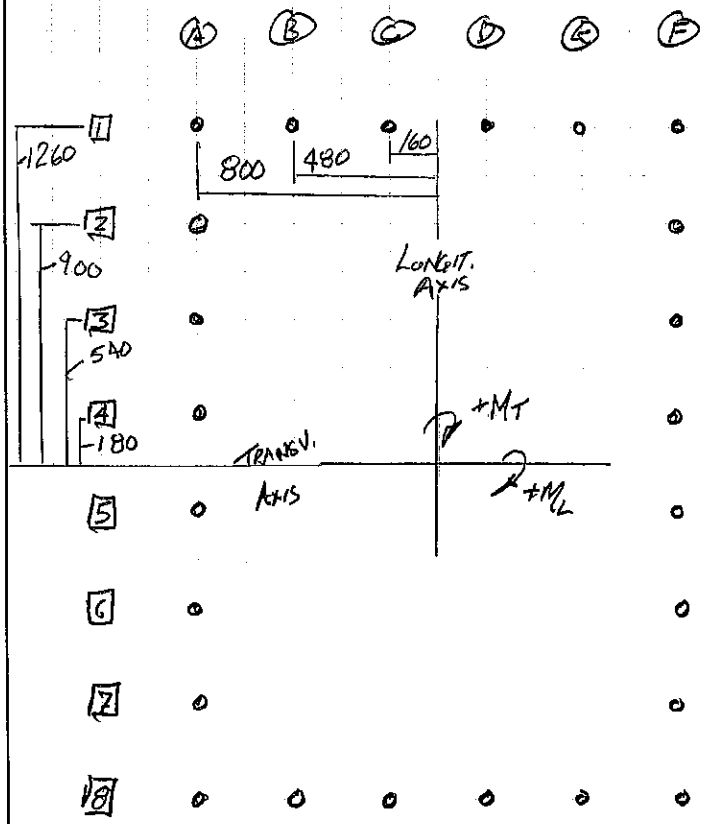


$$P_L = \frac{V_L(925-344)}{1810} = \frac{581}{1810} V_L$$

LOADCASE 4: (MAX. UPLIFT)
TRANSV: 25287 kN
LONGIT: 1628 kN
UPLIFT: 9539 kN

LOADCASE 5: (MAX. TRANSVERSE)
TRANSV: 30496 kN
LONGIT: 8186 kN
DOWNFORCE: 16441 kN

LOOK AT SYSTEM IN SIMILAR MANNER TO A PILE CAP WITH AXIAL & MOMENTS.



$I_T = 16(800)^2 + 4(480)^2 + 4(160)^2$

$= 11\,264\,000\ mm^2$

$\times \frac{1}{800} = 14\,080\ mm$ (A)/(F)

$\times \frac{1}{480} = 23\,467\ mm$ (B)/(E)

$\times \frac{1}{160} = 70\,400\ mm$ (C)/(D)

$I_L = 12(1260)^2 + 4(900)^2 + 4(540)^2 + 4(180)^2$

$= 23\,587\,200\ mm^2$

$\times \frac{1}{1260} = 18\,720\ mm$ 1/8

$\times \frac{1}{900} = 26\,208\ mm$ 2/7

$\times \frac{1}{540} = 43\,680\ mm$ 3/6

$\times \frac{1}{180} = 131\,040\ mm$ 4/5

LOADCASE 4 @

- NET CLAMPING = 24(2510 kN) − 9539 kN = 50 701 kN (2113 kN/BOLT)
  - LONGIT. COUPLE = 581/1810 × 1628 kN = 523 kN ↓ ↑
  - MOMENT FROM LONGIT COUPLE = 523 × 1810 = 946 630 kN-mm
  - LONGIT COUPLE EFFECTS:
    - 1/8 = 946 630/18 720 = +/− 51 kN
    - 2/7 = 946 630/26 208 = +/− 36 kN
    - 3/6 = 946 630/43 680 = +/− 22 kN
    - 4/5 = 946 630/131 040 = +/− 7 kN
  - TRANSV. COUPLE = 785/1030 · V_T
  - MOMENT FROM TRANSV. COUPLE = 785/1030 · V_T · 1030 → 785 V_T
  - TRANSV. COUPLE EFFECTS:
    - (A)/(F) = +/− 785/14 080 · V_T
    - (B)/(E) = +/− 785/23 467 · V_T
    - (C)/(D) = +/− 785/70 400 · V_T

BASIC EQUATION TO SOLVE:

$\mu_{S\ STEEL} \cdot \Sigma$ BOLT LOADS = V_T, WHERE V_T IS TRANSV. CAPACITY WITH CONSTANT UPLIFT & V_L FORCES.

L.C. 4, CONT'D

SOLVE THIS IN EXCEL, AS BOLT LOADS ARE ALSO A FUNCTION OF V_T. ADDITIONALLY, THEY HAVE TO BE LIMITED TO PRELOAD OF 2510 kN ON "COMPRESSION" SIDE, WHERE V_T HELPS REDUCE UPLIFT EFFECTS,

(SEE PAGE 4 FOR RESULTS)

V_T CAPACITY = 21 712 kN/BRG (25 287 kN APPLIED, + 16 %)

LOADCASE 5:

- NET CLAMPING = 24(2510 kN) = 60 240 kN
- LONGIT. COUPLE = 581/1810 × 8186 = 2628 kN ↓↑
- MOMENT FROM LONGIT. COUPLE = 2628 × 1810 = 4 756 680 kN-mm
- LONGIT. COUPLE EFFECTS:
  - [1] / [8] = 4756 680 / 18 720 = +/- 254 kN
  - [2] / [7] = 4 756 680 / 26 208 = +/- 181 kN
  - [3] / [6] = 4 756 680 / 43 680 = +/- 109 kN
  - [4] / [5] = 4 756 680 / 131 040 = +/- 36 kN
- TRANSV. COUPLE = 785/1030 · V_T
- MOMENT FROM TRANSV. COUPLE = 785 · V_T
- TRANSV. COUPLE EFFECTS:
  - Ⓐ / Ⓕ = +/- 785/14080 · V_T
  - Ⓑ / Ⓔ = +/- 785/23 467 · V_T
  - Ⓒ / Ⓓ = +/- 785/70 400 · V_T
- IN ADDITION, VERTICAL DOWNFORCE CAN NEGATE SOME UPLIFT:
  (16 441)/24 = 685 kN/BOLT CAN BE ADDED BACK IN, UP TO PRELOAD FORCE OF 2510 kN

SOLVE IN EXCEL:

(SEE PAGE 5 FOR RESULTS)

V_T CAPACITY = 25 652 kN/BRG (30496 kN APPLIED, +19 %)

Loadcase 4

V longit. 1628 kN

Vt 21,712 kN (iterate this value)

V Resultant 21,773 kN

sum Anchor Forces 43545 kN
coeff friction 0.5
Friction Force 21773 kN (100.00% V Resultant)

	A1	B1	C1	D1	E1	F1	
	851	1336	1820	2304	2510	2510	
A2	866					2510	F2
A3	880					2510	F3
A4	895					2510	F4
A5	909					2510	F5
A6	924					2510	F6
A7	938					2510	F7
	953	1438	1922	2406	2510	2510	
	A8	B8	C8	D8	E8	F8	

Loadcase 5

V longit. 8186 kN

Vt	25,652 kN	(iterate this value)

V Resultant 26,926 kN

sum Anchor Forces 53852 kN
coeff friction 0.5
Friction Force 26926 kN (100.00% V Resultant)

	A1	B1	C1	D1	E1	F1	
	1511	2083	2510	2510	2510	2510	
A2	1584					2510	F2
A3	1656					2510	F3
A4	1729					2510	F4
A5	1801					2510	F5
A6	1874					2510	F6
A7	1946					2510	F7
	2019	2510	2510	2510	2510	2510	
	A8	B8	C8	D8	E8	F8	

80 BOLTS - TOP HOUSING TO BOX @ 0.50 FRICTION (40)
48 BOLTS - STUB TO CONC. @ 0.67 FRICTION (32.16) ← CONTROLS

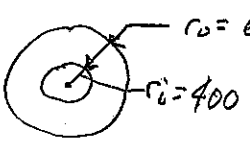
$32.16 \times 2510\ kN = 80\ 722\ kN$ TO SLIP

- CHECK BEARING ON RING/STUB. BRONZE PORTION HAS 414 MPa YIELD, SO CASTING STILL GOVERNS @ 345 MPa

WIDTH IN BRG = 320 mm
DIA OF BRG = 1250 mm → $A = 400\ 000\ mm^2$

$$\sigma_{BRG} = \frac{80\ 722 \times 1000}{400\ 000} = 202\ MPa < 345, \text{ SO BEARING OK}$$

- CHECK SHEAR STRESSES ON STUB



$$A_G = \pi(625^2 - 400^2) = 724\ 530\ mm^2$$

$.58 \times 345 = 200\ MPa$ (APPROX SHEAR YIELD STRESS)

$$\text{SHEAR STRESS ON } A_G = \frac{80\ 722 \times 1000}{724\ 530} = 111\ MPa < 200\ MPa$$

AT YIELD, $\frac{V}{Y} = \frac{80\ 722 \times 200}{111 \times 2} = 72\ 723\ kN$

- BENDING STRESSES

$$I = \frac{1}{4}\pi(625^4 - 400^4) = 9.974 \times 10^{10}\ mm^4$$

$$M = (80\ 722)(720) = 58\ 119\ 840\ kN\text{-}mm$$

$$\frac{Mc}{I} = \frac{58\ 119\ 840 \times 1000 \times 625}{9.974 \times 10^{10}} = 364\ MPa > 345$$

BACKSOLVE FOR YIELD M

$$\frac{345 \times 9.974 \times 10^{10}}{625 \times 1000} = 55\ 056\ 480,\ \div 720 = \text{YIELD } V$$

$= 76\ 467\ kN$

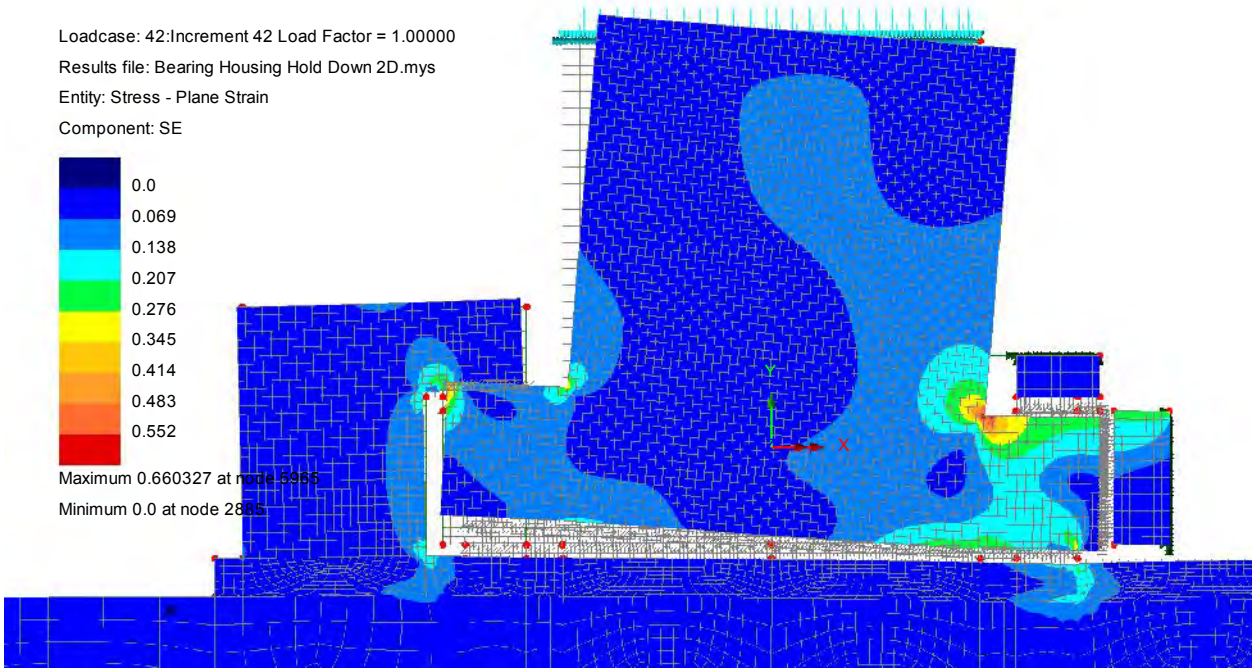
→ WHILE BENDING IS LIKELY NOT 100% APPLICABLE TO THIS SYSTEM, THERE IS LITTLE ELSE TO EXAMINE IN THE ABSENCE OF AN FEA (WHICH WAS DONE BY TPM), SO, TO SUMMARIZE THIS HAND-CALC. ANALYSIS IN A CONSERVATIVE MANNER, SAY CAPACITY OF SHEAR KEY IS $0.9 \times 72\ 723\ kN$
$= 65\ 451\ kN$

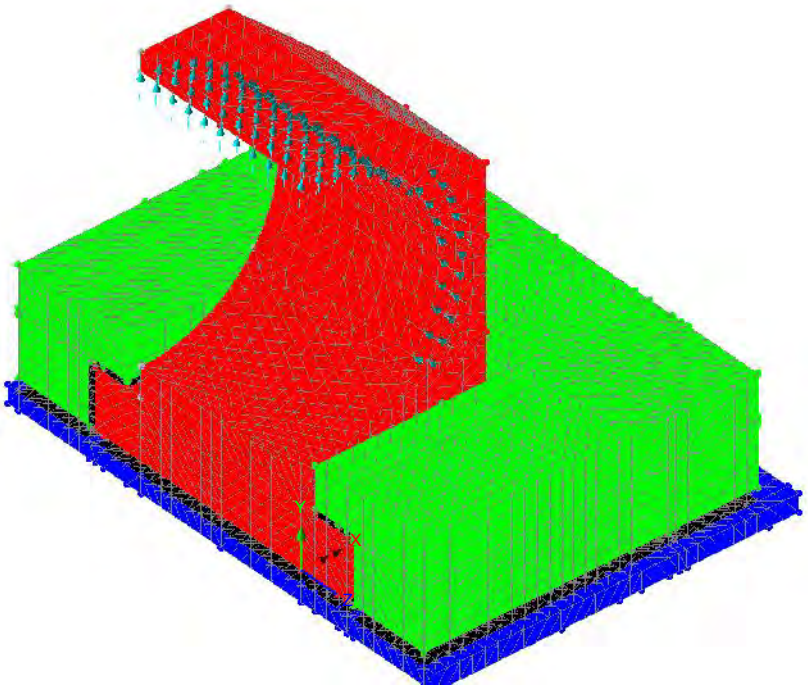
- Shear key capacity approximately: 6545 kN
  (conserv. assumption based on hand-calcs only.)

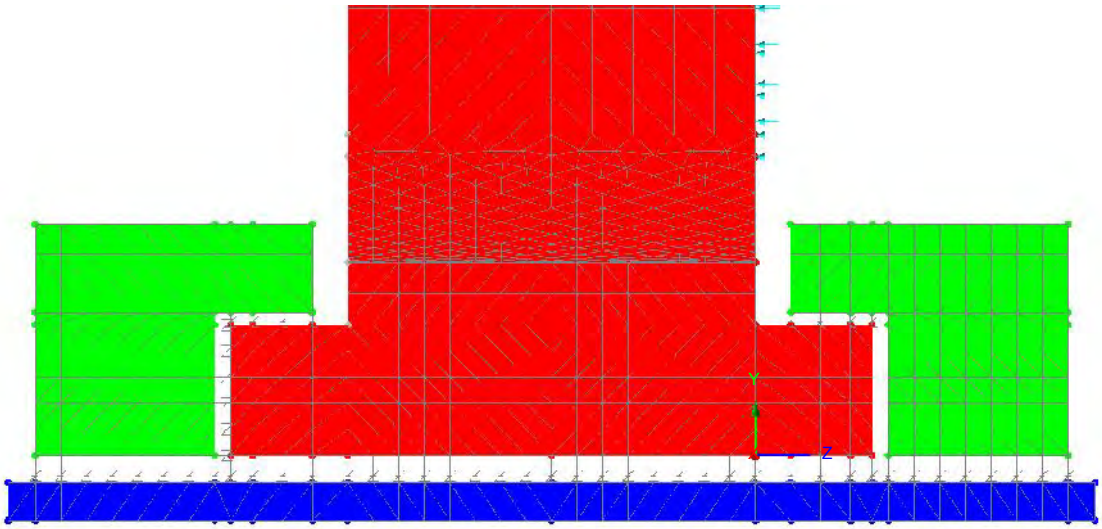
- In loadcase 4, bearings (each) have 21712 kN capacity to resist V_T, assuming V_L is 1628 kN and uplift is 9539 kN. Loadcase 4 has 25287 kN per bearing. By inspection, the combination of 4 bearings & 2 shear keys should be adequate.
- In loadcase 5, bearings each have 25652 kN capacity to resist V_T, assuming V_L is 8186 kN and down force is 16441 kN. Loadcase 5 has 30496 kN per bearing, By inspection, the combination of 4 bearings and 2 shear keys should be adequate.

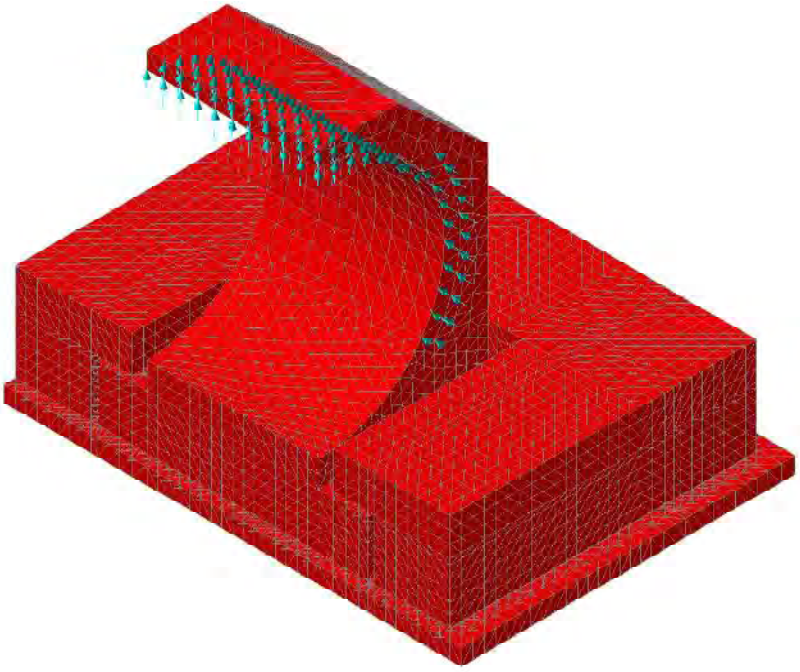
Appendix 2

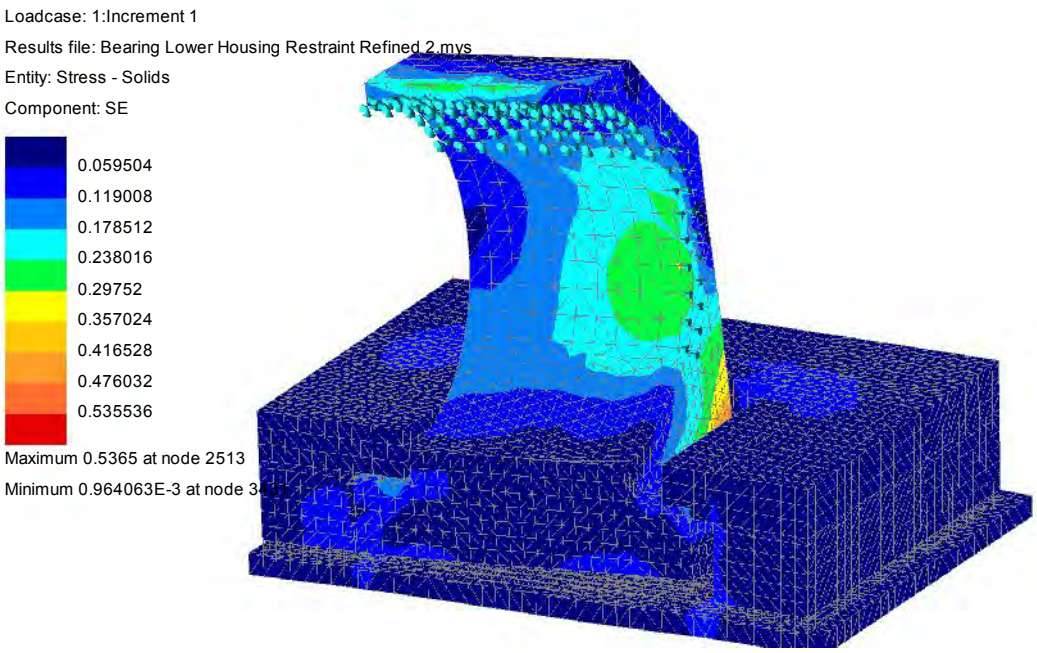
Finite Element Models of Bearings and Shear Keys

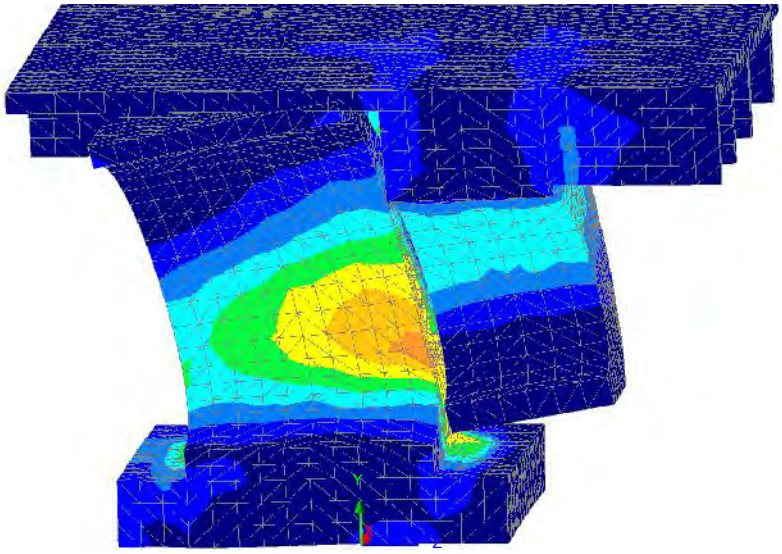

Loadcase: 42:Increment 42 Load Factor = 1.00000
Results file: Bearing Housing Hold Down 2D.mys
Entity: Stress - Plane Strain
Component: SE
0.0
0.069
0.138
0.207
0.276
0.345
0.414
0.483
0.552
Maximum 0.660327 at node 5965
Minimum 0.0 at node 2885
Y
X

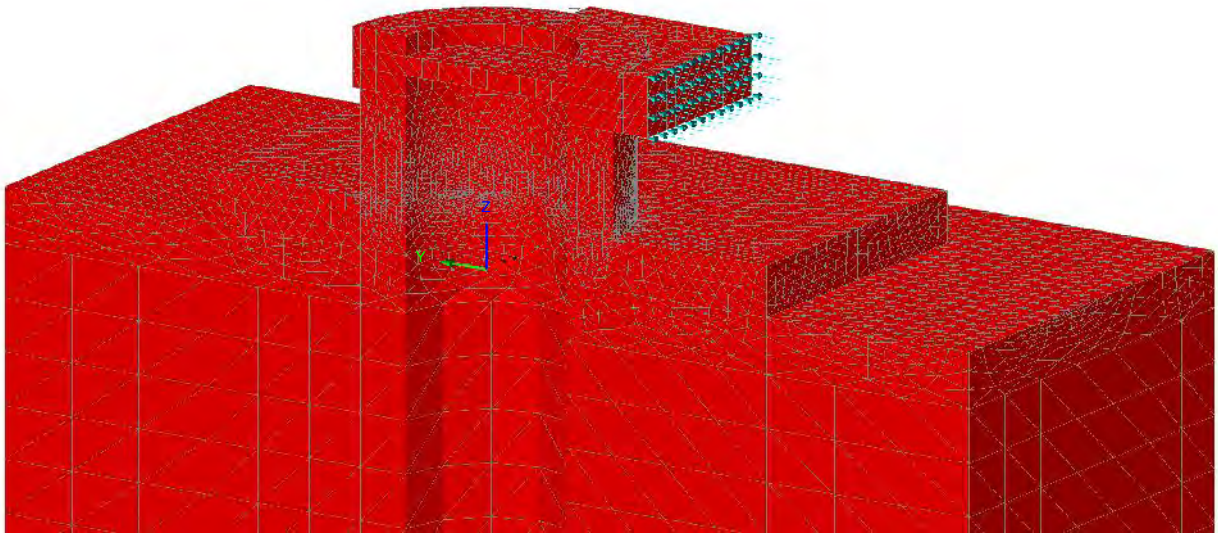


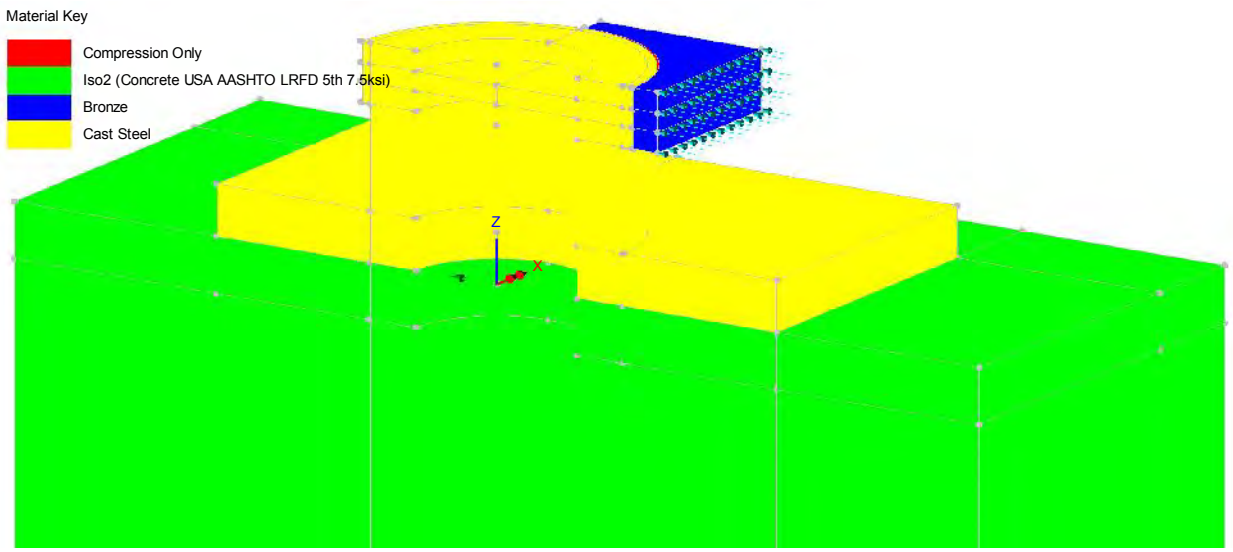





Loadcase: 1:Increment 1
Results file: Bearing Lower Housing Restraint Refined 2.mys
Entity: Stress - Solids
Component: SE
0.059504
0.119008
0.178512
0.238016
0.29752
0.357024
0.416528
0.476032
0.535536
Maximum 0.5365 at node 2513
Minimum 0.964063E-3 at node 3431





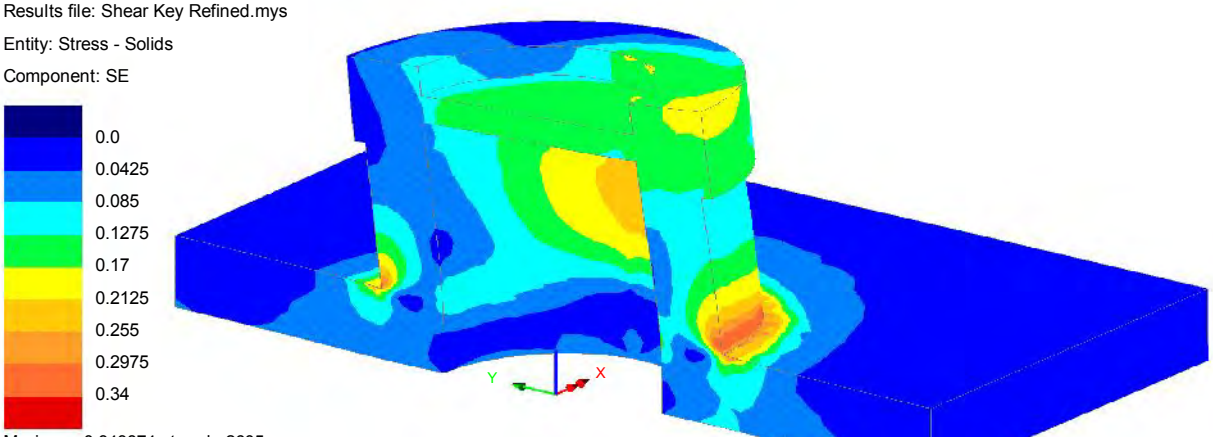

Material Key
Compression Only
Iso2 (Concrete USA AASHTO LRFD 5th 7.5ksi)
Bronze
Cast Steel
Z
X

Loadcase: 10:Increment 10 Load Factor = 0.500000

Results file: Shear Key Refined.mys

Entity: Stress - Solids

Component: SE



Maximum 0.343874 at node 2605

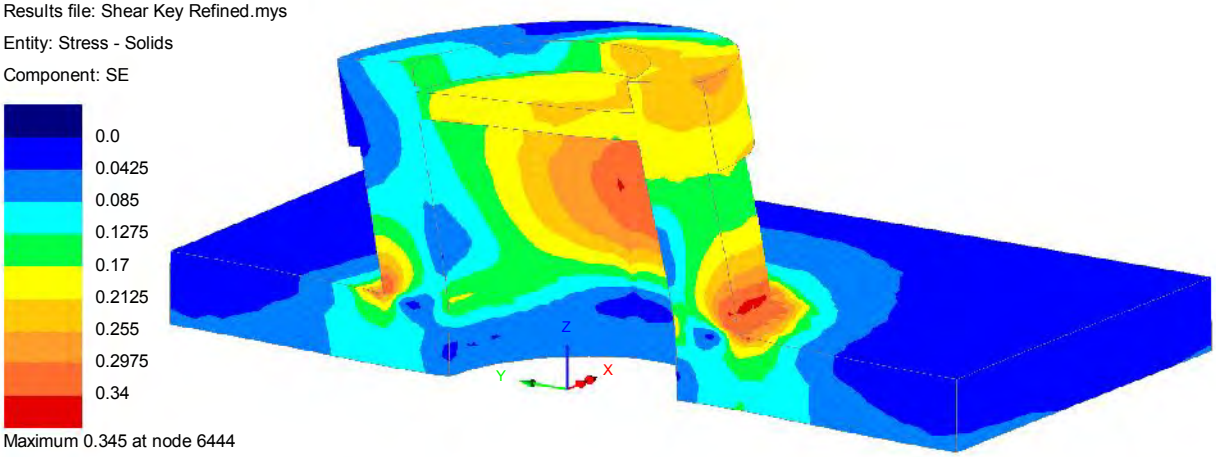
Minimum 1.13641E-3 at node 5823

Loadcase: 14:Increment 14 Load Factor = 0.700000

Results file: Shear Key Refined.mys

Entity: Stress - Solids

Component: SE



Maximum 0.345 at node 6444

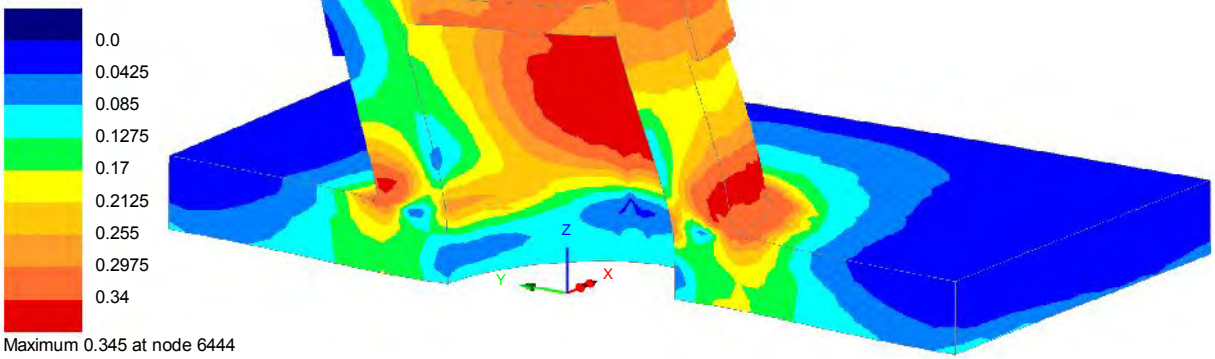
Minimum 1.59741E-3 at node 5823

Loadcase: 20:Increment 20 Load Factor = 1.00000

Results file: Shear Key Refined.mys

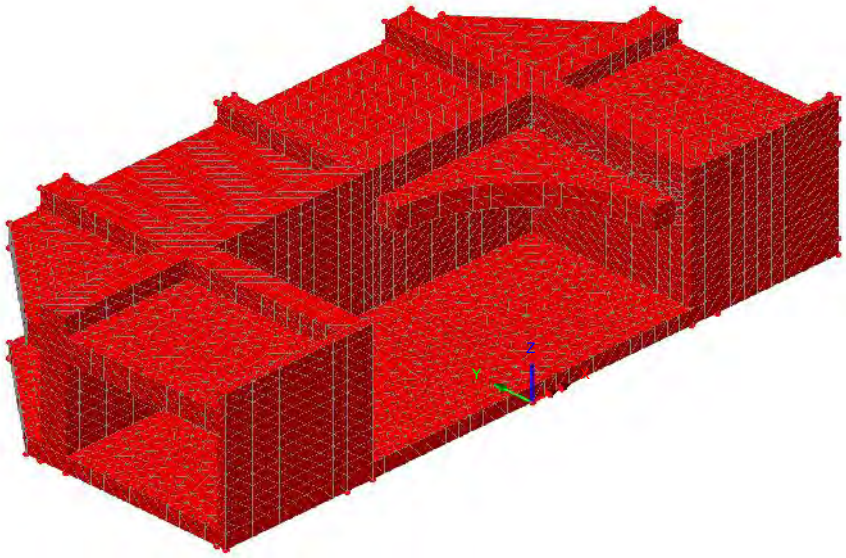
Entity: Stress - Solids

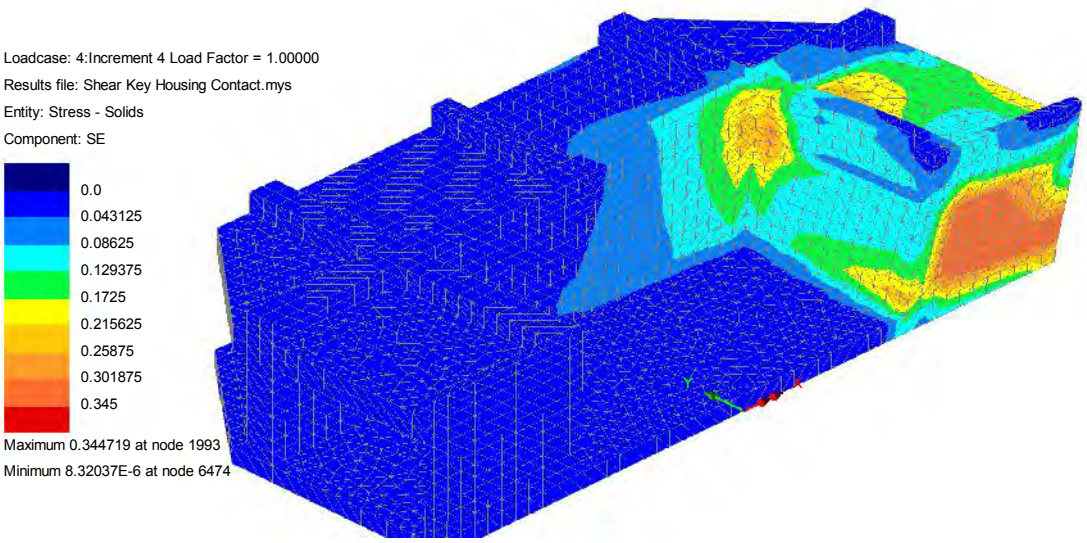
Component: SE



Maximum 0.345 at node 6444

Minimum 2.31343E-3 at node 5823




Loadcase: 4:Increment 4 Load Factor = 1.00000
Results file: Shear Key Housing Contact.mys
Entity: Stress - Solids
Component: SE
0.0
0.043125
0.08625
0.129375
0.1725
0.215625
0.25875
0.301875
0.345
Maximum 0.344719 at node 1993
Minimum 8.32037E-6 at node 6474

Appendix 3

- **Appendix 3A** – Modjeski and Masters Calculations – Steel Orthotropic Girder at Bearings and Steel Crossbeam at Shear Keys
- **Appendix 3B** – TYLin Calculations – Steel Orthotropic Girder at Bearings
- **Appendix 3C** – Design Drawings – Orthotropic Box Girder at Pier E2, Crossbeam at Pier E2, Bearing and Shear Key Details

Appendix 3A

Modjeski and Masters Calculations

Steel Orthotropic Girder at Bearings and Steel Crossbeam at Shear Keys

Assumptions:
1. Look at it from a "block shear" perspective.
2. Local effects only - assumed that load spreads quickly away from bearing interface.
3. A709M Grade 345 (A709 Grade 50) steel.

Fy =	345	MPa	50	ksi
Fu =	450	MPa	65	ksi

Bearing Demands - Load Path C - compression and uplift from sheet 882AR2

	MN	k
Compression	68	15300
Uplift	17	3825
Longitudinal	15	3375
Transverse	30	6750

Bearing "footprint"

Length, L =	3500	mm	137.8	in
Width, w =	2900	mm	114.2	in

Block Shear Bottom Flange

If Atn $\leq$ 0.58 Avn then $R_r = \phi_{bs}(0.58 F_y A_{vg} + F_u A_{tn})$ 6.13.4-1

otherwise $R_r = \phi_{bs}(0.58 F_u A_{vn} + F_y A_{tg})$ 6.14.4-2

ϕ_{bs} = 0.80 6.5.4.2

Case 1 - Looking at bottom flange from the most conservative perspective

1. Ignore presence of transverse webs and longitudinal shear plates
2. Assume free edges on one longitudinal and one transverse side
3. Assume bottom flange thickness = 60 mm 2.36 in transverse
4. Assume bottom flange thickness = 85 mm 3.35 in longitudinal
5. Assume 8 diameter 63 mm 2.48 in holes transverse
6. Assume 10 diameter 63 mm 2.48 in holes longitudinal

Transverse

Axial and shear areas

Atg =	297500	mm2	461.1	in2
Avg =	174000	mm2	269.7	in2
Atn =	243950	mm2	378.1	in2
Avn =	143760	mm2	222.8	in2

Rr = 115675.9 kN 26004 k D/C = 0.26 Ok

Shear areas only

Atg =	0	mm2	0.0	in2
Avg =	174000	mm2	269.7	in2
Atn =	0	mm2	0.0	in2
Avn =	143760	mm2	222.8	in2

Rr = 30017.09 kN 6748 k D/C = 1.00 Ok

Axial areas only

Atg =	297500	mm2	461.1	in2
Avg =	0	mm2	0.0	in2
Atn =	243950	mm2	378.1	in2
Avn =	0	mm2	0.0	in2

Rr = 87822 kN 19742 k D/C = 0.34 Ok

Longitudinal

Axial and shear areas

Atg =	174000	mm2	269.7	in2			
Avg =	297500	mm2	461.1	in2			
Atn =	143760	mm2	222.8	in2			
Avn =	243950	mm2	378.1	in2			
Rr =	99377.4	kN	22340	k	D/C =	0.15	Ok

Shear areas only

Atg =	0	mm2	0.0	in2			
Avg =	297500	mm2	461.1	in2			
Atn =	0	mm2	0.0	in2			
Avn =	243950	mm2	378.1	in2			
Rr =	50936.76	kN	11451	k	D/C =	0.29	Ok

Axial areas only

Atg =	174000	mm2	269.7	in2			
Avg =	0	mm2	0.0	in2			
Atn =	143760	mm2	222.8	in2			
Avn =	0	mm2	0.0	in2			
Rr =	51753.6	kN	11634	k	D/C =	0.29	Ok

Longitudinal shear plate

Assume 60% of longitudinal shear is transferred into longitudinal shear plate (rest stays in bottom flange)

	MN	k
Demand	9	2025

Capacity

t =	18	mm	0.71	in			
Shear capacity =	3602	N/mm	20.6	k/in			
Length required =	2499	mm	98.5	in			
Length of bearing =			3500	mm			
			137.8	in	D/C =	0.72	Ok

Transverse web plates

	MN	k
Demand	30	6750

Capacity (3 webs)

t =	35	mm	1.38	in			
Shear capacity =	21011	N/mm	119.9	k/in			
Length required =	1428	mm	56.3	in			
Width of bearing =			2900	mm			
			114.2	in	D/C =	0.49	Ok

Using very conservative assumptions, there is sufficient capacity to carry longitudinal and transverse shear loads up into the girder.

Area of steel within bearing footprint

Webs (3)

Width =	2900	mm	114.2	in
Thickness =	35	mm	1.38	in
Area (total) =	304500	mm2	472.0	in2

Shear plate

Width =	3500	mm	137.8	in
Thickness =	18	mm	0.71	in
Area (total) =	63000	mm2	97.7	in2

Longitudinal stiffeners (4)

Width =	3500	mm	137.8	in
Thickness =	45	mm	1.77	in
Area (total) =	630000	mm2	976.5	in2

Transverse shear plate stiffeners (8)

Width =	250	mm	9.8	in
Thickness =	25	mm	0.98	in
Area (total) =	50000	mm2	77.5	in2

Transverse plate stiffeners A (2)

Width =	550	mm	21.7	in
Thickness =	50	mm	1.97	in
Area (total) =	55000	mm2	85.3	in2

Transverse plate stiffeners B (2)

Width =	475	mm	18.7	in
Thickness =	50	mm	1.97	in
Area (total) =	47500	mm2	73.6	in2

Typical bearing assembly (14 pairs)

outer plates (2)

Width =	200	mm	7.9	in
Thickness =	35	mm	1.38	in

inner plate (1)

Width =	200	mm	7.9	in
Thickness =	40	mm	1.57	in
Area (1) =	22000	mm2	34.1	in2
Area (total) =	616000	mm2	954.8	in2

Total plate bearing area above bottom flange within bearing footprint

Area (total) =	1766000	mm2	2737.3	in2

Prestressing force

56 50 diameter A354 Grade BD anchor bolts

Area =	1612.9	mm2	2.50	in2
Fu =	1034	MPa	150	ksi

Conservatively assume that bolts are tensioned to Fu

Tension/bolt =	1.67	MN/bolt	375	k/bolt
Total force =	93	MN	21000	k

Conservatively assume that force transferred thru stiffeners only

Stress =	151.7	MPa	21.99	ksi	D/C =	0.44	Ok

Force through stiffeners webs and diaphragms

Stress =	81.2	MPa	11.8	ksi	D/C =	0.24	Ok

Axial reaction

Compression

Conservatively assume that force transferred thru shear and web plates only

Demand =	68000	kN	15289	k			
	185.03	MPa	26.84	ksi			

Tension

Conservatively assume that bolt pretension is 0.6Fu

Tension/bolt =	1.00	MN	225	k			
Total pretension =	56062	kN	12600	k			
Demand =	17000	kN	3822	k	D/C =	0.30	Ok

Pretension is never overcome - all plates active in tension

	9.63	MPa	1.40	ksi			

Conservatively assume that force transferred thru shear and web plates only

	46.26	MPa	6.71	ksi	D/C =	0.13	Ok

Look at prestressing stiffener assembly

Material properties

Steel plate

Fy =	345	MPa	50	ksi
Fu =	450	MPa	65	ksi

Weld metal

Fexx =	485	MPa	70	ksi
ϕe =	0.80			
Rexx =	232.8	MPa	33.6	ksi

50 diameter A354 Grade BD anchor bolts

Area =	1612.9	mm2	2.50	in2
Fu =	1034	MPa	150	ksi

Conservatively assume load on each bolt = Fu

Pu =	1.67	MN/bolt	375	k/bolt

Geometry

Top bearing plate

b =	200	mm	7.9	in
t =	100	mm	3.9	in
L =	200	mm	7.9	in
hole diameter =	63	mm	2.5	in

Center stiffener

b =	200	mm	7.9	in
t =	40	mm	1.6	in
L =	600	mm	23.6	in
tw =	35	mm	1.4	in

Outer stiffener

b =	200	mm	7.9	in
t =	35	mm	1.4	in
L =	600	mm	23.6	in
tw =	35	mm	1.4	in

Bearing plate capacity

Sxx (at hole) =	228333	mm3	13.93	in3			
My =	78775000	N-mm	696.7	k-in			

Assume elastic simply supported bearing plate
Mmax = 1/4 Pmax L

Pmax =	1.58	MN	354.5	k	D/C =	1.06	NG

Assume elastic continuous bearing plate
Mmax = 5/32 Pmax L

Pmax =	2.52	MN	567.2	k	D/C =	0.66	Ok

Reactions at stiffeners (conservatively use max of continuous or simple support)

Rcenter =	2.29	MN	515.7	k
Router =	0.83	MN	187.5	k

Center stiffener capacity

Compression - column analogy
Include 200mm of web

Imin =	25466667	mm4	61.2	in4			
A =	23000	mm2	35.7	in2			
r =	33.28	mm	1.31	in			
use k =	1.00	for mill to bear ends					
kL/r =	18.03						
sqrt(2 x π^2 x E / Fy) =	107.0						
Fcr =	340.1	MPa	49.3	ksi			
Pmax =	2.72	MN	612	k	D/C =	0.84	Ok

Shear

D/t =	15.00						
6000 sqrt(k) / sqrt(Fy) =	60.00						
C =	1.00						
ϕs =	1.00						
Vr =	4.8	MN	1080	k	D/C =	0.48	Ok

Check weld

PJP =	34.0	mm	1.34	in			
Weld strength =	4.7	MN	1068	k	D/C =	0.48	Ok

Outer stiffener capacity

Compression - column analogy
Include 200mm of web

Imin =	24762500	mm4	59.5	in4			
A =	21000	mm2	32.6	in2			
r =	34.34	mm	1.35	in			
use k =	1.00	for mill to bear ends					
kL/r =	17.47						
sqrt(2 x π^2 x E / Fy) =	107.0						
Fcr =	340.4	MPa	49.4	ksi			
Pmax =	2.38	MN	536	k	D/C =	0.35	Ok

Shear

D/t =	17.14						
6000 sqrt(k) / sqrt(Fy) =	60.00						
C =	1.00						
ϕs =	1.00						
Vr =	4.2	MN	945	k	D/C =	0.20	Ok

Check weld

PJP =	29.0	mm	1.14	in			
Weld strength =	4.1	MN	911	k	D/C =	0.21	Ok

Check block shear tearout of webs

Shear length =	1200	mm	47.24	in			
Axial length =	400	mm	15.75	in			
t =	35	mm	1.38	in			
Atn = Atg =	14000	mm2	21.7	in2			
Avn = Avg =	42000	mm2	65.1	in2			
ϕbs =	0.80						
Rr =	12.6336	MN	3	k	D/C =	0.53	Ok

Check shear of 50x700mm plates

Shear capacity

Vr =	7.0	MN	1574	k	D/C =	0.95	Ok

Weld capacity

Vr =	7.2	MN	1612	k	D/C =	0.93	Ok

Area of steel within bearing footprint

Webs (3)

Width =	2900	mm	114.2	in
Thickness =	35	mm	1.38	in
Area (total) =	304500	mm2	472.0	in2

Shear plate

Width =	3500	mm	137.8	in
Thickness =	18	mm	0.71	in
Area (total) =	63000	mm2	97.7	in2

Longitudinal stiffeners (4)

Width =	3500	mm	137.8	in
Thickness =	45	mm	1.77	in
Area (total) =	630000	mm2	976.5	in2

Transverse shear plate stiffeners (8)

Width =	250	mm	9.8	in
Thickness =	25	mm	0.98	in
Area (total) =	50000	mm2	77.5	in2

Transverse plate stiffeners A (2)

Width =	550	mm	21.7	in
Thickness =	50	mm	1.97	in
Area (total) =	55000	mm2	85.3	in2

Transverse plate stiffeners B (2)

Width =	475	mm	18.7	in
Thickness =	50	mm	1.97	in
Area (total) =	47500	mm2	73.6	in2

Typical bearing assembly (14 pairs)

outer plates (2)

Width =	200	mm	7.9	in
Thickness =	35	mm	1.38	in

inner plate (1)

Width =	200	mm	7.9	in
Thickness =	40	mm	1.57	in
Area (1) =	22000	mm2	34.1	in2
Area (total) =	616000	mm2	954.8	in2
Ixx =	754141666.7	mm4	1811.8	in4
Iyy =	1124991667	mm4	2702.8	in4

Total plate bearing area above bottom flange within bearing footprint

Area (total) =	1766000	mm2	2737.3	in2

Moments of inertia assuming all plates active

Assume symmetry - not really correct

	Longit. mm4	Transv. mm4	Longit. in4	Transv. in4
Shear plate	64312500000	1701000	154511.3993	4.086668847
Web 1	2.28385E+11	71134583333	548698.0257	170901.5201
Web 2	10361458.33	71134583333	24.89350322	170901.5201
Web 3	2.28385E+11	71134583333	548698.0257	170901.5201
Longit stiff 1	1.60781E+11	1.27602E+11	386278.4982	306564.0177
Longit stiff 2	1.60781E+11	39401578125	386278.4982	94662.6701
Longit stiff 3	1.60781E+11	39401578125	386278.4982	94662.6701
Longit stiff 4	1.60781E+11	1.27602E+11	386278.4982	306564.0177
Transv shear plate stiff 1	5348307292	260416666.7	12849.35967	625.6535443
Transv shear plate stiff 2	1410807292	260416666.7	3389.478076	625.6535443
Transv shear plate stiff 3	1410807292	260416666.7	3389.478076	625.6535443
Transv shear plate stiff 4	5348307292	260416666.7	12849.35967	625.6535443
Transv plate stiff 1	18957588542	37460880534	45545.78865	90000.12548
Transv plate stiff 2	18957588542	37460880534	45545.78865	90000.12548
Transv plate stiff 3	18957588542	37460880534	45545.78865	90000.12548
Transv plate stiff 4	18957588542	37460880534	45545.78865	90000.12548
Bearing assemblies	4.71643E+11	15762143333	1133126.319	37868.70083
Total moment of inertia =	1.72521E+12	7.14059E+11	4144833.487	1715533.839
	Longit. mm3	Transv. mm3	Longit. in3	Transv. in3
Section modulus =	985834258	492454549	2368.5	1183.1

Loadings

Arm = 750 mm

	VT (MN)	VL (MN)	P (MN)	MT (MN-mm)	ML (MN-mm)
U	25.3	1.6	-9.5	18975	1200
T	30.5	8.2	16.4	22875	6150
L	1.3	13.2	19.3	975	9900
C	30	15	68	22500	11250

Max/Min Stress P/A + Mx/Sx + My/Sy

	Max (MPa)	Min (MPa)	Max (ksi)	Min (ksi)
U	34.37	-45.13	4.98	-6.54
T	61.98	-43.40	8.99	-6.29
L	22.95	-1.09	3.33	-0.16
C	95.61	-18.60	13.86	-2.70

Add prestressing force

Conservatively assume that force transferred thru stiffeners only

Stress = 151.68 MPa 21.99 ksi

	Max (MPa)	Min (MPa)	Max (ksi)	Min (ksi)	D/C	
U	186.05	106.56	26.98	15.45	0.54	Ok
T	213.66	108.28	30.98	15.70	0.62	Ok
L	174.63	150.59	25.32	21.84	0.51	Ok
C	247.29	133.09	35.86	19.30	0.72	Ok

Area of steel within bearing footprint

Webs (3)

Width =	2900	mm	114.2	in
Thickness =	35	mm	1.38	in
Area (total) =	304500	mm2	472.0	in2

Shear plate

Width =	3500	mm	137.8	in
Thickness =	18	mm	0.71	in
Area (total) =	63000	mm2	97.7	in2

Longitudinal stiffeners (4)

Width =	3500	mm	137.8	in
Thickness =	45	mm	1.77	in
Area (total) =	630000	mm2	976.5	in2

Transverse shear plate stiffeners (8)

Width =	250	mm	9.8	in
Thickness =	25	mm	0.98	in
Area (total) =	50000	mm2	77.5	in2

Transverse plate stiffeners A (2)

Width =	550	mm	21.7	in
Thickness =	50	mm	1.97	in
Area (total) =	55000	mm2	85.3	in2

Transverse plate stiffeners B (2)

Width =	475	mm	18.7	in
Thickness =	50	mm	1.97	in
Area (total) =	47500	mm2	73.6	in2

Typical bearing assembly (14 pairs)

outer plates (2)

Width =	200	mm	7.9	in
Thickness =	35	mm	1.38	in

inner plate (1)

Width =	200	mm	7.9	in
Thickness =	40	mm	1.57	in
Area (1) =	22000	mm2	34.1	in2
Area (total) =	616000	mm2	954.8	in2
Ixx =	754141666.7	mm4	1811.8	in4
Iyy =	1124991667	mm4	2702.8	in4

Total plate bearing area above bottom flange within bearing footprint

Area (total) =	1766000	mm2	2737.3	in2

Moments of inertia assuming all plates active

Assume symmetry - not really correct

	Longit. mm4	Transv. mm4	Longit. in4	Transv. in4
Shear plate	64312500000	1701000	154511.3993	4.086668847
Web 1	2.28385E+11	71134583333	548698.0257	170901.5201
Web 2	10361458.33	71134583333	24.89350322	170901.5201
Web 3	2.28385E+11	71134583333	548698.0257	170901.5201
Longit stiff 1				
Longit stiff 2				
Longit stiff 3				
Longit stiff 4				
Transv shear plate stiff 1				
Transv shear plate stiff 2				
Transv shear plate stiff 3				
Transv shear plate stiff 4				
Transv plate stiff 1				
Transv plate stiff 2				
Transv plate stiff 3				
Transv plate stiff 4				
Bearing assemblies				
Total moment of inertia =	5.21094E+11	2.13405E+11	1251932.344	512708.6469
	Longit. mm3	Transv. mm3	Longit. in3	Transv. in3
Section modulus =	297767763	147176173	715.4	353.6

Loadings

Arm = 750 mm

	VT (MN)	VL (MN)	P (MN)	MT (MN-mm)	ML (MN-mm)
U	25.3	1.6	-9.5	18975	1200
T	30.5	8.2	16.4	22875	6150
L	1.3	13.2	19.3	975	9900
C	30	15	68	22500	11250

Max/Min Stress P/A + Mx/Sx + My/Sy

	Max (MPa)	Min (MPa)	Max (ksi)	Min (ksi)
U	127.58	-138.34	18.50	-20.06
T	185.37	-166.79	26.88	-24.19
L	50.80	-28.94	7.37	-4.20
C	229.16	-152.15	33.23	-22.06

Add prestressing force

Force through stiffeners webs and diaphragms

Stress = 81.25 MPa 11.78 ksi

	Max (MPa)	Min (MPa)	Max (ksi)	Min (ksi)	D/C	
U	208.83	-57.09	30.28	-8.28	0.61	Ok
T	266.62	-85.54	38.66	-12.40	0.77	Ok
L	132.05	52.31	19.15	7.58	0.38	Ok
C	310.41	-70.90	45.01	-10.28	0.90	Ok

Prestressing force

56 50 diameter A354 Grade BD anchor bolts

Area =	1612.9	mm2	2.50	in2
Fu =	1034	MPa	150	ksi

Assume that bolts are tensioned to 0.68 Fu

Tension/bolt =	1.13	MN/bolt	253	k/bolt
Total force =	63	MN	14175	k

Friction coefficient, μ, steel to steel
- assume class B surface

μ = 0.5 Table 6.13.2.8-3

Lateral capacity at interface

- With no other loads present

P =	63	MN	14175	k
μ x P =	31.5	MN	7088	k

- With uplift of 13.3 MN 2989.84 k

P =	50	MN	11185	k
μ x P =	24.9	MN	5593	k

Demand

	VT (MN)	VL (MN)	P (MN)	Vtotal (MN)	Capacity	D/C	
U	25.3	1.6	-9.5	25.4	26.8	0.95	Ok
T	30.5	8.2	16.4	31.6	39.7	0.79	Ok
L	1.3	13.2	19.3	13.3	41.2	0.32	Ok
All maximums concurrent							
	30.5	13.2	-9.5	31.6	26.8	1.18	NG
Design demands							
C	30	15	-17	33.5	23.0	1.46	NG

Assumptions:
1. Look at it from a "block shear" perspective.
2. Local effects only - assumed that load spreads quickly away from bearing.
3. A709M Grade 345 (A709 Grade 50) steel.

Fy =	345	MPa	50	ksi
Fu =	450	MPa	65	ksi

Shear Key Demand

	MN	k
Compression	0	0
Uplift	0	0
Longitudinal	0	0
Transverse	60	13500

Shear Key "footprint"

Length, L =	3600	mm	141.7	in
Width, w =	3400	mm	133.9	in

Key plate "footprint"

Length, L =	4400	mm	173.2	in
Width, w =	4200	mm	165.4	in

Block Shear

If Atn $\leq$ 0.58 Avn then Rr = ϕbs (0.58 Fy Avg + Fu Atn) 6.13.4-1

otherwise Rr = ϕbs (0.58 Fu Avn + Fy Atg) 6.14.4-2

ϕbs = 0.80 6.5.4.2

Case 1 - Looking at bottom flange from the most conservative perspective

1. Ignore presence of transverse webs and longitudinal shear plates
2. Use minimum of key plate - holes or bottom flange no holes
3. Assume bottom flange thickness = 35 mm 1.38 in
4. Assume key plate thickness = 75 mm 2.95 in longitudinal
5. Assume 8 diameter 100 mm 3.94 in holes transverse
6. Assume 8 diameter 100 mm 3.94 in holes longitudinal

Transverse

Axial and shear areas

Atg =	308000	mm2	477.4	in2
Avg =	294000	mm2	455.7	in2
Atn =	308000	mm2	477.4	in2
Avn =	294000	mm2	455.7	in2

Rr = 157943.5 kN 35506 k D/C = 0.38 Ok

Shear areas only

Atg =	0	mm2	0.0	in2
Avg =	294000	mm2	455.7	in2
Atn =	0	mm2	0.0	in2
Avn =	294000	mm2	455.7	in2

Rr = 61387.2 kN 13800 k D/C = 0.98 Ok

Axial areas only

Atg =	308000	mm2	477.4	in2			
Avg =	0	mm2	0.0	in2			
Atn =	308000	mm2	477.4	in2			
Avn =	0	mm2	0.0	in2			
Rr =	110880	kN	24926	k	D/C =	0.54	Ok

Longitudinal

Axial and shear areas

Atg =	294000	mm2	455.7	in2			
Avg =	308000	mm2	477.4	in2			
Atn =	294000	mm2	455.7	in2			
Avn =	308000	mm2	477.4	in2			
Rr =	155144.6	kN	34877	k	D/C =	0.00	Ok

Shear areas only

Atg =	0	mm2	0.0	in2			
Avg =	308000	mm2	477.4	in2			
Atn =	0	mm2	0.0	in2			
Avn =	308000	mm2	477.4	in2			
Rr =	64310.4	kN	14457	k	D/C =	0.00	Ok

Axial areas only

Atg =	294000	mm2	455.7	in2			
Avg =	0	mm2	0.0	in2			
Atn =	294000	mm2	455.7	in2			
Avn =	0	mm2	0.0	in2			
Rr =	105840	kN	23793	k	D/C =	0.00	Ok

Transverse web plates

	MN	k
Demand	60	13500

Capacity (only consider 3 interior webs)

t =	40	mm	1.57	in			
Shear capacity =	24012	N/mm	137.0	k/in			
Length required =	2499	mm	98.5	in			
Width of bearing =			3400	mm			
			133.9	in	D/C =	0.74	Ok

Using conservative assumptions, there is sufficient capacity to carry transverse shear loads up into the girder.

Area of steel within shear key footprint

Webs (3)

Width =	3400	mm	133.9	in
Thickness =	40	mm	1.57	in
Area (total) =	408000	mm2	632.4	in2

Longitudinal stiffener

Width =	3600	mm	141.7	in
Thickness =	50	mm	1.97	in
Area (total) =	180000	mm2	279.0	in2

Longitudinal diaphragms (2)

Width =	3600	mm	141.7	in
Thickness =	50	mm	1.97	in
Area (total) =	720000	mm2	1116.0	in2

Bearing assembly 1 (4)

outer plates (2)				
Width =	300	mm	11.8	in
Thickness =	35	mm	1.38	in
inner plate (1)				
Width =	300	mm	11.8	in
Thickness =	50	mm	1.97	in
Area (1) =	36000	mm2	55.8	in2
Area (total) =	144000	mm2	223.2	in2

Bearing assembly 2 (4 pairs)

outer plates (2)				
Width =	300	mm	11.8	in
Thickness =	35	mm	1.38	in
inner plates (2)				
Width =	300	mm	11.8	in
Thickness =	40	mm	1.57	in
Area (1) =	45000	mm2	69.8	in2
Area (total) =	360000	mm2	558.0	in2

Bearing assembly 3 (2 pairs)

outer plates (2)				
Width =	300	mm	11.8	in
Thickness =	35	mm	1.38	in
inner plates (2)				
Width =	300	mm	11.8	in
Thickness =	40	mm	1.57	in
center plate (1)				
Width =	300	mm	11.8	in
Thickness =	50	mm	1.97	in
Area (1) =	60000	mm2	93.0	in2
Area (total) =	240000	mm2	372.0	in2

Total plate bearing area above bottom flange within shear key footprint

Area (total) =	2052000	mm2	3181	in2

Prestressing force (stiffened bolts)

48 76 diameter A354 Grade BD anchor bolts

Area =	3851.6	mm2	5.97	in2			
Fu =	966	MPa	140	ksi			
Conservatively assume that bolts are tensioned to Fu							
Tension/bolt =	3.72	MN/bolt	836	k/bolt			
Total force =	179	MN	40118	k			
Conservatively assume that force transferred thru stiffeners only							
Stress =	239.9	MPa	34.8	ksi	D/C =	0.70	Ok
Force through stiffeners webs and diaphragms							
Stress =	95.4	MPa	13.8	ksi	D/C =	0.20	Ok

Look at prestressing stiffener assembly

Material properties

Steel plate

Fy =	345	MPa	50	ksi
Fu =	450	MPa	65	ksi

Weld metal

Fexx =	485	MPa	70	ksi
ϕe =	0.80			
Rexx =	232.8	MPa	33.6	ksi

50 diameter A354 Grade BD anchor bolts

Area =	3851.6	mm2	5.97	in2
Fu =	966	MPa	140	ksi

Conservatively assume load on each bolt = 0.8Fu

Pu =	2.98	MN/bolt	668.64	k/bolt

Geometry

Top bearing plate

b =	300	mm	11.8	in
t =	200	mm	7.9	in
L =	400	mm	15.7	in
hole diameter =	100	mm	3.9	in

Center stiffener

b =	300	mm	11.8	in
t =	50	mm	2.0	in
L =	600	mm	23.6	in
tw =	40	mm	1.6	in

Interior stiffener

b =	300	mm	11.8	in
t =	50	mm	2.0	in
L =	600	mm	23.6	in
tw =	40	mm	1.6	in

Outer stiffener

b =	300	mm	11.8	in
t =	35	mm	1.4	in
L =	600	mm	23.6	in
tw =	40	mm	1.6	in

Bearing plate capacity

Look at shear between 2 bearing plates

I =	200000000	mm4	480.5	in4			
Q =	1500000	mm3	91.5	in4			
t =	90	mm	3.54	in			
Vmax =	2.23	MN	501.5	k			
VQ/It =	185.94	MPa	26.96	ksi	D/C =	0.80	

D/C <= 1.00 - therefore can assume bearing plates act as single unit

Sxx (at hole) =	1333333	mm3	81.36	in3			
My =	460000000	N-mm	4068.2	k-in			

Assume elastic simply supported bearing plate
Mmax = 1/4 Pmax L

Pmax =	4.60	MN	1035.0	k	D/C =	0.65	Ok

Reactions at stiffeners (conservatively use max of continuous or simple support)

Rcenter =	4.09	MN	919.6	k
Router =	1.49	MN	334.4	k

Center stiffener capacity

Compression - column analogy
Include 200mm of web

Imin =	32916667	mm4	79.1	in4			
A =	38000	mm2	58.9	in2			
r =	29.43	mm	1.16	in			
use k =	1.00	for mill to bear ends					
kL/r =	20.39						
sqrt(2 x π^2 x E / Fy) =	107.0						
Fcr =	338.7	MPa	49.1	ksi			
Pmax =	5.08	MN	1142	k	D/C =	0.81	Ok

Shear

D/t =	12.00						
6000 sqrt(k) / sqrt(Fy) =	60.00						
C =	1.00						
ϕs =	1.00						
Vr =	6.0	MN	1349	k	D/C =	0.68	Ok

Check weld

PJP =	32.0	mm	1.26	in			
Weld strength =	4.5	MN	1005	k	D/C =	0.92	Ok

Outer stiffener capacity

Compression - column analogy
Include 200mm of web

Imin =	28810417	mm4	69.2	in4
A =	29000	mm2	45.0	in2
r =	31.52	mm	1.24	in
use k =	1.00	for mill to bear ends		
kL/r =	19.04			

sqrt(2 x π^2 x E / Fy) =	107.0						
Fcr =	339.5	MPa	49.2	ksi			
Pmax =	3.57	MN	801	k	D/C =	0.42	Ok
Shear							
D/t =	17.14						
6000 sqrt(k) / sqrt(Fy) =	60.00						
C =	1.00						
ϕs =	1.00						
Vr =	4.2	MN	945	k	D/C =	0.35	Ok
Check weld							
PJP =	29.0	mm	1.14	in			
Weld strength =	4.1	MN	911	k	D/C =	0.37	Ok

Check block shear tearout of diaphragms

Shear length =	1200	mm	47.24	in			
Axial length =	1100	mm	43.31	in			
t =	50	mm	1.97	in			
Atn = Atg =	55000	mm2	85.3	in2			
Avn = Avg =	60000	mm2	93.0	in2			
ϕbs =	0.80						
Rr =	29.4	MN	6.6	k	D/C =	0.76	Ok

Check block shear tearout of webs

Shear length =	1800	mm	70.87	in			
Axial length =	1220	mm	48.03	in			
teff =	43.3	mm	1.71	in			
Atn = Atg =	52867	mm2	81.9	in2			
Avn = Avg =	78000	mm2	120.9	in2			
ϕbs =	0.80						
Rr =	31.5	MN	7.1	k	D/C =	0.94	Ok

Area of steel within bearing footprint

Webs (3)

Width =	3400	mm	133.9	in
Thickness =	40	mm	1.57	in
Area (total) =	408000	mm2	632.4	in2

Diaphragms (2)

Width =	3600	mm	141.7	in
Thickness =	50	mm	1.97	in
Area (total) =	540000	mm2	837.0	in2

Total plate bearing area above bottom flange within bearing footprint

Area (total) =	948000	mm2	632.4	in2

Moments of inertia assuming all plates active

Assume symmetry

	Transv. mm4	Transv. in4
Web 1	1.31013E+11	314760.7924
Web 2	0	0
Web 3	1.31013E+11	314760.7924
Diaphragm 1	3.52838E+11	847695.4845
Diaphragm 2	3.52838E+11	847695.4845
Total moment of inertia =	9.67702E+11	2324912.554
	Transv. mm3	Transv. in3
Section modulus =	691215476	42180.6

Loadings

Transverse Demand =	42	MN
Arm =	750	mm
Moment =	31500	MN-mm

Max/Min Stress = My/Sy

	Max (MPa)	Min (MPa)	Max (ksi)	Min (ksi)
Normal Stress	45.57	-45.57	6.61	-6.61

Add prestressing force

Force through stiffeners webs and diaphragms

Stress =	95.35	MPa	13.83	ksi

	Max (MPa)	Min (MPa)	Max (ksi)	Min (ksi)	D/C	
T	140.93	49.78	20.43	7.22	0.41	Ok

Prestressing force

80 76 diameter A354 Grade BD anchor bolts

Area =	3852	mm2	5.97	in2
Fu =	966	MPa	140	ksi

Assume that bolts are tensioned to 0.68 Fu

Tension/bolt =	2.510	MN/bolt	564	k/bolt
Total force =	201	MN	45133	k

Friction coefficient, μ, steel to steel
- assume class B surface

μ = 0.5 Table 6.13.2.8-3

Lateral capacity at interface

- No other axial loads present

P =	201	MN	45133	k			
Shear capacity							
μ x P =	100	MN	22567	k	D/C =	0.60	Ok

Cross Beam Estimated Section Properties

Top flange				
Width =	10000	mm	393.7	in
Thickness =	20	mm	0.8	in
Stiffeners				
Number =	20			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
"Effective" top flange				
Width =	10000	mm	393.7	in
Thickness =	29.02	mm	1.1	in
Outer webs				
Width =	5500	mm	216.5	in
Thickness =	20	mm	0.8	in
Stiffeners				
Number =	13			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
"Effective" outer web				
Width =	5500	mm	216.5	in
Thickness =	30.66	mm		
Inner webs1				
Width1 =	3275	mm	128.9	in
Thickness1 =	20	mm	0.8	in
Stiffeners1				
Number =	7			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
Width2 =	2225	mm	87.6	in
Thickness2 =	40	mm	1.6	in
Stiffeners2				
Number =	4			
Width =	200	mm	7.9	in
Thickness =	40	mm	1.6	in
"Effective" inner web1				
Width1 =	3275	mm	128.9	in
Thickness1 =	29.64	mm	1.2	in
Width2 =	2225	mm	87.6	in
Thickness2 =	54.38	mm	2.1	in

Inner webs2				
Width1 =	3275	mm	128.9	in
Thickness1 =	20	mm	0.8	in
Stiffeners1				
Number =	7			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
Width2 =	2225	mm	87.6	in
Thickness2 =	40	mm	1.6	in
Stiffeners2				
Number =	5			
Width =	200	mm	7.9	in
Thickness =	40	mm	1.6	in
"Effective" inner web2				
Width1 =	3275	mm	128.9	in
Thickness1 =	29.64	mm	1.2	in
Width2 =	2225	mm	87.6	in
Thickness2 =	57.98	mm	2.3	in
Bottom flange				
Width1 =	3000	mm	118.1	in
Thickness1 =	35	mm	1.4	in
Stiffeners1				
Number =	7			
Width =	310	mm	12.2	in
Thickness =	35	mm	1.4	in
Width2 =	4000	mm	157.5	in
Thickness2 =	35	mm	1.4	in
Width3 =	3000	mm	118.1	in
Thickness3 =	35	mm	1.4	in
Stiffeners 3				
Number =	7			
Width =	310	mm	12.2	in
Thickness =	35	mm	1.4	in
"Effective" bottom flange				
Width1 =	3000	mm	118.1	in
Thickness1 =	60.3	mm	2.4	in
Width2 =	4000	mm	157.5	in
Thickness2 =	35.0	mm	1.4	in
Width3 =	3000	mm	118.1	in
Thickness3 =	60.3	mm	2.4	in
Area =	1791570	mm2	2776.9	in2
NAxx (from top) =	3236	mm	127.4	in
NAyy (from center) =	0	mm	0.0	in
Ixx =	8.19082E+12	mm4	19678521	in4
Sxtop =	2531494140	mm3	154481.3	in3
Sxbot =	3617160932	mm3	220732.7	in3
Iyy =	1.55463E+13	mm4	37350231	in4
Sy =	777317000	mm3	47434.79	in3

Cable geometry (from Suspension Cable Layout No. 3)

	WP1	WPA	EP1	EPA
X	393	35852	393	34114
Y	36045	29461	-36025	-29939
Z	266	-3106	-1176	-4339

Angle in XY plane	West	0.18359	East	0.17856	radians
		10.519		10.231	degrees
Angle in XZ plane	West	0.09481	East	0.09353	radians
		5.432		5.359	degrees

Estimated max cable force

Fa =	689	MPa	100	ksi	(From General Notes No. 1)
net area =	0.39848	m2	617.6	in2	(From Suspension Cable Layout No. 1)
Pmax =	275	MN	61719	k	

Estimated forces in crossbeam at Pier E2

X =	50.1	MN	11267	k
ex =	500	mm	20	in
Y =	4.6	MN	1033	k
ey =	10785	mm	425	in
Z =	0.4	MN	98	k
ez =	2986	mm	118	in
Mx = X ez + Z ey =	154353.5	MN-mm	113841	k-ft
My = Y ex =	2296.6	MN-mm	1694	k-ft
P/A + Mx/Sx + My/Sy =	73.6	MPa	10.67	ksi

Seismic shear force

Peq =	120.0	MN	26976	k			
ez =	3014.4	mm	118.7	in			
P/A + Mx/Sx =	67.8	MPa	9.83	ksi			
Total stress =	141.4	MPa	20.51	ksi	D/C =	0.41	Ok

Cross Beam Estimated Section Properties

Top flange				
Width =	4000	mm	157.5	in
Thickness =	20	mm	0.8	in
Stiffeners				
Number =	6			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
"Effective" top flange				
Width =	4000	mm	157.5	in
Thickness =	26.765	mm	1.1	in
Outer webs				
Width =	5500	mm	216.5	in
Thickness =	0	mm	0.0	in
Stiffeners				
Number =	0			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
"Effective" outer web				
Width =	5500	mm	216.5	in
Thickness =	0	mm		
Inner webs1				
Width1 =	3275	mm	128.9	in
Thickness1 =	20	mm	0.8	in
Stiffeners1				
Number =	7			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
Width2 =	2225	mm	87.6	in
Thickness2 =	40	mm	1.6	in
Stiffeners2				
Number =	4			
Width =	200	mm	7.9	in
Thickness =	40	mm	1.6	in
"Effective" inner web1				
Width1 =	3275	mm	128.9	in
Thickness1 =	29.64	mm	1.2	in
Width2 =	2225	mm	87.6	in
Thickness2 =	54.38	mm	2.1	in

Inner webs2				
Width1 =	3275	mm	128.9	in
Thickness1 =	20	mm	0.8	in
Stiffeners1				
Number =	7			
Width =	205	mm	8.1	in
Thickness =	22	mm	0.9	in
Width2 =	2225	mm	87.6	in
Thickness2 =	40	mm	1.6	in
Stiffeners2				
Number =	5			
Width =	200	mm	7.9	in
Thickness =	40	mm	1.6	in
"Effective" inner web2				
Width1 =	3275	mm	128.9	in
Thickness1 =	29.64	mm	1.2	in
Width2 =	2225	mm	87.6	in
Thickness2 =	57.98	mm	2.3	in
Bottom flange				
Width1 =	3000	mm	118.1	in
Thickness1 =	0	mm	0.0	in
Stiffeners1				
Number =	0			
Width =	310	mm	12.2	in
Thickness =	35	mm	1.4	in
Width2 =	4000	mm	157.5	in
Thickness2 =	35	mm	1.4	in
Width3 =	3000	mm	118.1	in
Thickness3 =	0	mm	0.0	in
Stiffeners 3				
Number =	0			
Width =	310	mm	12.2	in
Thickness =	35	mm	1.4	in
"Effective" bottom flange				
Width1 =	3000	mm	118.1	in
Thickness1 =	0.0	mm	0.0	in
Width2 =	4000	mm	157.5	in
Thickness2 =	35.0	mm	1.4	in
Width3 =	3000	mm	118.1	in
Thickness3 =	0.0	mm	0.0	in
Area =	909270	mm2	1409.4	in2
NAxx (from top) =	3163	mm	124.5	in
NAyy (from center) =	0	mm	0.0	in
Ixx =	3.48304E+12	mm4	8368031	in4
Sxtop =	1101169898	mm3	67197.51	in3
Sxbot =	1490409752	mm3	90950.38	in3
Iyy =	1.31073E+12	mm4	3149037	in4
Sy =	163841041.7	mm3	9998.194	in3

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Y	36045	29461	-36025	-29939
Z	266	-3106	-1176	-4339

Angle in XY plane	West	0.18359	East	0.17856	radians
		10.519		10.231	degrees
Angle in XZ plane	West	0.09481	East	0.09353	radians
		5.432		5.359	degrees

Estimated max cable force

Fa =	689	MPa	100	ksi	(From General Notes No. 1)
net area =	0.39848	m2	617.6	in2	(From Suspension Cable Layout No. 1)
Pmax =	275	MN	61719	k	

Estimated forces in crossbeam at Pier E2

X =	50.1	MN	11267	k
ex =	500	mm	20	in
Y =	4.6	MN	1033	k
ey =	10785	mm	425	in
Z =	0.4	MN	98	k
ez =	2913	mm	115	in
Mx = X ez + Z ey =	150718.0	MN-mm	111159	k-ft
My = Y ex =	2296.6	MN-mm	1694	k-ft
P/A + Mx/Sx + My/Sy =	170.3	MPa	24.69	ksi

Seismic shear force

Peq =	0.0	MN	0	k			
ez =	3087.0	mm	121.5	in			
P/A + Mx/Sx =	2.1	MPa	0.30	ksi			
Total stress =	172.3	MPa	24.99	ksi	D/C =	0.50	Ok