

The Engineer's Toolkit

Validation examples

Issue date	Revisions
1 June 2011	ANSI/AISC 360-10. Added singly symmetric I shape examples
7 July 2012	Canadian S16-09 added. BS EN 1993-6 runway beam added
17 October 2012	ANSI/AISC 360-10 Tee section. AISC Web capacities
20 February 2014	Stiffened plate DNV C201. Vortex vibration (air) DNV C205
28 April 2014	Revised runway beam, BS EN 1993-6

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1.0 General

This volume contains worked examples of the various programs contained in the Engineer's toolkit suite.

All examples provide hand calculations together with program output.

- 2.0 Roark rings**
- 2.1 Roark Ring Analysis
- 2.2 2-D Analysis

2.1 Roark ring analysis

The 'Roark cases' option of the program uses the ring analysis formulae of "Roark's formulas for stress and strain", Warren E Young, 6th Ed. to calculate member forces around a ring for selected loadcases.

The combinations in the 'Roark Combs' option are simply in-built combinations of basic Roark cases.

Users can combine up to 24 individual loadcases to form a total combination which is then analysed.

The member stresses calculated include the curved beam effects given in table 16 of the reference

Roark Rings, table 17 definitions

2.1.2

$$M_x = M_a - N_a.R(1-u) + V_a.Rz + LT_m$$

$$N_x = N_a.u + V_a.z + LT_n$$

$$V = -N_a.z + V_a.u + LT_v$$

$$s = \sin(\theta), c = \cos(\theta), z = \sin(x), u = \cos(x)$$

Design case

Rectangular section $B = 0.02\text{m}$ $D = 0.1\text{m}$

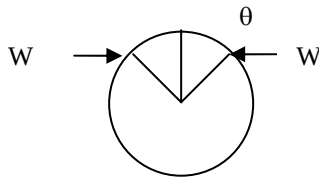
$$A = 0.02 * 0.10 = 0.002\text{m}^2$$

$$I = 0.02 * 0.1^3/12 = 1.67\text{E}-6$$

$$\alpha = I/(AR^2) = 1.67\text{E}-6/(0.002 * .5^2) = 0.003$$

$$K2 = 1 - \alpha \approx \text{approximately } 1$$

Load case 2



$$W = 10\text{kN}, \theta = 45^\circ = \pi/4$$

$$M_a = -W.R/\pi [(\pi - \theta) (1 - c) - s (K2 - c)]$$

$$\text{where } c = 0.7071, s = 0.7071$$

$$M_a = -1.59 [2.356 * 0.29 - 0.21]$$

$$M_a = -0.764$$

$$N_a = -W/p (\pi - \theta + s c)$$

$$N_a = -3.183 (2.356 + 0.5)$$

$$N_a = -9.09$$

$$V_a = 0$$

At point $x = 45 = \pi/4$, i.e. at the load point, $x - \theta = \text{zero}$

$$LT_m = -WR (c-u) < x - \theta > \quad x < \theta$$

$$LT_m = 0$$

$$LT_n = Wu < x - \theta > = 0$$

$$LT_v = -Wz < x - \theta > = 0$$

$$M_{(x=45)} = -0.764 + 9.09 * .5 (1 - 0.7071) + 0 + 0 = 0.567$$

$$N_{(x=45)} = -9.09 * 0.7071 + 0 + 0 = -6.43$$

$$V_{(x=45)} = 9.09 * 0.7071 + 0 = 6.43$$

2.1.3

For $x = 135^\circ = 3\pi/4$

$u = \cos(x) = -0.707$

$z = \sin(x) = 0.707$

$LT_m = -WR (c-u) < x - \theta >$

$(c - u) = \cos(45) - \cos(135)$
 $= 1.414$

$(x - \theta) = 135 - 45$
 $= 90^\circ = 1$

$LT_m = -WR (c-u) * 1$

$LT_m = -10 * 0.5 (1.414) * 1$

$LT_m = -7.07$

$LT_n = W.u < 1 >$

$LT_n = -7.07$

$LT_v = W.z < 1 >$

$LT_v = -7.07$

$M_{(x=135)} = -0.764 + 9.09 * .5 (1 + 0.7071) + 0 + (-0.707)$
 $= -0.076$

$N_{(x=135)} = -9.09 * 0.7071 + 0 + (-7.071)$
 $= -0.64$

$V_{(x=135)} = -(-9.09) * 0.7071 + 0 + (-7.071)$
 $= 0.64$

Beam stresses

2.1.4

Calculate curved beam factor using table 16

Using millimetres

B = 20, D = 100

Radius (R) = 500

$$c = D/2 = 50$$

$$R/c = 10 \text{ and from table, } h/c = 0.033$$

Stress factors

$$K_i = 1.071 = \sigma_i / \sigma$$

$$K_o = 0.973 = \sigma_o / \sigma$$

Consider stress at $x = 45$

$$\text{Area} = 100 * 20 = 2000 \text{mm}^2$$

$$\text{Elastic modulus} = Z = B * D^2 / 6 = 33.33 \text{E}3$$

$$M_{45} = 0.56 \text{ kNm}$$

$$P_{45} = - 6.43 \text{ kN}$$

$$V_{45} = 6.43 \text{ kN}$$

Bending stress

$$f_{bi} = k_i * M/Z = 18 \text{MPa}$$

$$f_{bo} = k_o * M/Z = 15.7 \text{MPa}$$

$$f_{ax} = P/A = 3.2 \text{MPa}$$

$$f_v = V/A = 3.2 \text{MPa}$$

These compare with the printed output at 45 degrees

G. Simms

2.1.6

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2

Solve ring loading using 'Roark's formulas for stress & strain',
W. C. Young, 6th edition, 1989. Tables 16 & 17. (ver 2.13.2)

Section data (mm)

radius to outer flange = 550

outer flange web
0.0 x 0.0 100.0 x 20.0

inner flange
0.0 x 0.0

shape
(out)

area = 2000.0 mm²

I n-a = 1.67 x10⁶ mm⁴

z outer = 33.33 x10³ mm³

z inner = 33.33 x10³ mm³

curved beam factors

k outer = .94

k inner = 1.07

ring radius to n-a = 500.0

Load combination

Case	W or M (kN, kNm)	theta (deg)	Phi (deg)	phase (deg)
2	10	45.0	0.0	0.0

Maximum section stresses (MPa)

axial= -4.55 bend= -24.75 max(fax + fb)= -29.3 shear= 3.21

NB The shear stress is the average (radial force/web area).

Users should adjust this for rectangular sections etc. (parabolic distribution

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2

Member actions and stresses

... Actions				Stresses (tension =+ve)				...
Angle is measured clockwise from 12 o'clock (up the page)								
Angle	Moment	Axial	Shear	fb(o)	fb(i)	fa	fv	(max)
(Deg)	(kN-m)	(kN)	(kN)	(MPa)	(MPa)	(MPa)	(MPa)	(fb+fa)
0	-0.77	-9.09	0.00	21.6	-24.8	-4.5	0.0	-29.3
15	-0.61	-8.78	2.35	17.3	-19.8	-4.4	1.2	-24.2
30	-0.16	-7.87	4.55	4.5	-5.1	-3.9	2.3	-9.1
45	0.56	-6.43	6.43	-15.8	18.1	-3.2	3.2	-19.1
60	0.47	0.45	-0.79	-13.2	15.1	0.2	-0.4	15.3
75	0.36	0.24	-0.88	-10.1	11.6	0.1	-0.4	11.7
90	0.24	0.00	-0.91	-6.8	7.8	0.0	-0.5	7.8
105	0.12	-0.24	-0.88	-3.5	4.0	-0.1	-0.4	3.9
120	0.01	-0.45	-0.79	-0.4	0.5	-0.2	-0.4	-0.6
135	-0.08	-0.64	-0.64	2.2	-2.6	-0.3	-0.3	-2.9
150	-0.15	-0.79	-0.45	4.3	-4.9	-0.4	-0.2	-5.3
165	-0.20	-0.88	-0.24	5.6	-6.4	-0.4	-0.1	-6.8
180	-0.21	-0.91	0.00	6.0	-6.8	-0.5	0.0	-7.3
195	-0.20	-0.88	0.24	5.6	-6.4	-0.4	0.1	-6.8
210	-0.15	-0.79	0.45	4.3	-4.9	-0.4	0.2	-5.3
225	-0.08	-0.64	0.64	2.2	-2.6	-0.3	0.3	-2.9
240	0.01	-0.45	0.79	-0.4	0.5	-0.2	0.4	-0.6
255	0.12	-0.24	0.88	-3.5	4.0	-0.1	0.4	3.9
270	0.24	0.00	0.91	-6.8	7.8	0.0	0.5	7.8
285	0.36	0.24	0.88	-10.1	11.6	0.1	0.4	11.7
300	0.47	0.45	0.79	-13.2	15.1	0.2	0.4	15.3
315	0.56	-6.43	-6.43	-15.8	18.1	-3.2	-3.2	-19.1
330	-0.16	-7.87	-4.55	4.5	-5.1	-3.9	-2.3	-9.1
345	-0.61	-8.78	-2.35	17.3	-19.8	-4.4	-1.2	-24.2

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2

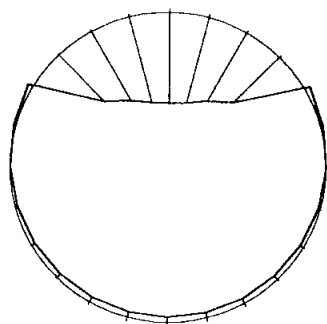
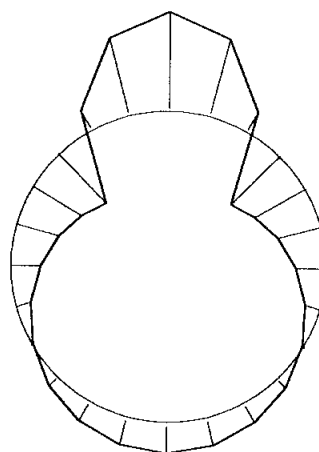
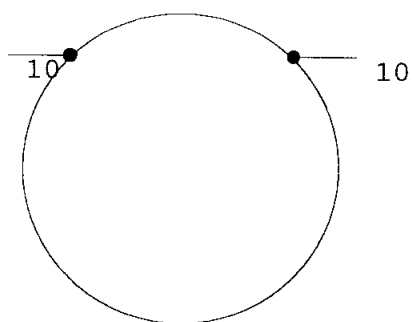
Loading (kN)

- = point load/reaction
- = UDL load/reaction
(shear reactions not shown.)

Bending moment

(plotted on tension side of ring)

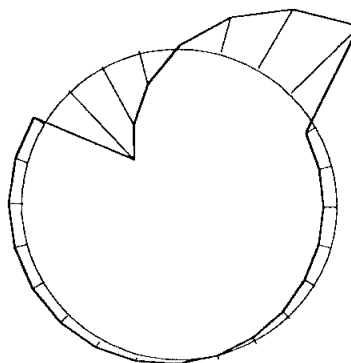
Max moment = -0.77 kN-m



Hoop load

(compression plotted on inside of ring)

Max axial = -9.09 kN



Radial shear

Max shear = 6.43 kN

2.2 2-D ring analysis

The '2-D analysis cases uses a 2-D plane frame solution to determine the member actions on a circular structure with nodes at the pre-set number of degrees around the circumference.

The member stresses calculated include the curved beam effects given in table 16 of the reference

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings - 2D

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2 - 2D analysis at 5deg node spacing

Solve ring loading using a 2D analysis with nodes
at every 5 degrees.

Section data (mm)

radius to outer flange = 550

outer flange	web
0.0 x 0.0	100.0 x 20.0

inner flange
0.0 x 0.0

shape
(out)

area = 2000.0 mm²I n-a = 1.67 x10⁶ mm⁴z outer = 33.33 x10³ mm³z inner = 33.33 x10³ mm³

curved beam factors

k outer = .94

k inner = 1.07

ring radius to n-a = 500.0

Load combination

Case	W or M (kN, kNm)	theta (deg)	Phi (deg)	phase (deg)
90	10	315.0	0.0	0.0
90	-10	45.0	0.0	0.0

Maximum section stresses (MPa)

axial= -4.54 bend= -24.64 max(fax + fb)= -29.17 shear= 3.07

NB The shear stress is the average (radial force/web area).

Users should adjust this for rectangular sections etc. (parabolic distribution)

Support reactions

Node	Angle	FX (kN)	FY (kN)	MZ (kN.m)
19	90	0.00	0.00	0.00

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PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings - 2D

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2 - 2D analysis at 5deg node spacing

Member actions and stresses

... Actions 				Stresses (tension =+ve)				...
Angle is measured clockwise from 12 o'clock (up the page) (max)								
Angle	Moment	Axial	Shear	fb(o)	fb(i)	fa	fv	(fb+fa)
(Deg)	(kN-m)	(kN)	(kN)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	-0.77	-9.07	0.40	21.5	-24.6	-4.5	0.2	-29.2
5	-0.75	-9.07	0.40	21.1	-24.1	-4.5	0.2	-28.6
5	-0.75	-9.01	1.19	21.1	-24.1	-4.5	0.6	-28.6
10	-0.70	-9.01	1.19	19.6	-22.4	-4.5	0.6	-26.9
10	-0.70	-8.87	1.97	19.6	-22.4	-4.4	1.0	-26.8
15	-0.61	-8.87	1.97	17.2	-19.7	-4.4	1.0	-24.1
15	-0.61	-8.66	2.73	17.2	-19.7	-4.3	1.4	-24.0
20	-0.49	-8.66	2.73	13.8	-15.8	-4.3	1.4	-20.1
20	-0.49	-8.39	3.48	13.8	-15.8	-4.2	1.7	-20.0
25	-0.34	-8.39	3.48	9.6	-10.9	-4.2	1.7	-15.1
25	-0.34	-8.06	4.19	9.6	-10.9	-4.0	2.1	-15.0
30	-0.16	-8.06	4.19	4.4	-5.0	-4.0	2.1	-9.1
30	-0.16	-7.66	4.88	4.4	-5.0	-3.8	2.4	-8.9
35	0.06	-7.66	4.88	-1.6	1.8	-3.8	2.4	-5.4
35	0.06	-7.21	5.53	-1.6	1.8	-3.6	2.8	-5.2
40	0.30	-7.21	5.53	-8.4	9.6	-3.6	2.8	-12.0
40	0.30	-6.70	6.14	-8.4	9.6	-3.3	3.1	-11.7
45	0.57	-6.70	6.14	-15.9	18.2	-3.3	3.1	-19.3
45	0.57	0.62	-0.68	-15.9	18.2	0.3	-0.3	18.5
50	0.54	0.62	-0.68	-15.1	17.2	0.3	-0.3	17.6
50	0.54	0.56	-0.73	-15.1	17.2	0.3	-0.4	17.5
55	0.50	0.56	-0.73	-14.2	16.2	0.3	-0.4	16.5
55	0.50	0.49	-0.77	-14.2	16.2	0.2	-0.4	16.5
60	0.47	0.49	-0.77	-13.2	15.1	0.2	-0.4	15.4
60	0.47	0.42	-0.81	-13.2	15.1	0.2	-0.4	15.3
65	0.43	0.42	-0.81	-12.2	14.0	0.2	-0.4	14.2
65	0.43	0.35	-0.85	-12.2	14.0	0.2	-0.4	14.2
70	0.40	0.35	-0.85	-11.2	12.8	0.2	-0.4	13.0
70	0.40	0.28	-0.87	-11.2	12.8	0.1	-0.4	12.9
75	0.36	0.28	-0.87	-10.1	11.6	0.1	-0.4	11.7
75	0.36	0.20	-0.90	-10.1	11.6	0.1	-0.4	11.7
80	0.32	0.20	-0.90	-9.0	10.3	0.1	-0.4	10.4
80	0.32	0.12	-0.91	-9.0	10.3	0.1	-0.5	10.4
85	0.28	0.12	-0.91	-7.9	9.0	0.1	-0.5	9.1
85	0.28	0.04	-0.92	-7.9	9.0	0.0	-0.5	9.1
90	0.24	0.04	-0.92	-6.8	7.8	0.0	-0.5	7.8
90	0.24	-0.04	-0.92	-6.8	7.8	0.0	-0.5	7.7
95	0.20	-0.04	-0.92	-5.7	6.5	0.0	-0.5	6.4
95	0.20	-0.12	-0.91	-5.7	6.5	-0.1	-0.5	6.4
100	0.16	-0.12	-0.91	-4.5	5.2	-0.1	-0.5	5.1
100	0.16	-0.20	-0.90	-4.5	5.2	-0.1	-0.4	5.1
105	0.12	-0.20	-0.90	-3.4	3.9	-0.1	-0.4	3.8

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings - 2D

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2 - 2D analysis at 5deg node spacing

Angle (Deg)	Moment (kN-m)	Axial (kN)	Shear (kN)	fb(o) (MPa)	fb(i) (MPa)	fa (MPa)	fv (MPa)	(fb+fa) (MPa)
105	0.12	-0.28	-0.87	-3.4	3.9	-0.1	-0.4	3.8
110	0.08	-0.28	-0.87	-2.4	2.7	-0.1	-0.4	2.6
110	0.08	-0.35	-0.85	-2.4	2.7	-0.2	-0.4	-2.5
115	0.05	-0.35	-0.85	-1.3	1.5	-0.2	-0.4	-1.5
115	0.05	-0.42	-0.81	-1.3	1.5	-0.2	-0.4	-1.5
120	0.01	-0.42	-0.81	-0.3	0.4	-0.2	-0.4	-0.5
120	0.01	-0.49	-0.77	-0.3	0.4	-0.2	-0.4	-0.6
125	-0.02	-0.49	-0.77	0.6	-0.7	-0.2	-0.4	-1.0
125	-0.02	-0.56	-0.73	0.6	-0.7	-0.3	-0.4	-1.0
130	-0.05	-0.56	-0.73	1.5	-1.7	-0.3	-0.4	-2.0
130	-0.05	-0.62	-0.68	1.5	-1.7	-0.3	-0.3	-2.0
135	-0.08	-0.62	-0.68	2.3	-2.7	-0.3	-0.3	-3.0
135	-0.08	-0.68	-0.62	2.3	-2.7	-0.3	-0.3	-3.0
140	-0.11	-0.68	-0.62	3.1	-3.6	-0.3	-0.3	-3.9
140	-0.11	-0.73	-0.56	3.1	-3.6	-0.4	-0.3	-3.9
145	-0.13	-0.73	-0.56	3.8	-4.3	-0.4	-0.3	-4.7
145	-0.13	-0.77	-0.49	3.8	-4.3	-0.4	-0.2	-4.7
150	-0.16	-0.77	-0.49	4.4	-5.0	-0.4	-0.2	-5.4
150	-0.16	-0.81	-0.42	4.4	-5.0	-0.4	-0.2	-5.4
155	-0.17	-0.81	-0.42	4.9	-5.6	-0.4	-0.2	-6.0
155	-0.17	-0.85	-0.35	4.9	-5.6	-0.4	-0.2	-6.1
160	-0.19	-0.85	-0.35	5.4	-6.1	-0.4	-0.2	-6.5
160	-0.19	-0.87	-0.28	5.4	-6.1	-0.4	-0.1	-6.6
165	-0.20	-0.87	-0.28	5.7	-6.5	-0.4	-0.1	-6.9
165	-0.20	-0.90	-0.20	5.7	-6.5	-0.4	-0.1	-7.0
170	-0.21	-0.90	-0.20	5.9	-6.8	-0.4	-0.1	-7.2
170	-0.21	-0.91	-0.12	5.9	-6.8	-0.5	-0.1	-7.2
175	-0.22	-0.91	-0.12	6.1	-7.0	-0.5	-0.1	-7.4
175	-0.22	-0.92	-0.04	6.1	-7.0	-0.5	0.0	-7.4
180	-0.22	-0.92	-0.04	6.1	-7.0	-0.5	0.0	-7.5
180	-0.22	-0.92	0.04	6.1	-7.0	-0.5	0.0	-7.5
185	-0.22	-0.92	0.04	6.1	-7.0	-0.5	0.0	-7.4
185	-0.22	-0.91	0.12	6.1	-7.0	-0.5	0.1	-7.4
190	-0.21	-0.91	0.12	5.9	-6.8	-0.5	0.1	-7.2
190	-0.21	-0.90	0.20	5.9	-6.8	-0.4	0.1	-7.2
195	-0.20	-0.90	0.20	5.7	-6.5	-0.4	0.1	-7.0
195	-0.20	-0.87	0.28	5.7	-6.5	-0.4	0.1	-6.9
200	-0.19	-0.87	0.28	5.4	-6.1	-0.4	0.1	-6.6
200	-0.19	-0.85	0.35	5.4	-6.1	-0.4	0.2	-6.5
205	-0.17	-0.85	0.35	4.9	-5.6	-0.4	0.2	-6.1
205	-0.17	-0.81	0.42	4.9	-5.6	-0.4	0.2	-6.0
210	-0.16	-0.81	0.42	4.4	-5.0	-0.4	0.2	-5.4
210	-0.16	-0.77	0.49	4.4	-5.0	-0.4	0.2	-5.4
215	-0.13	-0.77	0.49	3.8	-4.3	-0.4	0.2	-4.7

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings - 2D

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2 - 2D analysis at 5deg node spacing

Angle (Deg)	Moment (kN-m)	Axial (kN)	Shear (kN)	fb(o) (MPa)	fb(i) (MPa)	fa (MPa)	fv (MPa)	(fb+fa) (MPa)
215	-0.13	-0.73	0.56	3.8	-4.3	-0.4	0.3	-4.7
220	-0.11	-0.73	0.56	3.1	-3.6	-0.4	0.3	-3.9
220	-0.11	-0.68	0.62	3.1	-3.6	-0.3	0.3	-3.9
225	-0.08	-0.68	0.62	2.3	-2.7	-0.3	0.3	-3.0
225	-0.08	-0.62	0.68	2.3	-2.7	-0.3	0.3	-3.0
230	-0.05	-0.62	0.68	1.5	-1.7	-0.3	0.3	-2.0
230	-0.05	-0.56	0.73	1.5	-1.7	-0.3	0.4	-2.0
235	-0.02	-0.56	0.73	0.6	-0.7	-0.3	0.4	-1.0
235	-0.02	-0.49	0.77	0.6	-0.7	-0.2	0.4	-1.0
240	0.01	-0.49	0.77	-0.3	0.4	-0.2	0.4	-0.6
240	0.01	-0.42	0.81	-0.3	0.4	-0.2	0.4	-0.5
245	0.05	-0.42	0.81	-1.3	1.5	-0.2	0.4	-1.5
245	0.05	-0.35	0.85	-1.3	1.5	-0.2	0.4	-1.5
250	0.08	-0.35	0.85	-2.4	2.7	-0.2	0.4	-2.5
250	0.08	-0.28	0.87	-2.4	2.7	-0.1	0.4	2.6
255	0.12	-0.28	0.87	-3.4	3.9	-0.1	0.4	3.8
255	0.12	-0.20	0.90	-3.4	3.9	-0.1	0.4	3.8
260	0.16	-0.20	0.90	-4.5	5.2	-0.1	0.4	5.1
260	0.16	-0.12	0.91	-4.5	5.2	-0.1	0.5	5.1
265	0.20	-0.12	0.91	-5.7	6.5	-0.1	0.5	6.4
265	0.20	-0.04	0.92	-5.7	6.5	0.0	0.5	6.4
270	0.24	-0.04	0.92	-6.8	7.8	0.0	0.5	7.7
270	0.24	0.04	0.92	-6.8	7.8	0.0	0.5	7.8
275	0.28	0.04	0.92	-7.9	9.0	0.0	0.5	9.1
275	0.28	0.12	0.91	-7.9	9.0	0.1	0.5	9.1
280	0.32	0.12	0.91	-9.0	10.3	0.1	0.5	10.4
280	0.32	0.20	0.90	-9.0	10.3	0.1	0.4	10.4
285	0.36	0.20	0.90	-10.1	11.6	0.1	0.4	11.7
285	0.36	0.28	0.87	-10.1	11.6	0.1	0.4	11.7
290	0.40	0.28	0.87	-11.2	12.8	0.1	0.4	12.9
290	0.40	0.35	0.85	-11.2	12.8	0.2	0.4	13.0
295	0.43	0.35	0.85	-12.2	14.0	0.2	0.4	14.2
295	0.43	0.42	0.81	-12.2	14.0	0.2	0.4	14.2
300	0.47	0.42	0.81	-13.2	15.1	0.2	0.4	15.3
300	0.47	0.49	0.77	-13.2	15.1	0.2	0.4	15.4
305	0.50	0.49	0.77	-14.2	16.2	0.2	0.4	16.5
305	0.50	0.56	0.73	-14.2	16.2	0.3	0.4	16.5
310	0.54	0.56	0.73	-15.1	17.2	0.3	0.4	17.5
310	0.54	0.62	0.68	-15.1	17.2	0.3	0.3	17.6
315	0.57	0.62	0.68	-15.9	18.2	0.3	0.3	18.5
315	0.57	-6.70	-6.14	-15.9	18.2	-3.3	-3.1	-19.3
320	0.30	-6.70	-6.14	-8.4	9.6	-3.3	-3.1	-11.7
320	0.30	-7.21	-5.53	-8.4	9.6	-3.6	-2.8	-12.0
325	0.06	-7.21	-5.53	-1.6	1.8	-3.6	-2.8	-5.2

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings - 2D

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2 - 2D analysis at 5deg node spacing

Angle (Deg)	Moment (kN-m)	Axial (kN)	Shear (kN)	fb(o) (MPa)	fb(i) (MPa)	fa (MPa)	fv (MPa)	(fb+fa) (MPa)
325	0.06	-7.66	-4.88	-1.6	1.8	-3.8	-2.4	-5.4
330	-0.16	-7.66	-4.88	4.4	-5.0	-3.8	-2.4	-8.9
330	-0.16	-8.06	-4.19	4.4	-5.0	-4.0	-2.1	-9.1
335	-0.34	-8.06	-4.19	9.6	-10.9	-4.0	-2.1	-15.0
335	-0.34	-8.39	-3.48	9.6	-10.9	-4.2	-1.7	-15.1
340	-0.49	-8.39	-3.48	13.8	-15.8	-4.2	-1.7	-20.0
340	-0.49	-8.66	-2.73	13.8	-15.8	-4.3	-1.4	-20.1
345	-0.61	-8.66	-2.73	17.2	-19.7	-4.3	-1.4	-24.0
345	-0.61	-8.87	-1.97	17.2	-19.7	-4.4	-1.0	-24.1
350	-0.70	-8.87	-1.97	19.6	-22.4	-4.4	-1.0	-26.8
350	-0.70	-9.01	-1.19	19.6	-22.4	-4.5	-0.6	-26.9
355	-0.75	-9.01	-1.19	21.1	-24.1	-4.5	-0.6	-28.6
355	-0.75	-9.07	-0.40	21.1	-24.1	-4.5	-0.2	-28.6
360	-0.77	-9.07	-0.40	21.5	-24.6	-4.5	-0.2	-29.2

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark rings - 2D

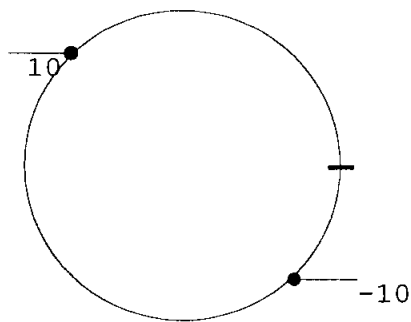
CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 2 - 2D analysis at 5deg node spacing

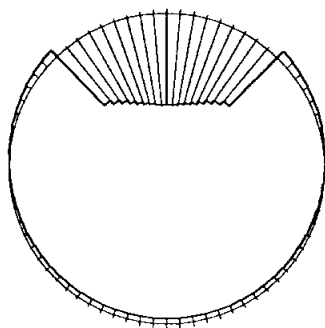
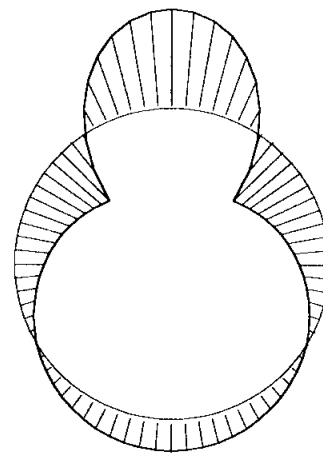
Loading (kN)

- = point load/reaction
 —• = UDL load/reaction
 (shear reactions not shown.)

**Bending moment**

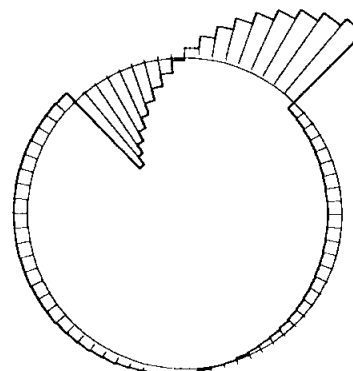
(plotted on tension side of ring)

Max moment = 0.77 kN-m

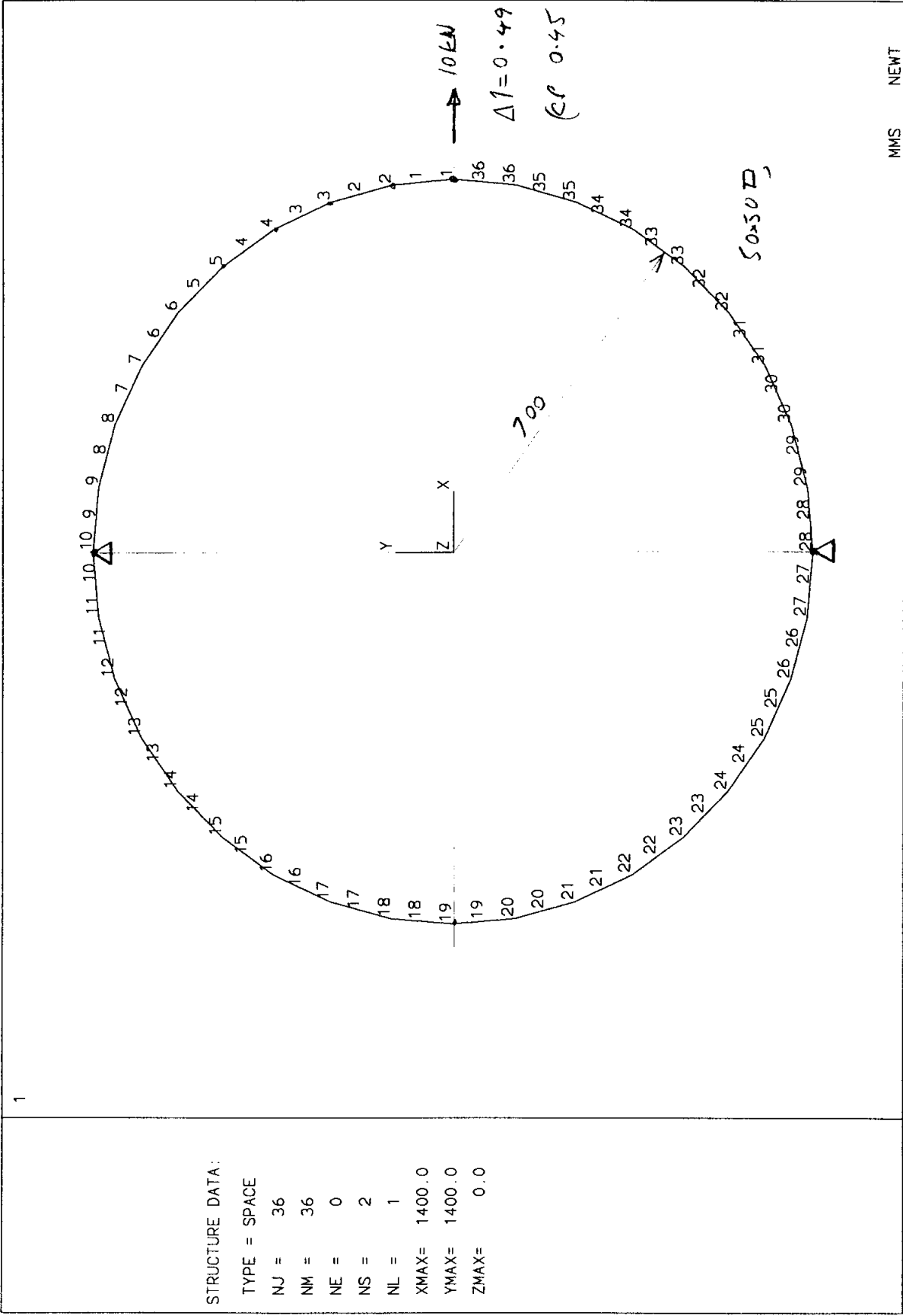
**Hoop load**

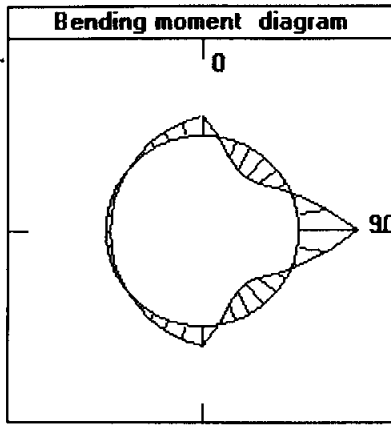
(compression plotted on inside of ring)

Max axial = -9.07 kN

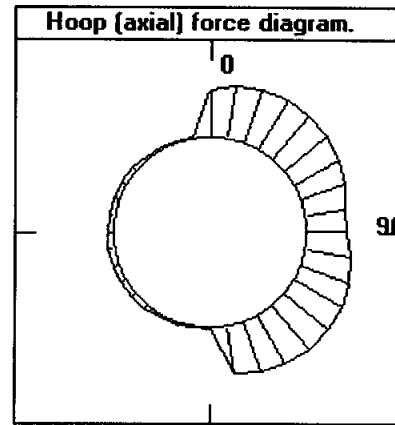
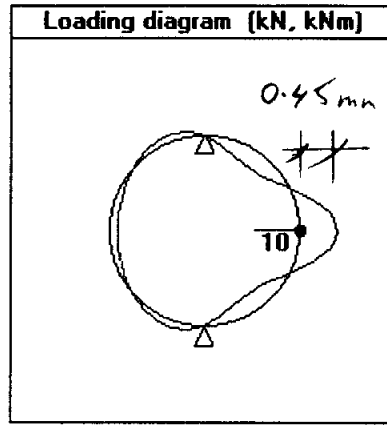
**Radial shear**

Max shear = 6.14 kN





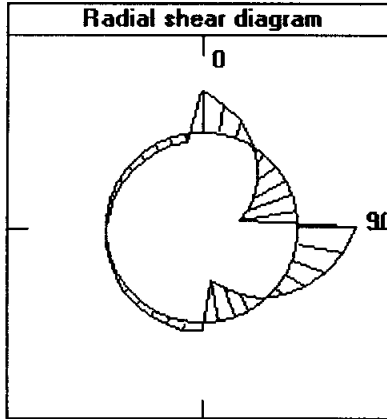
Plotted on tension side of ring



Compression plotted inside ring.

Stresses. (MPa)
 f_a = axial f_v = shear
 $f_a + f_b$ = max of (f_a + f_{bend})

Angle	f_a	f_v	$f_a + f_b$
0	2.1	1.4	19.6
10	2.3	1.0	4.3
20	2.5	0.6	18.3
30	2.5	0.1	26.3
40	2.5	-0.3	28.0
50	2.4	-0.7	23.5
60	2.3	-1.2	12.8
70	2.0	-1.5	7.8



----- Deflected shape (plotted radially)
 2D analysis only

Max. moment = 1.12 kN-m

Max. hoop force = 6.32 kN

Max. shear force = -4.64 kN

MAX OF HOOP (AXIAL) FORCE

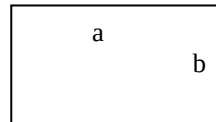
3.0 Roark flat plate analysis

The program uses "Roark's formulas for stress and strain", Warren E Young, 6th Ed. to calculate stresses and deflections of flat.

Roark flat plate – Table 26

Case 1a

$t = 10\text{mm}$
 $a = 1000\text{mm}$
 $b = 500\text{mm}$
 $a/b = 2$



$\beta = 0.61$
 $\alpha = 0.11$
 $\gamma = 0.503$

$q = 50 \text{ kPa (kN/m}^2\text{)} = 50\text{E-}3 \text{ N/mm}^2$

$\sigma_b = \beta q b^2 / t^2$
 $\sigma_b = 0.61 * 50\text{E-}3 * 500^2 / 10^2$
 $\sigma_b = 76.3 \text{ MPa}$

$y = -\alpha q b^4 / Et^3$
 $y = -0.11 * 50\text{E-}3 * 500^4 / (200\text{E}6 * E3)$
 $y = -1.7\text{mm}$

Case 1c

$t = 10\text{mm}$
 $a = 1000$ $a1 = 300$
 $b = 750$ $b1 = 300$

$a/b = 1.33$ $a1/b = 0.4$ $b1/b = 0.4$

β for $a/b = 1$ is 0.84
 β for $a/b = 1.4$ is 1.0

For $a/b = 1.33$,
 $\beta = 0.84 + 0.33/0.4 (1 - 0.84)$
 $\beta = 0.972$

$W = 20 \text{ kN}$

$\sigma = 0.972 * 20\text{E}3 / 10^2$
 $\sigma = 194 \text{ MPa (N/mm}^2\text{)}$

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark plate formulae - table 26

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 1a

Plate formulae to Roark 6th Ed. (table 26).

(ver=4.0.6)

Table 26, case 1a

Supports, S = pinned, F = fixed

Loading

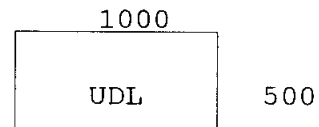
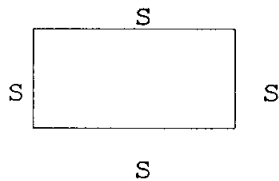


Plate Data (mm)

breadth (B) 500.0
length (L) 1000.0
thickness (t) 10.0

plate is simply supported on all sides

stress = $\beta \cdot \text{pressure} \cdot B^2 / t^2$

deflection = $\alpha \cdot \text{pressure} \cdot B^4 / E \cdot t^3$

alpha = 0.111

beta = 0.610

Results

Applied load (kPa, kN/m²) = 50.00

Plate stress (MPa, N/mm²) = 76.3

Maximum deflection (mm) = 1.7

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Roark plate formulae - table 26

CALC BY : GJS DATE : 25-Jan-1998

CHECKED :

Case 1c

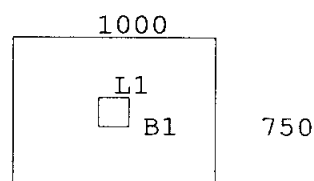
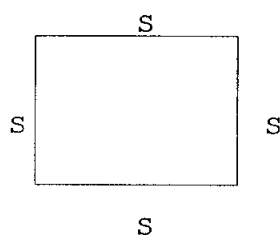
Plate formulae to Roark 6th Ed. (table 26).

(ver=4.0.6)

Table 26, case 1c

Supports, S = pinned, F = fixed

Loading

**Plate Data (mm)**

breadth (B) 750.0
length (L) 1000.0
thickness (t) 10.0

plate is simply supported on all sides

stress = $\beta \cdot W/t^2$ $\beta = 0.973$ **Results**

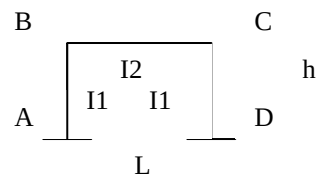
Applied load (kN) = 20.00
Length L1 (//L) (mm) = 300.0
Length B1 (//B) (mm) = 300.0
Plate stress (MPa, N/mm²) = 194.7

4.0 Frame Analysis

The program uses a 2-D frame solver to calculate the member forces and deflections in plane frames.

The examples given for validation use standard design formulae and Kleinlogel frames taken from “The Steel Designer’s Handbook”.

Kleinlogel – Frame I



Let
 $I_1 = I_1$
 $H = 5$
 $L = 10$

$$k = I_2 / I_1 * h / L$$

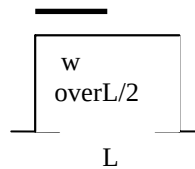
$$N_1 = k + 2$$

$$N_2 = 6k + 1$$

$$K = 0.5$$

$$N_1 = 2.5 \quad N_2 = 4$$

$$W = 10 \text{ kN/m}$$



$$M_A = wL^2/8 * [1/N_1 - 1/8N_2]$$

$$M_A = 125[0.102]$$

$$M_A = 12.76 \text{ kNm}$$

$$M_B = -125 * [2/3N_1 + 1/8N_2] = 37.24 \text{ kNm}$$

$$M_C = -125 * [2/3N_1 - 1/8N_2] = 29.43 \text{ kNm}$$

$$M_D = 125 * [1/3N_1 + 1/8N_2] = 20.58 \text{ kNm}$$

$$V_D = 10 * 5 / 8 * [1/N_1 - 1/8N_2] = 11.7 \text{ kN}$$

$$V_A = 10 * 5 - 11.7 = 38.3 \text{ kN}$$

$$H_A = H_D = wL^2/8hN_1 = 10 \text{ kN}$$

G. Simms

4.2

PROJECT : Toolkit Validation

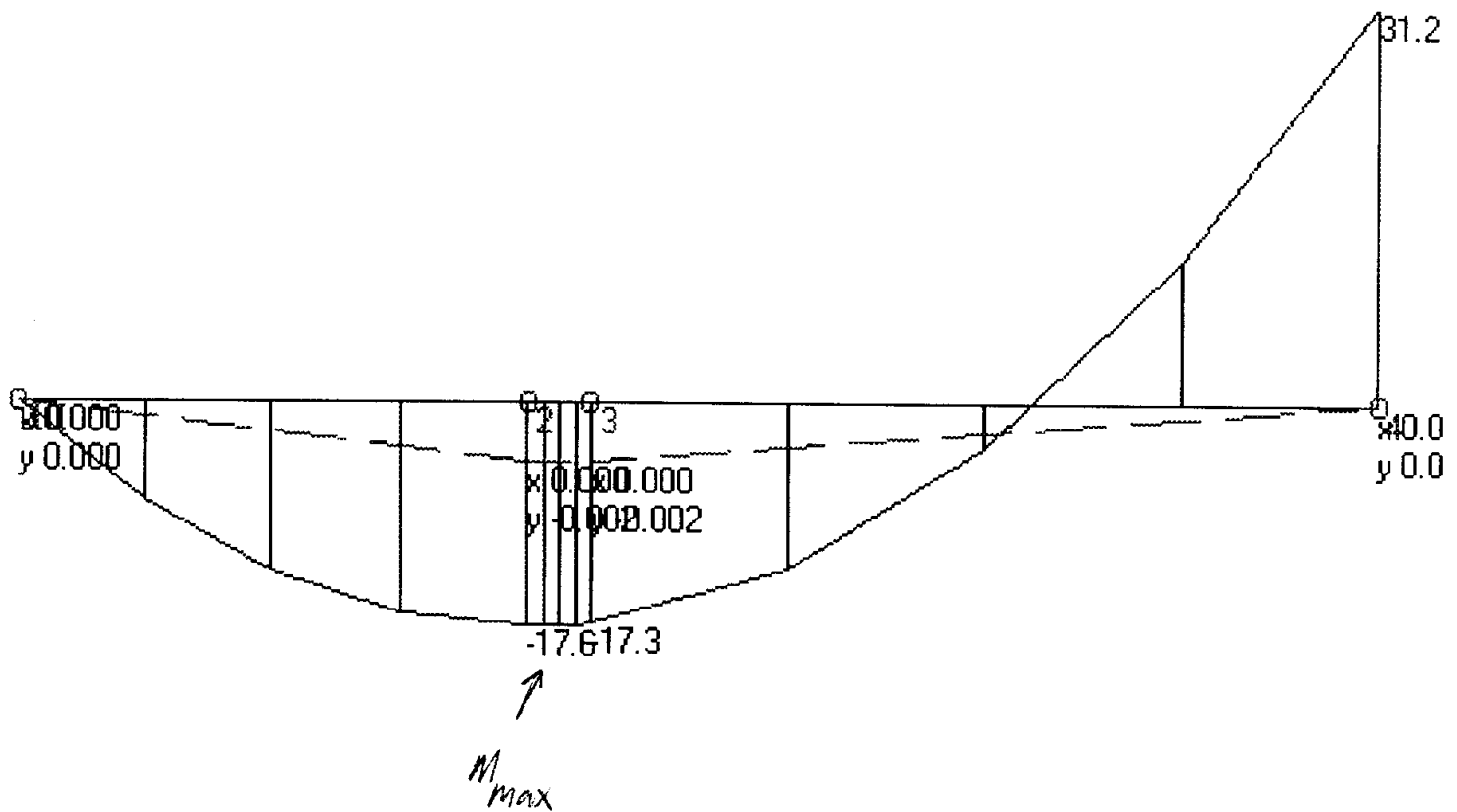
JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Propped cantilever



G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Propped cantilever

Member forces

Member	Node	FX	FY	MZ
1	1	0.0000	18.7500	0.0000
	2	0.0000	0.0000	17.5781
2	2	0.0000	0.0000	-17.5781
	3	0.0000	2.3200	17.3090
3	3	0.0000	-2.3200	-17.3090
	4	0.0000	31.2500	-31.2500

Reactions

Node	FX	FY	MZ
4	0.0000	31.2500	-31.2500
1	0.0000	18.7500	0.0000

G. Simms

PROJECT : Toolkit Validation

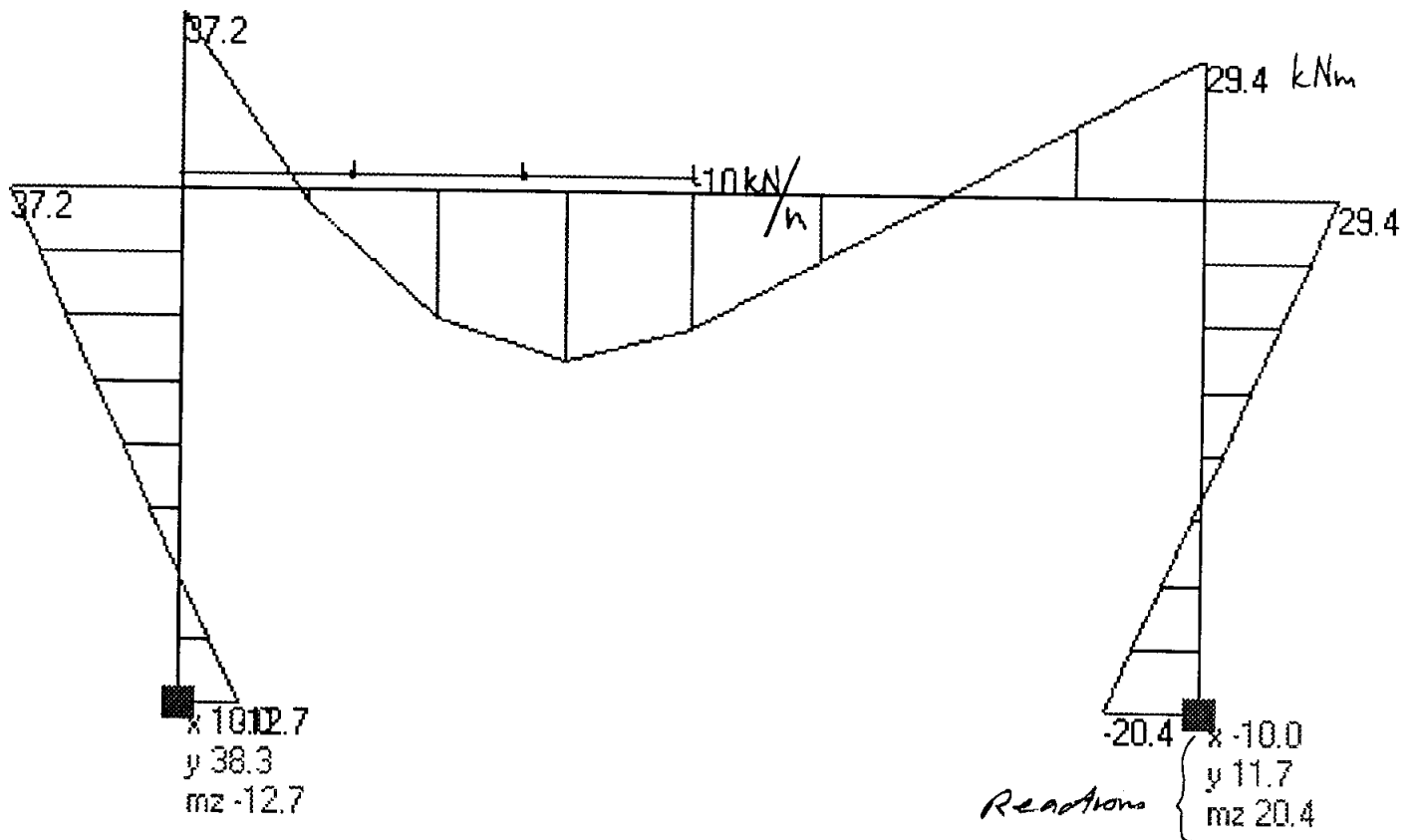
JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Kleinlogel, frame I



G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Kleinlogel, frame I- Beam actions on member 2

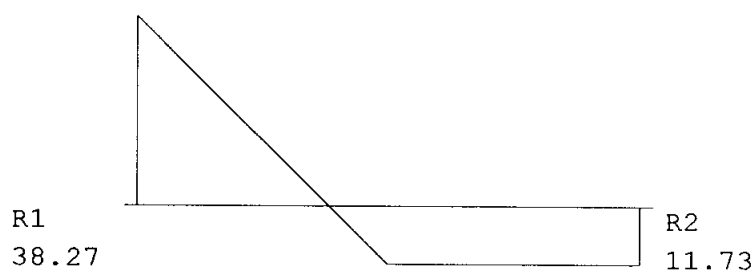
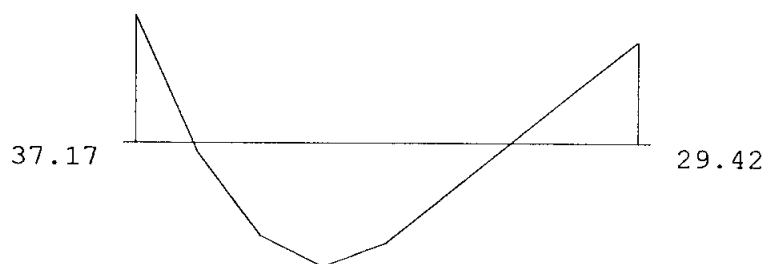
Element number 2 305x165UB40

Start node = 2 , continuous. End node = 3 continuous

Member length = 10.000

Section properties

E = 205,000,000 Area = 51.60e-04 Iz-z = 85.50e-06

max shear force = 25.77
Shear at 5.00 = -11.73max moment = 37.17
Moment at 5.00 = -29.21

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Kleinlogel, frame I

2D frame ver 1.0.1

Run on 29-Jan-98 17:35

Structure file : c:\tk_safe.dat

Nodes	X	Y
1	0.000	0.000
2	0.000	5.000
3	10.000	5.000
4	10.000	0.000

Members(end moment releases are :- 0= pinned, 1=continuous)
releases

Member	Start	End	s	e	Description	Area	I bend.	Length
1	1	2	1	1	305x165UB40	0.00516	0.0000855	5.000
2	2	3	1	1	305x165UB40	0.00516	0.0000855	10.000
3	3	4	1	1	305x165UB40	0.00516	0.0000855	5.000

Youngs Modulus 205,000,000

Supports

Node	Restraints
1	x y rz
4	x y rz

Member loads

Member	Type	Axes	P,M,w1	a	w2	b
2	U	GY	-10	0.000	-10	5.000

Displacements

Node	X	Y	RZ
1	0.000000	0.000000	0.000000
2	0.002809	-0.000181	-0.003493
3	0.002715	-0.000055	0.001284
4	0.000000	0.000000	0.000000

Member forces

Member	Node	FX	FY	MZ
1	1	38.2747	-9.9683	-12.6745
	2	-38.2747	9.9683	-37.1669
2	2	9.9683	38.2747	37.1669
	3	-9.9683	11.7253	-29.4204
3	3	11.7253	9.9683	29.4204
	4	-11.7253	-9.9683	20.4210

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Kleinlogel, frame I

Reactions

Node	FX	FY	MZ
1	9.9683	38.2747	-12.6745
4	-9.9683	11.7253	20.4210

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Propped cantilever

2D frame ver 1.0.1

Run on 29-Jan-98 17:14

Structure file : c:\tk_safe.dat

Nodes	X	Y
1	0.000	0.000
2	1.875	0.000
3	2.107	0.000
4	5.000	0.000

Members

(end moment releases are :- 0= pinned, 1=continuous)
releases

Member	Start	End	s	e	Description	Area	I bend.	Length
1	1	2	1	1	356x127UB33	0.00418	0.0000819	1.875
2	2	3	1	1	356x127UB33	0.00418	0.0000819	0.232
3	3	4	1	1	356x127UB33	0.00418	0.0000819	2.893

Youngs Modulus 205,000,000

Supports

Node	Restraints
4	x y rz
1	x y

Member loads

Member	Type	Axes	P,M,w1	a	w2	b
1	U	GY	-10	0.000	-10	1.875
2	U	GY	-10	0.000	-10	0.232
3	U	GY	-10	0.000	-10	2.893

Displacements

Node	X	Y	RZ
1	0.000000	0.000000	-0.001551
2	0.000000	-0.001988	-0.000242
3	0.000000	-0.002016	-0.000001
4	0.000000	0.000000	0.000000

← max Δ

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame analysis

CALC BY : GJS DATE : 29-Jan-1998

CHECKED :

Propped cantilever

Member forces

Member	Node	FX	FY	MZ
1	1	0.0000	18.7500	0.0000
	2	0.0000	0.0000	17.5781
2	2	0.0000	0.0000	-17.5781
	3	0.0000	2.3200	17.3090
3	3	0.0000	-2.3200	-17.3090
	4	0.0000	31.2500	-31.2500

Reactions

Node	FX	FY	MZ
4	0.0000	31.2500	-31.2500
1	0.0000	18.7500	0.0000

5.0 Wave load

- 5.1 Data point grid.
Calculates the motions of water particles during the passing of a wave.

- 5.2 Load generator and frame analysis.
Uses the water particle motions to apply wave loading to a 2D structure.
Analyses and code checks the structure.

5.1 Wave grid

Compare results of the wave grid particle motion calculations with those from the SEADYN output

Dataset	Program	Distances		Motions			
				Velocity		Acceleration	
		Horiz.	Vert.	u	v	u'	v'
A	Seadyn	0	89	6.445	0	0	-2.183
	Waveload	0	89	6.444	0	0	-2.243
B	Seadyn	0	40	2.268	0	0	-0.721
	Waveload	0	40	2.266	0	0	-0.723
C	Seadyn	30	40	1.721	1.071	0.64	-0.513
	Waveload	30	40	1.719	1.071	0.69	-0.514

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7353	7420	7423	7425	7427	7430	7433	7435	7437	7440	7443	7445	7447
7450	7453	5110	5115	5140	5145	5150	5155	5190	5195	5610	5612	5615
5619	5620	5622	5625	5629	5630	5635	5640	5645	5650	5655	5659	5670
5675	5680	5683	5687	5689	5691	5692	5693	5695	5697	5698	4110	4190
4140	4150	4610	4612	4614	4617	4619	4620	4622	4624	4627	4629	4630
4635	4640	4645	4650	4655	4659	4670	4673	4677	4679	4680	4683	4687
4689	4691	4692	4693	4695	4696	4697	4660	3110	3190	3140	3150	3610
3612	3614	3619	3620	3622	3624	3629	3630	3635	3640	3645	3650	3653
3657	3659	3671	3675	3678	3680	3683	3684	3686	3687	3689	3691	3692
3695	3696	3660	2110	2115	2140	2145	2150	2155	2190	2195	2610	2620
2630	2635	2640	2645	2650	2653	2657	2659	2671	2675	2678	2680	2683
2684	2686	2687	2689	8158	8160	8258	8260	8358	8360	8458	8460	6110
6115	6140	6145	6150	6155	6190	6195	6120	6125	6130	6135	6160	6165
6180	6185	6710	6720	6730	6740	6610	6615	6618	6620	6625	6628	6630
6635	6638	6640	6645	6648	9101	9102	9103	9104	9105	9106	9107	9108
9109	9110	9111	9112	9113	9114	9115	9116	9117	9118	9119	9120	9121
9201	9202	9203	9204	9205	9206	9207	9208	9209	9210	9211	9212	9213
9214	9215	9216	9217	9218	9219	9220	9221	9301	9302	9303	9304	9305
9306	9307	9308	9309	9310	9311	9312	9313	9314	9315	9316	9317	9318
9319	9320	9321	9401	9402	9403	9404	9405	9406	9407	9408	9409	9410
9411	9412	9413	9414	9415	9416	9417	9418	9419	9420	9421	9501	9502
9503	9504	9505	9506	9507	9508	9509	9510	9511	9512	9513	9514	9515
9516	9517	9518	9519	9520	9521							

1*****
*** WAVE GRID DATA ***

NUMBER OF HORIZONTAL GRID POINTS = 11
NUMBER OF VERTICAL GRID POINTS = 13

WAVE GRID KINEMATIC FACTORS
X-VELOCITY = 1.000E+00
Y-VELOCITY = 1.000E+00
X-ACCELERATION = 1.000E+00
Y-ACCELERATION = 1.000E+00

(212) > LIST SEA WAVE PROFILE

*** RESULTS OF LATEST SEADYN ANALYSIS ***

2/4H EKO 2/4 H EKOFISK

ACTIVE UNITS - LENGTH M WEIGHT KN ANGLE DEG TEMPERATURE DEGF TIME SEC

Dataset A →

DISTANCE	ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION
0.000E+00	8.900568E+01	6.445E+00	0.000E+00	0.000E+00	-2.183E+00
1.500E+01	8.789451E+01	5.841E+00	2.174E+00	1.148E+00	-1.911E+00
3.000E+01	8.503510E+01	4.324E+00	3.722E+00	1.944E+00	-1.235E+00
4.500E+01	8.142501E+01	2.456E+00	4.448E+00	2.290E+00	-4.215E-01
6.000E+01	7.787645E+01	6.486E-01	4.479E+00	2.269E+00	3.306E-01
7.500E+01	7.479227E+01	-9.016E-01	4.018E+00	2.001E+00	9.282E-01
9.000E+01	7.233363E+01	-2.120E+00	3.241E+00	1.587E+00	1.351E+00
1.050E+02	7.054890E+01	-2.990E+00	2.278E+00	1.100E+00	2.617E+00
1.200E+02	6.943536E+01	-3.517E+00	1.216E+00	5.812E-01	1.759E+00
1.350E+02	6.900896E+01	-3.712E+00	1.118E-01	5.325E-02	1.807E+00
1.365E+02	6.900533E+01	-3.713E+00	-1.049E-06	-4.995E-07	1.807E+00

(213) > LIST SEA GRID DATA
1

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 0.000E+00

FREE SURFACE ELEVATION = 1.151E+01

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	1.542E+00	0.000E+00	0.000E+00	0.000E+00	0.000	
8.000E+00	1.568E+00	0.000E+00	0.000E+00	-1.292E-01	0.000	
1.600E+01	1.650E+00	0.000E+00	0.000E+00	-2.621E-01	0.000	
2.400E+01	1.790E+00	0.000E+00	0.000E+00	-4.025E-01	0.000	
3.200E+01	1.993E+00	0.000E+00	0.000E+00	-5.542E-01	0.000	
4.000E+01	2.268E+00	0.000E+00	0.000E+00	-7.210E-01	0.000	
4.800E+01	2.624E+00	0.000E+00	0.000E+00	-9.062E-01	0.000	
5.600E+01	3.076E+00	0.000E+00	0.000E+00	-1.113E+00	0.000	
6.400E+01	3.642E+00	0.000E+00	0.000E+00	-1.343E+00	0.000	
7.200E+01	4.346E+00	0.000E+00	0.000E+00	-1.596E+00	0.000	
8.000E+01	5.217E+00	0.000E+00	0.000E+00	-1.869E+00	0.000	CONSTANT
8.800E+01	6.293E+00	0.000E+00	0.000E+00	-2.148E+00	0.000	CONSTANT
8.901E+01	6.445E+00	0.000E+00	0.000E+00	-2.183E+00	0.000	CONSTANT

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 1.500E+01

FREE SURFACE ELEVATION = 1.039E+01

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	1.448E+00	0.000E+00	2.369E-01	0.000E+00	0.000	
8.000E+00	1.473E+00	9.915E-02	2.417E-01	-1.201E-01	0.000	
1.600E+01	1.550E+00	2.020E-01	2.561E-01	-2.435E-01	0.000	
2.400E+01	1.680E+00	3.125E-01	2.810E-01	-3.736E-01	0.000	
3.200E+01	1.870E+00	4.349E-01	3.174E-01	-5.136E-01	0.000	
4.000E+01	2.126E+00	5.739E-01	3.671E-01	-6.667E-01	0.000	
4.800E+01	2.458E+00	7.353E-01	4.324E-01	-8.356E-01	0.000	
5.600E+01	2.879E+00	9.258E-01	5.167E-01	-1.022E+00	0.000	
6.400E+01	3.405E+00	1.154E+00	6.241E-01	-1.228E+00	0.000	
7.200E+01	4.057E+00	1.429E+00	7.604E-01	-1.450E+00	0.000	
8.000E+01	4.863E+00	1.766E+00	9.328E-01	-1.684E+00	0.000	CONSTANT
8.789E+01	5.843E+00	2.174E+00	1.148E+00	-1.911E+00	0.000	CONSTANT

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 3.000E+01

FREE SURFACE ELEVATION = 7.535E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	1.180E+00	0.000E+00	4.493E-01	0.000E+00	0.000	
8.000E+00	1.200E+00	1.854E-01	4.580E-01	-9.434E-02	0.000	
1.600E+01	1.262E+00	3.777E-01	4.847E-01	-1.909E-01	0.000	
2.400E+01	1.366E+00	5.840E-01	5.304E-01	-2.916E-01	0.000	
3.200E+01	1.518E+00	8.121E-01	5.973E-01	-3.986E-01	0.000	
4.000E+01	1.721E+00	1.071E+00	6.882E-01	-5.132E-01	0.000	
4.800E+01	1.985E+00	1.370E+00	8.075E-01	-6.363E-01	0.000	
5.600E+01	2.317E+00	1.723E+00	9.608E-01	-7.677E-01	0.000	
6.400E+01	2.730E+00	2.143E+00	1.155E+00	-9.049E-01	0.000	
7.200E+01	3.239E+00	2.650E+00	1.401E+00	-1.042E+00	0.000	
8.000E+01	3.862E+00	3.266E+00	1.710E+00	-1.169E+00	0.000	CONSTANT
8.504E+01	4.341E+00	3.741E+00	1.954E+00	-1.229E+00	0.000	CONSTANT

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 4.500E+01

FREE SURFACE ELEVATION = 3.925E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	7.718E-01	0.000E+00	6.136E-01	0.000E+00	0.000	
8.000E+00	7.845E-01	2.480E-01	6.251E-01	-5.588E-02	0.000	
1.600E+01	8.232E-01	5.050E-01	6.598E-01	-1.123E-01	0.000	
2.400E+01	8.890E-01	7.801E-01	7.193E-01	-1.696E-01	0.000	
3.200E+01	9.838E-01	1.084E+00	8.060E-01	-2.279E-01	0.000	
4.000E+01	1.110E+00	1.427E+00	9.235E-01	-2.863E-01	0.000	
4.800E+01	1.273E+00	1.822E+00	1.077E+00	-3.431E-01	0.000	
5.600E+01	1.475E+00	2.286E+00	1.272E+00	-3.947E-01	0.000	
6.400E+01	1.723E+00	2.836E+00	1.519E+00	-4.348E-01	0.000	
7.200E+01	2.024E+00	3.494E+00	1.828E+00	-4.528E-01	0.000	
8.000E+01	2.385E+00	4.290E+00	2.212E+00	-4.313E-01	0.000	CONSTANT
8.143E+01	2.461E+00	4.462E+00	2.297E+00	-4.155E-01	0.000	CONSTANT

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 6.000E+01

FREE SURFACE ELEVATION = 3.765E-01

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	2.748E-01	0.000E+00	7.094E-01	0.000E+00	0.000	
8.000E+00	2.788E-01	2.797E-01	7.219E-01	-1.040E-02	0.000	
1.600E+01	2.907E-01	5.691E-01	7.598E-01	-1.959E-02	0.000	
2.400E+01	3.108E-01	8.784E-01	8.244E-01	-2.610E-02	0.000	
3.200E+01	3.391E-01	1.218E+00	9.181E-01	-2.791E-02	0.000	
4.000E+01	3.758E-01	1.601E+00	1.044E+00	-2.202E-02	0.000	
4.800E+01	4.208E-01	2.040E+00	1.208E+00	-3.992E-03	0.000	
5.600E+01	4.737E-01	2.550E+00	1.415E+00	3.290E-02	0.000	
6.400E+01	5.338E-01	3.152E+00	1.672E+00	9.877E-02	0.000	
7.200E+01	5.991E-01	3.867E+00	1.990E+00	2.088E-01	0.000	
7.788E+01	6.485E-01	4.495E+00	2.276E+00	3.388E-01	0.000	CONSTANT

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

5.4

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DISTANCE FROM CRESTLINE = 7.500E+01

FREE SURFACE ELEVATION = -2.708E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	-2.500E-01	0.000E+00	7.225E-01	0.000E+00	0.000	
8.000E+00	-2.550E-01	2.777E-01	7.344E-01	3.589E-02	0.000	
1.600E+01	-2.702E-01	5.646E-01	7.705E-01	7.454E-02	0.000	
2.400E+01	-2.964E-01	8.704E-01	8.318E-01	1.190E-01	0.000	
3.200E+01	-3.352E-01	1.205E+00	9.203E-01	1.731E-01	0.000	
4.000E+01	-3.886E-01	1.580E+00	1.039E+00	2.415E-01	0.000	
4.800E+01	-4.600E-01	2.007E+00	1.190E+00	3.308E-01	0.000	
5.600E+01	-5.537E-01	2.501E+00	1.379E+00	4.499E-01	0.000	
6.400E+01	-6.760E-01	3.077E+00	1.611E+00	6.112E-01	0.000	
7.200E+01	-8.353E-01	3.754E+00	1.890E+00	8.325E-01	0.000	
7.479E+01	-9.079E-01	4.033E+00	2.007E+00	9.395E-01	0.000	

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 9.000E+01

FREE SURFACE ELEVATION = -5.166E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	-7.406E-01	0.000E+00	6.484E-01	0.000E+00	0.000	
8.000E+00	-7.536E-01	2.434E-01	6.584E-01	7.740E-02	0.000	
1.600E+01	-7.931E-01	4.946E-01	6.886E-01	1.587E-01	0.000	
2.400E+01	-8.607E-01	7.616E-01	7.399E-01	2.482E-01	0.000	
3.200E+01	-9.589E-01	1.053E+00	8.133E-01	3.507E-01	0.000	
4.000E+01	-1.092E+00	1.377E+00	9.105E-01	4.721E-01	0.000	
4.800E+01	-1.264E+00	1.744E+00	1.034E+00	6.199E-01	0.000	
5.600E+01	-1.484E+00	2.165E+00	1.184E+00	8.039E-01	0.000	
6.400E+01	-1.760E+00	2.652E+00	1.365E+00	1.037E+00	0.000	
7.200E+01	-2.104E+00	3.216E+00	1.578E+00	1.336E+00	0.000	
7.233E+01	-2.122E+00	3.243E+00	1.588E+00	1.353E+00	0.000	

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 1.050E+02

FREE SURFACE ELEVATION = -6.951E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	-1.141E+00	0.000E+00	4.940E-01	0.000E+00	0.000	
8.000E+00	-1.160E+00	1.820E-01	5.012E-01	1.099E-01	0.000	
1.600E+01	-1.219E+00	3.696E-01	5.229E-01	2.245E-01	0.000	
2.400E+01	-1.319E+00	5.686E-01	5.595E-01	3.485E-01	0.000	
3.200E+01	-1.463E+00	7.848E-01	6.117E-01	4.876E-01	0.000	
4.000E+01	-1.657E+00	1.025E+00	6.802E-01	6.479E-01	0.000	
4.800E+01	-1.906E+00	1.294E+00	7.657E-01	8.372E-01	0.000	
5.600E+01	-2.220E+00	1.601E+00	8.687E-01	1.065E+00	0.000	
6.400E+01	-2.608E+00	1.953E+00	9.891E-01	1.342E+00	0.000	
7.055E+01	-2.997E+00	2.282E+00	1.101E+00	1.622E+00	0.000	

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 1.200E+02

FREE SURFACE ELEVATION = -8.065E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	-1.407E+00	0.000E+00	2.776E-01	0.000E+00	0.000	
8.000E+00	-1.431E+00	1.010E-01	2.814E-01	1.308E-01	0.000	
1.600E+01	-1.502E+00	2.051E-01	2.931E-01	2.666E-01	0.000	
2.400E+01	-1.622E+00	3.152E-01	3.128E-01	4.126E-01	0.000	
3.200E+01	-1.796E+00	4.347E-01	3.407E-01	5.744E-01	0.000	
4.000E+01	-2.028E+00	5.667E-01	3.770E-01	7.583E-01	0.000	
4.800E+01	-2.326E+00	7.146E-01	4.219E-01	9.717E-01	0.000	
5.600E+01	-2.697E+00	8.819E-01	4.752E-01	1.223E+00	0.000	
6.400E+01	-3.153E+00	1.072E+00	5.362E-01	1.522E+00	0.000	
6.944E+01	-3.528E+00	1.219E+00	5.817E-01	1.766E+00	0.000	

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 1.350E+02

FREE SURFACE ELEVATION = -8.491E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	-1.511E+00	0.000E+00	2.604E-02	0.000E+00	0.000	
8.000E+00	-1.536E+00	9.431E-03	2.639E-02	1.388E-01	0.000	
1.600E+01	-1.612E+00	1.914E-02	2.747E-02	2.827E-01	0.000	
2.400E+01	-1.740E+00	2.942E-02	2.929E-02	4.370E-01	0.000	
3.200E+01	-1.925E+00	4.055E-02	3.185E-02	6.073E-01	0.000	
4.000E+01	-2.172E+00	5.283E-02	3.518E-02	7.999E-01	0.000	
4.800E+01	-2.488E+00	6.657E-02	3.927E-02	1.022E+00	0.000	
5.600E+01	-2.881E+00	8.208E-02	4.410E-02	1.281E+00	0.000	
6.400E+01	-3.361E+00	9.964E-02	4.958E-02	1.587E+00	0.000	
6.901E+01	-3.724E+00	1.121E-01	5.328E-02	1.814E+00	0.000	

1

WAVE EFFECTS ARE ON THEREFORE WAVE VELOCITIES AND ACCELERATIONS ARE INCLUDED
 CURRENT EFFECTS ARE ON THEREFORE IN-LINE CURRENT VELOCITIES ARE INCLUDED AND THE CONSTANT CURRENT PROFILE OPTION USED

DISTANCE FROM CRESTLINE = 1.365E+02

FREE SURFACE ELEVATION = -8.495E+00

ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION	REL CUR ANG	CUR FLAGS
0.000E+00	-1.512E+00	0.000E+00	-2.443E-07	0.000E+00	0.000	
8.000E+00	-1.537E+00	-8.849E-08	-2.477E-07	1.389E-01	0.000	
1.600E+01	-1.613E+00	-1.796E-07	-2.578E-07	2.828E-01	0.000	
2.400E+01	-1.741E+00	-2.760E-07	-2.748E-07	4.372E-01	0.000	
3.200E+01	-1.926E+00	-3.804E-07	-2.989E-07	6.075E-01	0.000	
4.000E+01	-2.173E+00	-4.957E-07	-3.301E-07	8.002E-01	0.000	
4.800E+01	-2.489E+00	-6.246E-07	-3.685E-07	1.022E+00	0.000	
5.600E+01	-2.882E+00	-7.701E-07	-4.138E-07	1.282E+00	0.000	
6.400E+01	-3.363E+00	-9.349E-07	-4.651E-07	1.588E+00	0.000	
6.901E+01	-3.726E+00	-1.052E-06	-4.998E-07	1.815E+00	0.000	

CI-w-cmdnfnd, Command 'DATA' is not recognized.

{ 214 } > LAST

{ 215 } > \$

{ 216 } > LIST SEA LOAD GROUP 'JTOTAL'

*** RESULTS OF LATEST SEADYN ANALYSIS ***

2/4H EKO 2/4 H EKOFISK

ACTIVE UNITS -	LENGTH	WEIGHT	ANGLE	TEMPERATURE	TIME
	M	KN	DEG	DEGF	SEC

*** GROUP LOAD HISTORIES ***

GROUP	POSITION(UP)	FORCE X	FORCE Y	FORCE Z	MOMENT X	MOMENT Y	MOMENT Z
JTOTAL	8.000E+00	1.264E+04	-3.649E+02	-7.746E-01	-2.741E+02	-5.811E+03	-7.923E+05

*** END GROUP LOAD HISTORIES ***

1

{ 217 } > LAST

{ 218 } > \$

{ 219 } > SEA LOAD GENERATE POSITION

{ 220 } > 1 'EXWA_W' 'STORM WAVE FROM PLATFORM WEST'

{ 221 } > LAST

{ 222 } > \$

{ 223 } > \$

{ 224 } > \$

{ 225 } > FINISH

1

----- RUN-TIME PERFORMANCE SUMMARY -----

CPU Time 00:00:16.01 Elapsed Time 0 00:00:24 On Fri Feb 6 12:09:39 1998

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Wave load validation

CALC BY : GJS DATE : 06-Feb-1998

CHECKED :

Test wave grid

Program Wave. version 1.0.8

Wave height = 20 Period = 13.2 Still water depth = 77.5 Celerity = 20.67
 Wave theory = Stokes 5th Wavelength = 272.83
 Crest elev = 89.00 Lambda = 0.22313 kd = 1.785

u and v are the horizontal and vertical wave axes respectively.
 Origin is on the seabed, beneath the crest.

Units are metres, sec

(normal = total component of u and v velocities, normal
 to the water surface (for wave slam).)

Surface data

u coord	elevation	u vel	v vel	u acc	v acc	slope	normal
0.000	89.000	6.444	0.000	0.000	-2.243	0.000000	0.00
10.000	88.500	6.169	1.496	0.804	-2.115	-0.099332	2.10
20.000	87.080	5.407	2.780	1.485	-1.765	-0.178745	3.70
30.000	85.020	4.320	3.723	1.971	-1.270	-0.227182	4.60
40.000	82.640	3.083	4.294	2.250	-0.717	-0.245251	4.91

Dataset

← A

Node results

u coord	elev.	u vel	v vel	u acc	v acc
0.000	50.000	2.725	0.000	0.000	-0.960
10.000	50.000	2.648	0.527	0.306	-0.926
20.000	50.000	2.421	1.021	0.593	-0.827
30.000	50.000	2.059	1.453	0.845	-0.671
40.000	50.000	1.586	1.798	1.046	-0.470
0.000	40.000	2.266	0.000	0.000	-0.723
10.000	40.000	2.202	0.388	0.248	-0.698
20.000	40.000	2.016	0.752	0.482	-0.627
30.000	40.000	1.719	1.071	0.690	-0.514
40.000	40.000	1.330	1.327	0.858	-0.368

← B

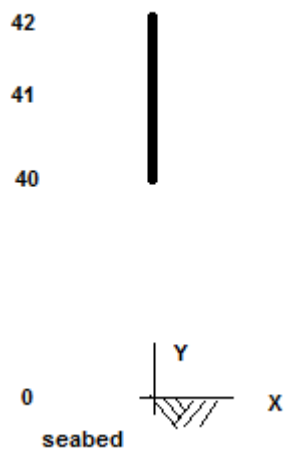
← C

5.2 Waveload- frame analysis

The particle motions are checked above, now check the load generation.

Consider a 2m long x 300mm diameter tubular with 100mm of marine growth and a current of 0.7m/s.

Wave data;
 $H = 10\text{m}$
 $T = 12\text{s}$
 $\text{SWL} = 50\text{m}$



From WaveLoad results
 $F_x = -3.4227 \text{ kN}$

From seadyn at crest
 $F_x = 3.432 \text{ kN} \quad (\rightarrow F_x)$

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#PAGINATE FORTRAN seadyn.9.0.0 hg000729 users 46B30

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Mon Feb 9 13:01:14 1998

1GTICES/C 1.4.5, November 1991.

Proprietary to Georgia Tech Research Corporation, U.S.A.

(1) > SEADYN 'GS_VALID' 'ANODE VALID'

SSSSSSSSSS	EEEEEEEEEEEE	AAAAAAAAAA	DDDDDDDDDD	YY	YY	NN	NN
SSSSSSSSSS	EEEEEEEEEEEE	AAAAAAAAAA	DDDDDDDDDD	YY	YY	NNN	NN
SS	EE	AA	DD	DD	YY	NNNN	NN
SS	EE	AA	DD	DD	YY	NN	NN
SSS	EE	AA	DD	DD	YY	NN	NN
SSSSSSSSSS	EEEEEEEE	AAAAAAAAAA	DD	DD	YYY	NN	NN
SSSSSSSSSS	EEEEEEEE	AAAAAAAAAA	DD	DD	YYY	NN	NN
SS	EE	AA	DD	DD	YY	NN	NN
SS	EE	AA	DD	DD	YY	NN	NN
SS	EE	AA	DD	DD	YY	NN	NN
SSSSSSSSSS	EEEEEEEEEEEE	AA	AA	DDDDDDDDDD	YY	NN	NN
SSSSSSSSSS	EEEEEEEEEEEE	AA	AA	DDDDDDDDDD	YY	NN	NN

00000000	9999999999	00000000	00000000	00000000	00000000
0000000000	99999999999	0000000000	0000000000	0000000000	0000000000
00	99	00	00	00	00
00	99	00	00	00	00
00	99	00	00	00	00
00	99999999999	00	00	00	00
00	99999999999	00	00	00	00
00	99	00	00	00	00
00	99	00	00	00	00
00	99	00	00	00	00
0000000000	99999999999	**	0000000000	0000000000	**
00000000	9999999999	**	00000000	00000000	**
			00000000	00000000	

COMPILED ON
Fri Jul 21 16:58:06 GMT 1995

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* * * KVAERNER EARL & WRIGHT - CONSULTING ENGINEERS * * * * *

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STAG PLACE

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1*** SEADYN version 9.0.0 status sheet (DOMAIN/OS) *****

* The following commands have not been implemented and hence are not recognized:

* CONVERGENCE, ENTER, EXIT, FILE, MAXIMUM, NONLINEAR, RIGIDITY, SOIL, TURN

* The following execute modules have been included in this version:

* ACCELL ANGLE AXPT CANDEL DGCONE FATIGE INOUT JOCKST LSGRD[1-8] LSMCST LSPCN1 LSPROJ LSSCN1 LSSCN2

* MBPROP MGROW MOVIT NODES POISON PSEUDO RAYLEI SEASHL SEGMENT STATCK STATUS UCNCHK

* Additions to the User Manual (Version 9)

* The DISPLAY command is available but must not be used until interactive graphics are implemented

* London office BP special member code checks are available, use: CHECK CODE API BP EDITION 18 n/m list...

* New platform load transfer option added: PLATFORM LOAD TRANSFER MEMBERS SIMPLE BEAM AT (START | END)

* Additional Sigmak vs. Nk information can be obtained from a spectral fatigue analysis for deterministic-type checks

* (use command SKNK MINIMUM v1 MAXIMUM v2 DIVISIONS il, documentation available)

* Execute module PSEUDO requires a local joint catalogue file SCAT.TYPE and produces files PSEUDO.CTOD.21 and PSEUDO.CTOD.22

* The following is a list of known problems that are not documented in the manual:

* - Hoop stress is equal to zero in hydrostatic checks if no wave height is specified.

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- * - Output level 1 for API member checks may not work properly. Use the summary report of level 2 instead.
- * - Ballast loads are not generated correctly for members that are flooded 100% but which are only partially submerged.
- * - The flag "BUCKLED" does not appear for output level 4 of the API member checks.
- * - Consecutive SEA LOAD ANALYSES are not possible if the grid is specified manually.
- * - The INERTIA FOR JOINTS CONSISTENT option does not work with the SUBSPACE ITERATION solution method.
- * - Periodic wave loading cannot be used in a modal dynamic analysis.
- * Warning : The use of Type 1 load databases (DD6) has not been checked.
- * Warning : The LIST DYNAMIC... commands have not been checked.
- * Warning : Wave grids must be defined exactly or over defined. If a grid has too few points/spaces defined SEADYN will crash.
- * Warning : PRINT NODE MENSURATION prints very large numbers in the simple mensuration output.
- * Warning : EXECUTE,C 'FATIGE' will crash if ALL hot spots around a member have lives greater than 9999.99 years.
- * Warning : EXECUTE 'FATIGE' can only handle less than 10 wave exceedence directions.
- * Warning : The INPUT command does not work on HP 700 series version of SEADYN, Apollo version is OK.
- * Warning : Stream wave theory will crash with water depths greater than 100 meters.
- * Warning : SUBSTRUCTURE CONDENSE fails if a stiffness analysis has been run previously.

```

=====
1=====
==
==
==          S E A D Y N   U N I T S   A N D   C O N S T A N T S   V A L U E S
==
=====

```

UNITS:

```

LENGTH = INCH
FORCE  = LB
TIME   = SEC
ANGLE  = RAD
TEMP   = DEGF

```

MEMBER CONSTANTS:

```

WEIGHT DENSITY    = 2.836000E-01 LB /INCH**3
ELASTIC MODULUS   = 2.900000E+07 LB /INCH**2
SHEAR MODULUS     = 1.115385E+07 LB /INCH**2
COEF. OF THER. EXP. = 6.500000E-06 1 /DEGF
BETA ANGLE        = 0.000 RAD
POISSON'S RATIO   = 0.300

```

STRUCTURE CONSTANTS:

```

TYPE              = SPACE FRAME
COORDINATE TYPE   = X Y Z

```

```

1
( 2) > $*****
( 3) > $
( 4) > $ PHILLIPS PETROLEUM COMPANY NORWAY
( 5) > $
( 6) > $ SOUTH EKOFISK FEASIBILITY STUDY
( 7) > $ C067 JANUARY 1998
( 8) > $
( 9) > $ NEW PRODUCTION AND WATER INJECTION JACKET
(10) > $
(11) > $-----
(12) > $ CAISSONS MODEL INPUT FILE
(13) > $-----
(14) > $
(15) > $ BY: AH 27/1/98
(16) > $ AH 02/02/98 UPDATED WITH DEEP CAISSONS AND STUBS
(17) > $
(18) > $*****
(19) > $
(20) > $
(21) > $
(22) > TYPE SPACE FRAME
(23) > $
(24) > $
(25) > $
(26) > UNITS MM DEG N
(27) > $
(28) > $
(29) > $
(30) > JOINT COORDINATES
(31) > 40 0 40000 0
(32) > 41 0 41000 0
(33) > 42 0 42000 0
(34) > LAST
(35) > $
(36) > $
(37) > $
(38) > MEMBER INCIDENCES
(39) > 40 40 41
(40) > 41 41 42
(41) > LAST
(42) > $
(43) > $
(44) > $
(45) > ESTABLISH MEMBER GROUP 'ANODE' INCL IDS -
(46) > 40 41
(47) > $
(48) > $
(49) > $
(50) > PLATFORM MEMBER TYPE CIRCULAR PRISMATIC
(51) > 40 41 OD 300 THI 10
(52) > LAST
(53) > $
(54) > $
(55) > $
(56) > UNITS N MM
(57) > CONSTANTS
(58) > BETA XYR X -1000E6 Y 0 Z 0 40 41
(59) > $
(60) > $

```

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```
( 61) > $
( 62) > $ MATERIAL PROPERTIES
( 63) > $
( 64) > E 210E3 'ANODE'
( 65) > DEN 0.0000001 'ANODE'
( 66) > POI 0.3 'ANODE'
( 67) > LAST
( 68) > $
( 69) > $
( 70) > $
( 71) > $SET ACTIVE MEMBERS ALL
( 72) > $$
( 73) > $SET UNITS M
( 74) > $SET DEVICE HP HP7475 A4 AUTO
( 75) > $SET EYE CAR -15000.0 4000.0 4000.0
( 76) > $$
( 77) > $$
( 78) > $$
( 79) > $SET LABEL MEMBERS OFF
( 80) > $SET LABEL JOINTS OFF
( 81) > $SET TITLE ' SOUTH EKOFISK STUDY, NEW JACKET MODEL'
( 82) > $PLOT STRUCTURE MEMBERS ALL
( 83) > $SET LABEL MEMBERS ALL
( 84) > $SET LABEL JOINTS ALL
( 85) > $PLOT STRUCTURE MEMBERS ALL
( 86) > $$
( 87) > $$
( 88) > $
( 89) > $
( 90) > $
( 91) > PLATFORM MEMBER SEGMENTATION
( 92) > $-----
( 93) > $
( 94) > ALL NUMB 10
( 95) > LAST
( 96) > $
( 97) > $
( 98) > $
( 99) > ESTABLISH MEMBER GROUP 'AWAVE' INC IDS 'ANODE'
( 100) > $
( 101) > $
( 102) > $
( 103) > $
( 104) > $
( 105) > $
( 106) > EXECUTE 'STATUS'
STATUS 2R1
```

 *** SEADYN DATA FROM INTERNAL STORAGE ***

GS_VALID ANODE VALID

ACTIVE UNITS -	LENGTH MM	WEIGHT N	ANGLE DEG	TEMPERATURE DEGF	TIME SEC
----------------	--------------	-------------	--------------	---------------------	-------------

ACTIVE JOINTS = 3, MEMBERS = 2, LOADINGS = 0

ACTIVE JOINTS
 40 41 42

ACTIVE MEMBERS
 40 41

```
( 107) > $
( 108) > $
( 109) > $
( 110) > $
( 111) > $ DEFAULT CD/CM
( 112) > $
( 113) > PLATFORM MEMBER COEFFICIENTS -
( 114) > _'AWAVE' INERTIA 1.7 DRAG 0.75
( 115) > $
( 116) > $
( 117) > $
( 118) > LAST
( 119) > $
( 120) > $
( 121) > $ *****
( 122) > $
( 123) > $
( 124) > $
( 125) > $
( 126) > $
( 127) > $
( 128) > $
( 129) > $
( 130) > $
( 131) > $print member properties 'JACKWAVE'
( 132) > $print member constants 'JACKWAVE'
( 133) > $
( 134) > $
( 135) > $
( 136) > $
( 137) > $
( 138) > $
( 139) > $
( 140) > $
( 141) > $
( 142) > UNIT M KN SEC DEG
( 143) > ORIGIN SEA FLOOR
( 144) > SEA CONSTANTS DEPTH 50 $ 2012 SUBSIDENCE + SURGE + TOL.
( 145) > WEIGHT DENSITY 10.069
```

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```

( 146) > LAST
( 147) > $
( 148) > $
( 149) > $ MARINE GROWTH PROFILE
( 150) > $ PROFILE ADJUSTED TO WATER DEPTH
( 151) > SEA MARINE GROWTH PROFILE FROM BOTTOM FOR ALL
( 152) > 0.00 0.100 $ MUDLINE
( 153) > 20.00 0.100
( 154) > 50.00 0.100
( 155) > $
( 156) > $
( 157) > $ CURRENT PROFILE ( EXTREME CONDITION )
( 158) > $ -----
( 159) > $
( 160) > SEA CURR PRO VAR FROM BOT CONSTANT ABOVE STILL WATER LEVEL
( 161) > 77.50 0.70
( 162) > 3.00 0.70
( 163) > 0.00 0.00
( 164) > $
( 165) > $
( 166) > $
( 167) > $
( 168) > $
( 169) > $
( 170) > $
( 171) > $ 1. EXTREME CONDITION WAVE & CURRENT FROM PLATFORM WEST (0 DEG)
( 172) > $ =====
( 173) > $
( 174) > $
( 175) > $
( 176) > INACTIVE MEMBERS ALL
ALL 2 MEMBERS HAVE BEEN INACTIVATED
( 177) > ACTIVE MEMBERS 'AWAKE'
2 MEMBERS HAVE BEEN ACTIVATED
( 178) > SEA LOAD GROUP 'JTOTAL' MEMBERS ALL
( 179) > LAST
( 180) > $
( 181) > $
( 182) > $
( 183) > $
( 184) > $
( 185) > $
( 186) > SEA WAVE DIRECTION 0.0
( 187) > SEA CURR DIRECTION 0.0
( 188) > $
( 189) > $
( 190) > $
( 191) > SEA WAVE PERIOD 12.0
( 192) > HEIGHT 10.0
( 193) > THEORY STOKES ORDER 5
( 194) > LAST
( 195) > $
( 196) > SEA WAVE GRID VERTICAL NODES -
( 197) > 6 SPA 6.0 10 SPA 3.0
( 198) > HORIZONTAL NODES -
( 199) > 13 SPA 3.0 20 SPA 5.0
( 200) > GENERATE
*** SEADYN WARNING *** (SEGRDX)
HORIZONTAL GRID EXCEEDS WAVE LENGTH OF 104.8 GRID REDUCED FROM 34 TO 28 GRID POINTS
*** SEADYN WARNING *** (SEGRDY)
VERTICAL GRID EXCEEDS WAVE HEIGHT OF 55.56 GRID REDUCED FROM 17 TO 14 GRID POINTS
( 201) > LAST
( 202) > $
( 203) > units m
( 204) > SEA LOAD ANALYSIS FROM 20 UPS TO 20 DOWN IN 10 STEPS
( 205) > $ SEA LOAD ANALYSIS AT 8.0 UP
( 206) > $
( 207) > PRINT SEA CONSTANTS
*****
*** SEADYN DATA FROM INTERNAL STORAGE ***
*****

GS_VALID ANODE VALID

ACTIVE UNITS - LENGTH WEIGHT ANGLE TEMPERATURE TIME
M KN DEG DEG SEC

1*****
*** SEA CONSTANTS DATA ***
*****

WATER DEPTH = 5.000E+01

WATER TEMPERATURE = 5.000E+01

WATER WEIGHT DENSITY = 1.007E+01

WATER MASS DENSITY = 1.026E+00

WATER VISCOSITY = 1.310E-06

MARINE GROWTH WEIGHT DENSITY = 1.007E+01

MARINE GROWTH MASS DENSITY = 1.026E+00
1*****
*** WIND AND CURRENT DATA ***
*****

CURRENT IS ON

CURRENT DIRECTION = 0.000E+00

```

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CURRENT PROFILE

AT DEPTH = 0.000E+00 VELOCITY = 0.000E+00 DIRECTION = 0.000E+00

AT DEPTH = 3.000E+00 VELOCITY = 7.000E-01 DIRECTION = 0.000E+00

AT DEPTH = 7.750E+01 VELOCITY = 7.000E-01 DIRECTION = 0.000E+00

1*****
*** WAVE DATA ***

WAVE HEIGHT = 1.000E+01

FREQUENCY/PERIOD = 5.236E-01/ 1.200E+01

WAVE LENGTH HAS NOT BEEN SPECIFIED BUT = 2.095E+02

WAVE DIRECTION = 0.000E+00

WAVE THEORY - STOKES 5TH ORDER

WAVE POSITIONED AT -2.000E+01 DOWNSTREAM

STEPPED TO -2.000E+01 DOWNSTREAM IN 10 STEPS

MARINE GROWTH PROFILE IS ON

GROWTH INCREASE ON RADIUS FROM SEA FLOOR

MARINE GROWTH PROFILE NUMBER 1

AT 0.000E+00 GROWTH = 1.000E-01

AT 2.000E+01 GROWTH = 1.000E-01

AT 5.000E+01 GROWTH = 1.000E-01

MEMBERS INCLUDED IN THIS MARINE GROWTH PROFILE ARE:

40 41

1*****
*** WAVE GRID DATA ***
*****NUMBER OF HORIZONTAL GRID POINTS = 28
NUMBER OF VERTICAL GRID POINTS = 14

WAVE GRID KINEMATIC FACTORS

X-VELOCITY = 1.000E+00

Y-VELOCITY = 1.000E+00

X-ACCELERATION = 1.000E+00

Y-ACCELERATION = 1.000E+00

{ 208} > LIST SEA WAVE PROFILE

*** RESULTS OF LATEST SEADYN ANALYSIS ***

GS_VALID ANODE VALID

ACTIVE UNITS -	LENGTH	WEIGHT	ANGLE	TEMPERATURE	TIME
	M	KN	DEG	DEGF	SEC

DISTANCE	ELEVATION	X-VELOCITY	Y-VELOCITY	X-ACCELERATION	Y-ACCELERATION
0.000E+00	5.556346E+01	3.450E+00	0.000E+00	0.000E+00	-1.438E+00
3.000E+00	5.553083E+01	3.430E+00	3.070E-01	1.834E-01	-1.427E+00
6.000E+00	5.543375E+01	3.372E+00	6.087E-01	3.634E-01	-1.396E+00
9.000E+00	5.527454E+01	3.276E+00	8.999E-01	5.369E-01	-1.344E+00
1.200E+01	5.505695E+01	3.146E+00	1.176E+00	7.010E-01	-1.274E+00
1.500E+01	5.478593E+01	2.984E+00	1.433E+00	8.532E-01	-1.187E+00
1.800E+01	5.446737E+01	2.794E+00	1.667E+00	9.915E-01	-1.085E+00
2.100E+01	5.410778E+01	2.579E+00	1.876E+00	1.114E+00	-9.718E-01
2.400E+01	5.371403E+01	2.346E+00	2.058E+00	1.221E+00	-8.490E-01
2.700E+01	5.329305E+01	2.096E+00	2.213E+00	1.310E+00	-7.193E-01
3.000E+01	5.285159E+01	1.835E+00	2.339E+00	1.382E+00	-5.853E-01
3.300E+01	5.239603E+01	1.567E+00	2.438E+00	1.436E+00	-4.492E-01
3.600E+01	5.193227E+01	1.294E+00	2.509E+00	1.475E+00	-3.133E-01
3.900E+01	5.146563E+01	1.021E+00	2.554E+00	1.497E+00	-1.792E-01
4.400E+01	5.069403E+01	5.696E-01	2.576E+00	1.502E+00	3.571E-02
4.900E+01	4.994554E+01	1.342E-01	2.536E+00	1.471E+00	2.351E-01
5.400E+01	4.923444E+01	-2.772E-01	2.443E+00	1.409E+00	4.152E-01
5.900E+01	4.857163E+01	-6.585E-01	2.304E+00	1.321E+00	5.737E-01
6.400E+01	4.796524E+01	-1.005E+00	2.129E+00	1.213E+00	7.100E-01
6.900E+01	4.742113E+01	-1.315E+00	1.922E+00	1.089E+00	8.244E-01
7.400E+01	4.694329E+01	-1.585E+00	1.691E+00	9.533E-01	9.183E-01
7.900E+01	4.653428E+01	-1.815E+00	1.442E+00	8.084E-01	9.933E-01
8.400E+01	4.619569E+01	-2.004E+00	1.177E+00	6.574E-01	1.051E+00
8.900E+01	4.592861E+01	-2.153E+00	9.026E-01	5.021E-01	1.094E+00
9.400E+01	4.573389E+01	-2.260E+00	6.203E-01	3.441E-01	1.124E+00
9.900E+01	4.561223E+01	-2.327E+00	3.332E-01	1.846E-01	1.142E+00
1.040E+02	4.556417E+01	-2.354E+00	4.376E-02	2.422E-02	1.149E+00
1.048E+02	4.556333E+01	-2.354E+00	-6.302E-07	-3.488E-07	1.149E+00

{ 209} > LAST

{ 210} > \$

{ 211} > LIST SEA LOAD GROUP 'JTOTAL'

*** RESULTS OF LATEST SEADYN ANALYSIS ***

GS_VALID ANODE VALID

Modified:02/09/98 1:01 PM:../disk5/c067/new_jkt/gs_anoda.out

5.14

5.15

Jas

Printed:02/09/98 1:02 PM

LENGTH WEIGHT ANGLE TEMPERATURE TIME
M KN DEG DEGF SEC

No : 0000

ISTORIES ***

SITION(UP)	FORCE X	FORCE Y	FORCE Z	MOMENT X	MOMENT Y	MOMENT Z
2.000E+01	2.981E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.223E+02
1.600E+01	3.205E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.314E+02
1.200E+01	3.377E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.385E+02
3.000E+00	3.470E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.423E+02
4.000E+00	3.490E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.431E+02
0.000E+00	3.432E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.408E+02
4.000E+00	3.281E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.346E+02
3.000E+00	3.055E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.253E+02
1.200E+01	2.763E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.133E+02
1.600E+01	2.405E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-9.865E+01
2.000E+01	2.009E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-8.240E+01

AD HISTORIES ***

AD GENERATE POSITION
WA_W' 'STORM WAVE FROM PLATFORM WEST'

Length/Flood
1.000
Y
1.000
Y

gs_anode'
ub-system SEADYN saved in file gs_anode.save.

----- RUN-TIME PERFORMANCE SUMMARY -----

03.02 Elapsed Time 0 00:00:08 On Mon Feb 9 13:01:20 1998

m/s2

(v)
56
00
00
00

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Wave load - validation

CALC BY : GJS DATE : 09-Feb-1998

CHECKED :

load factors (not applied to node loads)

w1 is applied to self weight and buoyancy.

w2 is applied to wave and current.

w1 = 1 We = 1

member loads (including load factors) (kN/m)

a= distance to start of load, b= length of a linear load)

member	type	axes	w1	a	w2	b
1	U	LY	-1.64	0.00	-1.66	0.250
1	U	LY	-1.66	0.25	-1.68	0.250
1	U	LY	-1.68	0.50	-1.69	0.250
1	U	LY	-1.69	0.75	-1.71	0.250
2	U	LY	-1.71	0.00	-1.73	0.250
2	U	LY	-1.73	0.25	-1.75	0.250
2	U	LY	-1.75	0.50	-1.76	0.250
2	U	LY	-1.76	0.75	-1.78	0.250

displacements

node	X (m)	Y (m)	RZ (radians)
1	0.000000	0.000000	0.000000
2	0.000036	0.000000	-0.000059
3	0.000101	0.000000	-0.000067

member forces (local axes)

member	node	FX (kN)	FY (kN)	MZ (kNm)
1	1	0.0000	3.4227	3.4691
	2	0.0000	-1.7461	-0.8790
2	2	0.0000	1.7461	0.8790
	3	0.0000	0.0000	0.0000

reactions

node	FX (kN)	FY (kN)	MZ (kNm)
1	-3.4227	0.0000	3.4691

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Wave load - validation

CALC BY : GJS DATE : 09-Feb-1998

CHECKED :

Load factors (not applied to node loads)

D1 is applied to self weight and buoyancy.

We is applied to wave and current.

D1 = 1

We = 1

Member loads (including load factors) (kN/m)

(a= distance to start of load, b= length of a linear load)

memb	type	axes	w1	a	w2	b
1	U	GY	-1.35	0.00	-1.35	1.000
2	U	GY	-1.35	0.00	-1.35	1.000
1	U	GY	0.18	0.00	0.18	0.250
1	U	LY	-1.64	0.00	-1.66	0.250
1	U	GY	0.18	0.25	0.18	0.250
1	U	LY	-1.66	0.25	-1.68	0.250
1	U	GY	0.18	0.50	0.18	0.250
1	U	LY	-1.68	0.50	-1.69	0.250
1	U	GY	0.18	0.75	0.18	0.250
1	U	LY	-1.69	0.75	-1.71	0.250
2	U	GY	0.18	0.00	0.18	0.250
2	U	LY	-1.71	0.00	-1.73	0.250
2	U	GY	0.18	0.25	0.18	0.250
2	U	LY	-1.73	0.25	-1.75	0.250
2	U	GY	0.18	0.50	0.18	0.250
2	U	LY	-1.75	0.50	-1.76	0.250
2	U	GY	0.18	0.75	0.18	0.250
2	U	LY	-1.76	0.75	-1.78	0.250

Displacements

Node	X (m)	Y (m)	RZ (radians)
1	0.000000	0.000000	0.000000
2	0.000036	-0.000001	-0.000059
3	0.000101	-0.000001	-0.000067

Member forces (local axes)

member	node	FX (kN)	FY (kN)	MZ (kNm)
1	1	2.3559	3.4227	3.4691
	2	-1.1780	-1.7461	-0.8790
2	2	1.1780	1.7461	0.8790
	3	0.0000	0.0000	0.0000

Reactions

node	FX (kN)	FY (kN)	MZ (kNm)
1	-3.4227	2.3559	3.4691

6.0 Anode

6.1 Pile driving

Calculates the stresses and fatigue damage in anode connections during pile driving

6.2 Storm wave

Calculates the stresses and in anode connections under wave loading

6.1 Pile driving

Consider pile driving damage to anode fixings

(a) Pile driving data

(i) Assume an impact duration of 0.005 sec



(ii) Assume 5000 blows to drive each pile

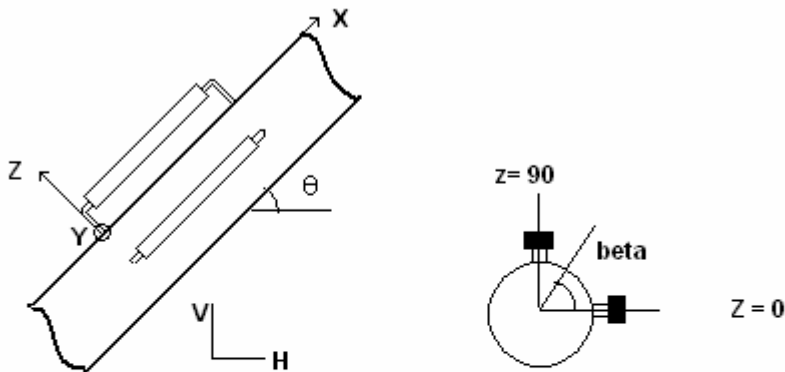
(iii) Assume each anode experiences
 2 x 5000 pile blows @ 10g (vertical)
 6 x 5000 pile blows @ 5g (vertical)

(iv) Assume that damage is caused by stress ranges $> S_0$, i.e. the gradient of the S-N curve is 3.

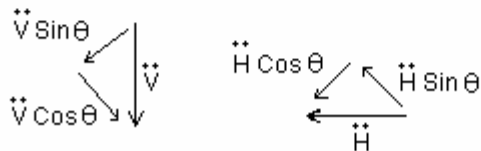
Therefore the equivalent accelerations to cause the same damage for only 5000 blows is;
 $Acc_{equivalent} = (2 \cdot 10g^3 + 6 \cdot 5g^3)^{1/3} = 14g$ (for 5000 blows)

(v) Assume horizontal = 20% of vertical

Loads on anode



Components of acceleration



Let

Az = in-plane acceleration (vertical)

Ax = in-plane acceleration (longitudinal)

Ay = out of plane acceleration

Hop = the horizontal acceleration in the anode out of plane direction

Thus the solutions are;
Beta = 90deg

Solution A

$$A_z = V \cdot \cos\theta - H \cdot \sin\theta$$

$$A_x = V \cdot \sin\theta + H \cdot \cos\theta$$

$$A_y = \quad + H \cdot \sin\theta$$

Solution B

$$A_z = V \cdot \cos\theta + H \cdot \sin\theta$$

$$A_x = V \cdot \sin\theta - H \cdot \cos\theta$$

$$A_y = \quad + H \cdot \sin\theta$$

Beta = 0 deg

Solution A

$$A_z = \quad + H \cdot \sin\theta$$

$$A_x = V \cdot \sin\theta + H \cdot \cos\theta$$

$$A_y = V \cdot \cos\theta - H \cdot \sin\theta$$

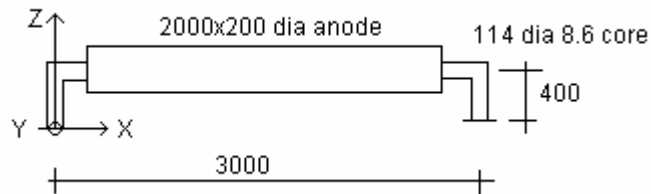
Solution B

$$A_z = \quad + H \cdot \sin\theta$$

$$A_x = V \cdot \sin\theta - H \cdot \cos\theta$$

$$A_y = V \cdot \cos\theta + H \cdot \sin\theta$$

Anode data



Anode displacement	= $1000 \text{ kg/m}^3 \cdot 2\pi \cdot 0.2^2$	= 63kg
Anode	= $2750 \text{ kg/m}^3 (2.0 \cdot \pi/4 (0.2^2 - 0.114^2))$	= 116kg
Core	= $7850 \text{ kg/m}^3 (2.0 \cdot 0.4 + 3) (\pi/4 (0.114^2 - (0.114 - 0.0086)^2))$	= 85kg

Added mass (hydrodynamic)

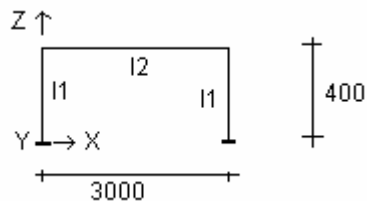
For tube, $C_m=1$

$$\text{mass}_x = 116 + 85 + 0 = 201\text{kg}$$

$$\text{mass}_y = 116 + 85 + 1 \cdot 63 = 264\text{kg}$$

$$\text{mass}_z = 116 + 85 + 1 \cdot 63 = 201\text{kg}$$

To determine dynamic characteristics and stresses at fixing of tubular calculate fixing moments and displacements for unit loads on a Kleinlogel frame 1



$$k = I_2/I_1 \cdot h/L = 0.1333$$

$$N_1 = 2.133 \quad N_2 = 1.8$$

17/10/2005

Unit X load

$$M_{a-y-1} = \text{moment at A about y axis for load of 1} \\ = 400/2 * (3k+1) / N2 = 155$$

$$M_{b-y-1} = -400/2 * (3k) / N2 = -44$$

Unit Y load

$$M_{a-y-1} = 400/2 \text{ (2 supports)} = 200$$

Apply Z load of total mass W

$$M_{a-z-1} = 3000/(12*2.133) = 117.2$$

Displacements of anode under unit loads

$$E = 205E3 \text{ N/mm}^2 \quad I = \pi/64 * (114^4 - 96.8^4) = 3.98E6 \\ EI = 816E9$$

$$\Delta x1 = 400^2/6EI * (2 * M_{a-x-1} + M_{b-y-1}) \\ = 400^2 * (2*155 - 44)/(6*816E9) \\ = 8.69E-6$$

$$\Delta y1 = \frac{1}{2} * 400^3/EI + 3000^3/384EI \\ = 13.07E-6 + 86.17E-6 \\ = 99.24E-6$$

$$\Delta z1 = 300^3/384EI \\ = 86.16E-6$$

Therefore the actual displacements are;

$$dx = 9.81 * 201 * 8.69E-6 = 17.14E-6m \\ dy = 9.81 * 264 * 99.24E-6 = 257E-6m \\ dz = 9.81 * 264 * 87.17E-6 = 225E-6m$$

natural frequencies ($=\sqrt{g/d}$)

$$wx = \sqrt{9.81 / 17.14E-6} = 765 \\ wy = \sqrt{9.81 / 257E-6} = 195 \\ wz = \sqrt{9.81 / 225E-6} = 209$$

Calculate DAFs for a forcing function of $T_f = 2 * 0.005 = 0.010 \text{ sec}$

$$wf = 1/T_f * 2 * \pi = 628$$

Ratios of wf/w_n	$wt1 = 2\pi/(1+1/R)$	$wt = wt1/R$
$R_x = 628/765 = 0.82$	2.83	3.45
$R_y = 628/195 = 3.22$	4.79	1.49
$R_z = 628/209 = 3.01$	4.72	1.57

DAF

For $R < 1$

$$DAF = 1 / (1 - R^2) * (\sin(wt1) - R * \sin(wt))$$

For $R \geq 1$

$$DAF = 2 * R * \cos(\pi/(2R)) / (R^2 - 1)$$

$$DAF_x = 1.69$$

$$DAF_y = 0.61 < 1. \text{ Use DAF} = 1$$

$$DAF_z = 0.65 < 1. \text{ Use DAF} = 1$$

Calculate loads on anode

Let $\beta = 90^\circ$, $\theta = 45^\circ$

$$V = 14g \quad H = 2.8g$$

Accelerations

Solution A

$$A_z = 14 * \cos(45) - 2.8 * \sin(45) = 7.92g$$

$$A_x = 14 * \cos(45) + 2.8 * \sin(45) = 11.9g$$

$$A_y = 2.8g$$

Solution B

$$A_z = 14 * \cos(45) + 2.8 * \sin(45) = 11.9g$$

$$A_x = 14 * \cos(45) - 2.8 * \sin(45) = 7.92g$$

$$A_y = 2.8g$$

Get moments at supports

$$M = DAF * \text{mass} * \text{acceleration}$$

$$M_{x-a} = \text{Moment about x at A}$$

$$= DAF_y * \text{Mass}_y * \text{abs}(\text{acceleration y}) * \text{Max-y-1}$$

$$= 1 * 264 * 2.8 * 9.81 * 200$$

$$= 1.46E6 \text{ Nmm (out of plane)}$$

$$M_{y-a} = \text{X direction acceleration} + \text{Z direction acceleration}$$

$$= 1.69 * 201 * 11.9 * 9.81 * 155 + 1.0 * 264 * 7.92 * 9.81 * 117.5$$

$$= 6.147E6 + 2.41E6$$

$$= 8.56E6 \text{ Nmm}$$

$$\text{Resultant moment} = 8.68E6 \text{ Nmm}$$

Solution B

$$M_{x-a} = 1 * 264 * 2.8 * 9.81 * 200$$

$$= 1.46E6 \text{ Nmm}$$

$$M_{y-a} = 1.69 * 201 * 7.92 * 9.81 * 155 + 1.0 * 264 * 11.92 * 9.81 * 117.5$$

$$= 4.1E6 + 3.62E6$$

$$= 7.72E6 \text{ Nmm}$$

$$\text{Resultant moment} = 7.86E6 \text{ Nmm}$$

Axial loads

Solution A

$$F_{ax-z} = DAF_z * \text{mass}_z * \text{acceleration z} / 2$$

$$+ DAF_x * (-2 * \text{mass}_x * \text{acceleration x} * \text{May-x-1} + \text{Mass}_x * \text{acceleration x} * h) / L$$

$$= 1 * 264 * 7.92 * 9.81 / 2 + 1.69 * 201 * 11.9 * 9.81 * (-2 * 155 + 400) / 3000$$

$$= 10.26E3 + 1.19E3 \text{ N}$$

$$= 11.45E3 \text{ N}$$

Solution B

$$F_{ax-z} = 16.28E3 \text{ N}$$

Stresses for solutions A and B

$$Z = \pi / (32 * 114) * (114^4 - 96.8^4) = 69.84E3 \text{ mm}^3$$

$$A = \pi / 4 * (114^2 - 96.8^2) = 2.848E3 \text{ mm}^2$$

Solution A

$$f_b = 8.68E6 / Z = 124 \text{ MPa}$$

$$f_a = 11.45E3 / A = 4 \text{ MPa}$$

Solution B

$$f_b = 7.86E6 / Z = 113 \text{ MPa}$$

$$f_a = 16.28E3 / A = 5.7 \text{ MPa}$$

From solutions A and B, the maximum stress is at A

$$f_b + f_a = 128 \text{ MPa}$$

$$\text{Therefore the stress range} = 2 * 128 = 256 \text{ MPa}$$

Using the F2 curve for $S_o = 35$

$$N = 10^{(11.63 - 3 \log(256))}$$

$$N = 25\,430 \text{ cycles}$$

$$\text{The total number of stress cycles} = 3.1 \text{ cycles per blow} * 5000 \text{ blows} = 15\,500.$$

$$\text{Therefore damage to core} = 15500/25430 = 0.61$$

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Anode - pile driving fatigue

CALC BY : GJS

DATE : 01-Feb-1998

CHECKED :

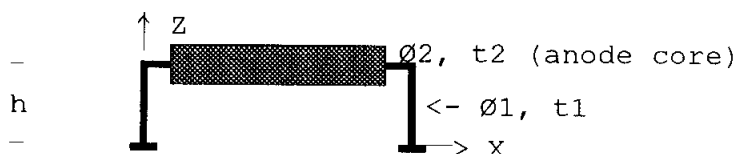
Anode data (mm)

total length = 3000 anode length = 2000
 anode diameter = 200
 diameter Ø1 = 114 thickness t1 = 8.6
 diameter Ø2 = 114 thickness t2 = 8.6
 height = 400 support tube D =
 anode x-z plane is vertical
 anode angle theta = 45 deg.
 Theta is angle between the x axis and the horizontal plane.
 Anode material does not contribute to structural strength of core.

anode mass = 116.6 kg

core mass = 84.9 kg

doubler plate not used

**Check anode for pile driving acceleration load fatigue**

Blows to drive one pile = 5000
 duration of impulse loading (s) = 0.005

Accelerations (g)

(equivalent accelerations for blow count for driving of one pile)
 Vertical = 14.0 horizontal = 2.8

	X	Y	Z
dynamic masses (kg)	201.6	266.0	266.0
DAF's			
calculated	1.69	0.61	0.65
used	1.69	1.00	1.00

Damage

maximum stress range (Sb) = 2 * DAF * fmax
 fmax = (fbx² + fby²)^{0.5} + fax
 core = 257.84

damage = 3.1(attenuation) * Number of blows to drive one pile/ SN curve
 damage to core = 0.623 (F2 curve, t=t1)

number of blows to fail core = 8.0e+003

Core to doubler/tubular connection - OK

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Anode - validation

CALC BY : GJS DATE : 10-Feb-1998

CHECKED :

Storm wave

Anode data (mm)

total length	=	2000	anode length	=	2000
anode diameter	=	200			
diameter $\phi 1$	=	114	thickness t1	=	10
diameter $\phi 2$	=	114	thickness t2	=	10
height	=	400	support tube	D	= 1000

anode x-z plane is vertical

anode angle theta = 90 deg.

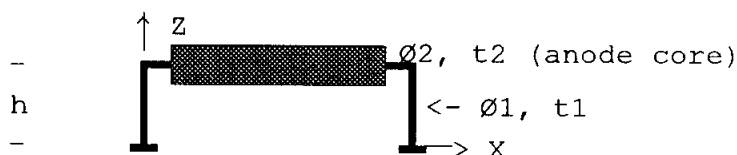
Theta is angle between the x axis and the horizontal plane.

Anode material does not contribute to structural strength of core.

anode mass = 116.6 kg

core mass = 71.8 kg

doubler plate not used

**Check anode for storm wave loading**

Depth below still water level 50

Depth below anode 40

Wave theory Stokes 5th

Cd = 0.7 Cm = 1.7 Marine growth = 50 mm

Horizontal (u) velocity increase $\{1 + (R_{tube}/R_{total})^2\} = 1.37$ R_{tube} = radius of supporting tubular + marine growth.R_{total} = distance from tubular C1 to anode C1.

u and v are the horizontal and vertical particle velocities and acceleration

H (m)	T (s)	u (m/s)	v (m/s)	u*(m/s ²)	v*(m/s ²)
-------	-------	---------	---------	-----------------------	-----------------------

8.00	12.00	1.779	0.000	0.000	-0.728
------	-------	-------	-------	-------	--------

Current velocity 1.000

Wave + current velocities, including (u) velocity increase.

3.817	0.000
-------	-------

Anode loading, in anode Y direction (kN)

from u, u* 3.136

from v, v* 0.000

Stresses (MPa)

bending

shear (load/(.4 area))

core 9.16

1.54

doubler

7.0 API - WSD - beam columns

API Design check

Design loads (WSD)

P = 1000kN compression Mx = 300kNm My = 50kNm

Section

457x12.7 Grtade 50 Fy = 355MPa
D = 457t = 12.7 Area = 17455 Elastic modulus = 1.888E6mm³
R = 157.2
Kx.L = 6000 Ky.L = 4000
Lx/r = 38 Ly/r = 25.5
D/t = 36.6

Section stresses (MPa)

fa = 1000/17.46 = 57
fbx = 300/1.888 = 159
fby = 50/1.888 = 26.5

Compression

Cc = $(2 * \pi^2 * E / Fy)^{1/2}$ = 108
K.L/r(min) = 6000/151.2 = 38
Kl/r / Cc = 0.35 and D/t < 60
use (3.2.2-1)

Fe'x = $12 * \pi^2 * E / (23 * 38^2)$ = 713
Fe'y = $12 * \pi^2 * E / (23 * 25.5^2)$ = 1583

Therefore

Fac = 0.524 Fy
Fac = 186MPa

Bending

For D/t = 36.6 = 12993/Fy
10340/Fy < D/t < 20680/Fy. Therefore use (3.2.3-1b)
Fb = $(0.84 - 1.74 * 355 * 457 / (205E3 * 12.5)) * Fy$
Fb = 0.735 Fy
Fb = 259 MPa

Section 3.3

(3.3.1-2)
= $57 / 0.6 * 355 + \text{sqr}(159^2 + 26.5^2)^{1/2} / 259$
= 0.27 + 0.62
= 0.89

(3.3.1-4)
= $57 / 186 + \text{sqr}((0.85 * 159 / (1 - 57 / 713))^2 + (0.85 * 36.5 / (1 - 57 / 1583))^2) / 259$
= 0.31 + $\text{sqr}(21577 + 1035) / 259$
= 0.31 + 0.58
= 0.89

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - WSD Beam column

CALC BY : GJS DATE : 25-May-1998

CHECKED :

Test API tubular section

Code check to API RP2A WSD (20th Ed) : 1993

(ver 1.48.5)

Applied loads kN kN-m
Axial load (Fx) = 1,000.00 Moment x-x (Mx) = 300.00
Shear (vect sum) = 500.00 Moment y-y (My) = 50.00

Effective lengths (mm)
Lb = 4000 Lx = 6000 Ly = 4000

Section 457x12.5 CHS Grade 50 Fy = 355 MPa

Section data
Dia = 457 t.wall = 12.5 D / t = 36.6
Area = 17,455 mm² w = 137 kg/m
rx = 157.2 ry = 157.2 mm Zx = 1,888,175
 Zy = 1,888,175 mm³

Lx/rx = 38.2 Ly/ry = 25.4

Allowable stresses (MPa)
Allowable stress factor = 1.00
Fbx = 259.1 (3.2.3-1b)
Fby = 259.1
Facx = 185.1 (3.2.2-1) Facy = 196.6 (3.2.2-1)
Fv(y) = 142.0

Mb(x-x) = 489 Mb(y-y) = 489 kN-m

Actual stresses (MPa) fac = 57.29 fbx = 158.88 fby = 26.48

Code check results

Cm(x) = 0.85 Cm(y) = 0.85

(3.3.1-2)
$$fa / 0.6 * Fy + [fbx^2 + fby^2]^{0.5} / Fb$$
$$0.27 + 0.62 = 0.89$$

(3.3.1-4)
$$fa / Fa + \{ [Cmx.fbx / (magn.)]^2 + [Cmy.fby / (magn.)]^2 \}^{0.5} / Fb$$
$$0.31 + 0.57 = 0.88$$

Shear (y):: fv / Fv = 0.40

Section O.K. use 457x12.5 CHS

8.0 API – Working stress design method, punching shear

The program carries out a punching shear code check to API 20th edition, Chapter 4

API 20th Edition WSD Chapter 4

Punching shear

$F_{yb} = F_{yc} = 355 \text{ MPa}$

$F_{ut} = 460 \text{ MPa}$

Therefore $F_{yi} = 2/3 * 460 = 307 \text{ MPa}$

Joint load	Pax	Mip	Mop	D	T
Chord	2000	500	400	1000	20
Brace	1200	300	200	800	10

Geometry

$\theta = 45\text{deg}$

$\tau = 10/20 = 0.5$

$\beta = 800/1000 = 0.8$

$\gamma = 1000/2*20 = 25$

Qq values

$Q\beta = 0.3/(\beta(1 - 0.833 \beta)) = 1.124$

$Qq_{ax} = 1.1 + 0.2/\beta = 1.35$

$Qq_{ip} = 3.72 + 0.67/\beta = 4.56$

$Qq_{op} = (1.37 + 0.67/\beta) Q\beta = 2.48$

Chord Stresses

1000x20, $A = 61575 \text{ mm}^2$ $Z = 14.79 \text{ E}6$ (elastic mod)

$f_a = 2000/A = 32.5 \text{ MPa}$

$f_{bip} = 500/Z = 33.8 \text{ MPa}$

$f_{bop} = 400/Z = 27 \text{ MPa}$

Therefore the chord A value is;

$A = \sqrt{(32.5^2 + 33.8^2 + 27^2)}/0.6*307$

$A = 0.29$

Therefore $Q_f = 1 - \lambda * 25 * 0.29^2 = 1 - 2.1 \lambda$

$Q_{fax} = 1 - 2.1 * 0.03 = 0.94$

$Q_{fip} = 1 - 2.1 * 0.045 = 0.90$

$Q_{fop} = 1 - 2.1 * 0.021 = 0.96$

$V_{pa(ax)} = 1.35 * 0.94 * 307 / 0.6 * 307 = 26 \text{ MPa}$

$V_{pa(ip)} = 4.56 * 0.90 * 307 / 0.6 * 307 = 83.5 \text{ MPa}$

$V_{pa(op)} = 2.48 * 0.96 * 307 / 0.6 * 307 = 48.7 \text{ MPa}$

Brace stresses

800x10 $A = 24.818 \text{ E}3 \text{ mm}^2$ $Z = 4.84 \text{ E}6$

$v_{p(ax)} = 0.5 * 1200 / A * 0.7071 = 17 \text{ MPa}$

$v_{p(ip)} = 0.5 * 300 / Z * 0.7071 = 17 \text{ MPa}$

$v_{p(op)} = 0.5 * 200 / Z * 0.7071 = 17 \text{ MPa}$

(4.1.1)

$= 355/307 * (25.5 * 0.5 * 0.7071) / (11 + 1.5 / 0.8) = 0.794$

$$(4.3.1-3a) \\ = (21.9 / 83.5)^2 + (14.6 / 48.7)^2 = 0.158$$

$$(4.3.1-3b) \\ = 17/26 + 2/\pi \sin^{-1}(0.158^{0.5}) * (\pi/180) = 0.914$$

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - WSD - Punching shear

CALC BY : GJS DATE : 27-Jan-1998

CHECKED :

Punch check to API RP2A WSD (20th Ed) : 1993

(ver 1.06.0)

Member data

	Dia mm	t mm	Fy MPa	Pax kN	Mip kNm	Mop kNm
Chord	1000	20	355	2000	500	400
Brace	800	10	355	1200	300	200

Chord tensile strength, Futs = 460 . Fyc = 306.7

Joint geometry

theta (deg) = 45.0	gap (mm) = 75.0	joint type = T/Y
tau (t/T) = 0.50	beta (d/D) = 0.80	gamma (D/2T) = 25.00

Q factors

chord stress ratio A = 0.29		
Qq(Ax) = 1.35	Qq(ip) = 4.56	Qq(op) = 2.48
Qf(Ax) = 0.94	Qf(ip) = 0.90	Qf(op) = 0.95

Member stresses (MPa)

Allowable stress factor = 1.00		
vp(Ax) = 17.1	vp(ip) = 21.9	vp(op) = 14.6
vpa(Ax) = 25.8	vpa(ip) = 84.1	vpa(op) = 48.4

Code check results

Section 4 equations

eq (4.1-1)	= 0.79
eq (4.3.1-3a)	= 0.07 + 0.09 = 0.16
eq (4.3.1-3b)	= 0.66 + 0.26 = 0.92

Joint O.K

9.0 API – Working stress design method, Hydrostatic check

The program carries out a hydrostatic design check to API 20th edition

API RP2A Hydrostatic check

Input data

Member, 1000x20 $F_y = 355\text{MPa}$
Area = 61575 $Z = 14.79\text{E6}$ (elastic mod) $r = 346.6$
Wave, $H_w = 8\text{m}$ $T = 12\text{ sec}$ $L = 1.56 \cdot T^2 = 225\text{m}$
 $k = 2 \pi / L = 0.0279$
 $k(d-z) = 0.559$
 $k_d = 1.955$
 $H_z = 50 + 8/2 \cdot (\cosh(1.395)/\cosh(1.953))$
 $H_z = 50 + 4 \cdot (e^{0.559} + e^{-0.559}) / (e^{1.955} + e^{-1.995})$
 $H_z = 51.29\text{m}$
 $\gamma_h = 10.05 \cdot 51.29$
 $\gamma_h = 515.5\text{ kPa}$

Member actions

$P = 2000\text{ kN}$ $M_r = 500\text{ kNm}$

Stresses

$f_a = 2000/A = 32.5\text{MPa}$
 $f_b = 500 / Z = 33.8\text{MPa}$
 $f_h = 515.5 \cdot 0.5/20 = 12.9\text{MPa}$

Elastic hoop stress

$M = 20/1 \cdot (2 \cdot 1000/20)^{1/2} = 200 = 4D/t > 1.6D/t$
Therefore $C_h = 0.44t/D$
 $F_{he} = 2 \cdot 0.44 \cdot 20 / 1000 \cdot 205\text{E}3 \cdot 20 / 1000$
 $F_{he} = 72.16\text{MPa}$
 $F_{he} = 0.2 \cdot F_y$

$F_{hc} = F_{he}$

Factors of safety

$SF_x(\text{tension}) = 1.67$
 $SF_x(\text{compr.})$
 $kL/r = 20000 \cdot 0.85/346.6$
 $kL/r = 49$
 $C_c = \sqrt{2 \pi E / F_y}$
 $kL/r < C_c$
 $SF_x(c) = 5/3 + 1/4 \sin(kL/r/C_c \cdot \pi/2)$ (radians)
 $SF_x(c) = 1.83$

SF(b)

$D/t = 1000/20 = 50 = 17750/F_y$
 $F_b = (0.84 - 1.74 \cdot 355 \cdot 1000/(205\text{E}3 \cdot 20)) \cdot F_y$
 $F_b = 0.689F_y$
 $SF(b) = 1.45$

$SF_h = 2.0$

$F_{xe} = 2 \cdot C \cdot E \cdot t/D$. for $C=0.3$ $F_{xe} = 2460$

$F_{aa} = F_{xe}/SF_x(c)$

$F_{aa} = 2460/1.83$

$F_{aa} = 1344\text{MPa}$

$F_{ha} = F_{hc}/SF_h$

$F_{ha} = 72.16/2$

$$F_{ha} = 36.1 \text{ MPa}$$

$$f_x = f_a + f_b + (0.5 f_h)$$

$$f_x = 32.5 + 33.8 + 6.4$$

$$f_x = 72.7 > 0.5 F_{ha} = 18 \text{ MPa}$$

Check $f_b > f_a + 0.5 f_h$
 $33.8 < 32.5 + 6.4$ OK
 $F_{xc} = F_y \quad (D/t \leq 60)$

Consider P as tension load

Clause 3.3.3-1

$$A = (32.5 + 33.8 - 0.5 * 12.9) / 355 * 1.67$$

$$A = 0.282$$

$$B = 12.9 / 72.16 * 2$$

$$B = 0.358$$

$$A^2 + B^2 + 2 * 0.3 |A| B < 1.0$$

$$0.282^2 + 0.358^2 + 2 * 0.282 * 0.358 = 0.27$$

For P as compression

3.3.4-1

$$(f_a + 0.5 f_h) / F_{xc} * S F_x + f_b / F_y * S F_b$$

$$= (32.5 + 6.4) / 355 * 1.83 + 33.8 / 355 * 1.45$$

$$= 0.2 + 0.138$$

$$= 0.358$$

3.3.4-3

$$(f_x - 0.5 F_{ha}) / (F_{aa} - 0.5 F_{ha}) + (f_h / F_{ha})^2$$

$$= (72.7 - 0.5 * 36.1) / (1344 - 18) + (12.9 / 36.1)^2$$

$$= 0.04 + 0.128$$

$$= 0.169$$

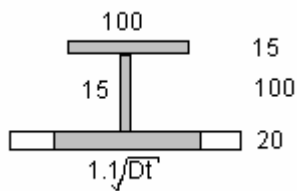
Now use ring stiffeners at 2000c/c

(a) External stiffener
 1000x20

$$I_c = F_{he} t L D^2 / 8E \quad (D = 1000 + 2 * (53.6 - 20) = 1067.2)$$

$$I_c = 72.16 * 20 * 20000 * 1067.2 / (8 * 200E3)$$

$$I_c = 20.55E6 \text{ mm}^4$$



$$1.1 * \sqrt{Dt} = 155.6 \text{ mm}$$

$$\text{Area} = 6112$$

$$X_{bar} = (155.6 * 20^2 / 2 + 15 * 100 * 70 + 1500 * 127.5) / A$$

$$X_{bar} = 53.6 \text{ mm}$$

$$I_{x-x} = 155.6 * 20^3 / 12 + 15 * 20 * 43.6^2$$

$$+ 15 * 100^3 / 12 + 1500 * (70 - 53.6)^2$$

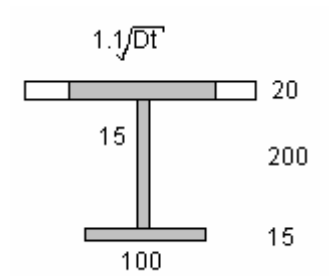
$$+ 100 * 15^3 / 12 + 1500 * (127.5 - 53.6)^2$$

$$I_{x-x} = 15.893E6$$

$I_{xx} < I_c$, Need to resize ring stiffener

For internal ring stiffener

$$I_c = 72.16 \cdot 20 \cdot 20000 \cdot 1000^2 / (8 \cdot 20000)$$
$$I_c = 18.04 \text{E}6 \text{mm}^3$$



$$A = 7612 \text{mm}^2$$
$$\bar{X} = 138.8$$
$$I_{x-x} = 60.8 \text{E}6 > I_c \text{ OK}$$

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - WSD - Hydrostatic

CALC BY : GJS DATE : 27-Jan-1998

CHECKED :

Compression axial load

Code check to API (hydrostatic) (20th Ed) : 1993 (ver 1.12)

Member properties (mm, mm², mm⁴)

Dia = 1000 tw = 20 ry = 346.6 length 17000
 Area = 61,575 I = 73.95E+08
 Fy = 355. MPa

Applied loads

Still water depth = 70 m Depth to member = 50 m
 Wave height = 8 m wave length = 225 m
 Design head = 51.3 m
 Axial = 2000 kN Moment = 500 kN-m

Member stresses (MPa)

fa = 32.5 fb = 33.8 fh = 12.9 fx = 72.7

Critical stresses (MPa)

Fhe = 72.2 Fhc = 72.2 Fxe = 2460.0 Fxc = 355.0

Safety factors

SFx = 1.8 SFh = 2.0 SFb = 1.5

Allowable stresses (MPa)

allowable stress factor = 1.00
 Fac = 173.8 Fb = 244.7 Faa = 1342.9 Fha = 36.1

Ring stiffener properties (mm, mm⁴)

tubular is unstiffened

Code check results

(3.3.4-1)

$$[fa + .5fh](SFx)/Fxc + fb(SFb)/Fy = 0.20 + 0.14 = 0.34$$

(3.3.4-2)

$$fh(SFh)/Fhc = 0.36$$

(3.3.4-3)

$$(fx - .5Fha)/(Faa - .5Fha) + (fh/Fha)^2 = 0.04 + 0.13 = 0.17$$

Section O.K.

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - WSD - Hydrostatic

CALC BY : GJS DATE : 27-Jan-1998

CHECKED :

Tension axial load

Code check to API (hydrostatic) (20th Ed) : 1993 (ver 1.12)

Member properties (mm, mm², mm⁴)

Dia = 1000 tw = 20 ry = 346.6 length 17000
 Area = 61,575 I = 73.95E+08
 Fy = 355. MPa

Applied loads

Still water depth = 70 m Depth to member = 50 m
 Wave height = 8 m wave length = 225 m
 Design head = 51.3 m
 Axial = -2000 kN Moment = 500 kN-m

Member stresses (MPa)

fa = -32.5 fb = 33.8 fh = 12.9

Critical stresses (MPa)

Fhe = 72.2 Fhc = 72.2 Fxe = 2460.0 Fxc = 355.0

Safety factors

SFx = 1.7 SFh = 2.0 SFb = 0.0

Allowable stresses (MPa)

allowable stress factor = 1.00
 Fac = 173.8 Fb = 244.7 Faa = 1342.9 Fha = 36.1

Ring stiffener properties (mm, mm⁴)

tubular is unstiffened

Code check results

(3.3.3-1) tension

$$A^2 + B^2 + 2v|A|B = 0.08 + 0.13 + 0.06 = 0.27$$

Section O.K.

Kvaerner Oil & Gas

Plant/Area Ref:		Project No.		Document/Item Ref.	
Toolkit validation		C045			
Subject:				Sheet	
API- WSD Hydrostatic				of	
Issue:	1	Date	2	Date	3
Made/Revised by:	GJS	Date	02-Oct-1998	Date	4
Checked by:		Date		Date	5
Approved - Process:		Date		Date	
Approved -		Date		Date	

Check ring stiffeners - External

Code check to API (hydrostatic) (20th Ed) : 1993 (ver 1.12)

Member properties (mm, mm², mm⁴)

Dia = 1000 tw = 20 ry = 346.6 length 1
 Area = 61,575 I = 73.95E+08
 Fy = 345. MPa

Applied loads

Still water depth = 70 m Depth to member = 50 m
 Wave height = 8 m wave length = 225 m
 Design head = 51.3 m
 Axial = kN Moment = kN-m

Member stresses (MPa)

fa = 0.0 fb = 0.0 fh = 12.9 fx = 6.4

Critical stresses (MPa)

Fhe = 72.2 Fhc = 72.2 Fxe = 2460.0 Fxc = 345.0

Safety factors

SFx = 1.7 SFh = 2.0 SFb = 1.4

Allowable stresses (MPa)

allowable stress factor = 1.00
 Fac = 207.0 Fb = 239.3 Faa = 1476.0 Fha = 36.1

Ring stiffener properties (mm, mm⁴)

ring stiffeners are external at 20000 mm centers
 web depth = 100 web thickness = 15
 flange width = 100 flange thickness = 15
 tributary shell width = 155.56
 I of ring = 15.89E+06 I required = 20.04E+06
 I required/I of ring = 1.26

Code check results

(3.3.4-1)

$$[fa + .5fh](SFx)/Fxc + fb(SFb)/Fy = 0.03 + 0.00 = 0.03$$

(3.3.4-2)

$$fh(SFh)/Fhc = 0.36$$

Section fails

Kvaerner Oil & Gas

Plant/Area Ref:		Project No.		Document/Item Ref.	
Toolkit validation		C045			
Subject:		Sheet			
API- WSD Hydrostatic		of			
Issue:	1	Date	2	Date	3
Made/Revised by:	GJS	02-Oct-1998		Date	4
Checked by:				Date	5
Approved - Process:				Date	
Approved -				Date	

Check ring stiffeners - Internal

Code check to API (hydrostatic) (20th Ed) : 1993 (ver 1.12)

Member properties (mm, mm², mm⁴)

Dia = 1000 tw = 20 ry = 346.6 length 1
 Area = 61,575 I = 73.95E+08
 Fy = 345. MPa

Applied loads

Still water depth = 70 m Depth to member = 50 m
 Wave height = 8 m wave length = 225 m
 Design head = 51.3 m
 Axial = kN Moment = kN-m

Member stresses (MPa)

fa = 0.0 fb = 0.0 fh = 12.9 fx = 6.4

Critical stresses (MPa)

Fhe = 72.2 Fhc = 72.2 Fxe = 2460.0 Fxc = 345.0

Safety factors

SFx = 1.7 SFh = 2.0 SFb = 1.4

Allowable stresses (MPa)

allowable stress factor = 1.00
 Fac = 207.0 Fb = 239.3 Faa = 1476.0 Fha = 36.1

Ring stiffener properties (mm, mm⁴)

ring stiffeners are internal at 20000 mm centers
 web depth = 200 web thickness = 15
 flange width = 100 flange thickness = 15
 tributary shell width = 155.56
 I of ring = 60.81E+06 I required = 17.60E+06
 I required/I of ring = 0.29

Code check results

(3.3.4-1)

[fa + .5fh](SFx)/Fxc + fb(SFb)/Fy = 0.03 + 0.00 = 0.03

(3.3.4-2)

fh(SFh)/Fhc = 0.36

Section O.K.

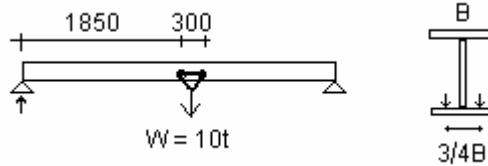
10.0 BS 2853 Runway beam code check

Code check of simply supported or cantilever runway (monorail) crane support beams

Crane beam (monorail)

Electrically operated

DAF = 1.25



Trolley weight = 300kg
SWL = 10000kg
Span = 4m

Dynamic load

$$W_d = (3 + 10) \times 1.25 = 16.25 \text{ kN}$$

$$R = 16.25/2 + 0.25 \times 4/2 = 8.625 \text{ kN}$$

Try 254x102UB25

$$f_b = (8.625 \times 1.85 - 0.25 \times 1.85^2/2) / 266148$$
$$f_b = 58.3 \text{ MPa}$$

$$(f_i = 58.3/15.44 = 3.8 \text{ tsi})$$

$$D/T = 257/8.4 = 31$$

$$l/r_y = 4000/21.5 = 186$$

$$F_b = 4.85 \text{ tsi} = 75 \text{ MPa (pbc)}$$

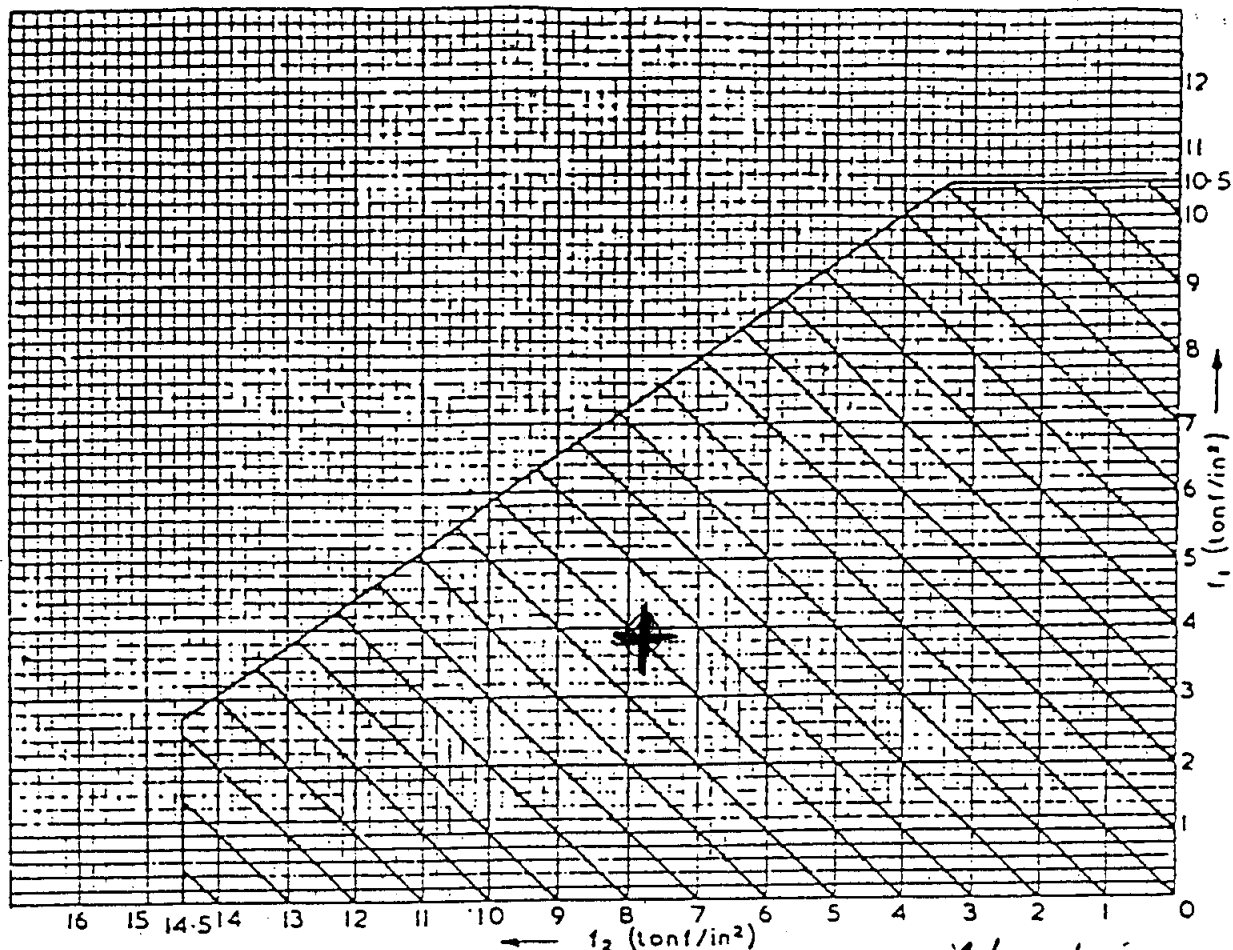
f_2 = Transverse stress, remote from beam end

$$f_2 = 1.4 C W_d / (K_1 T^2) \quad C = 0.5 \text{ from table 3} \quad k_1 = 1.3 \text{ from table 4}$$

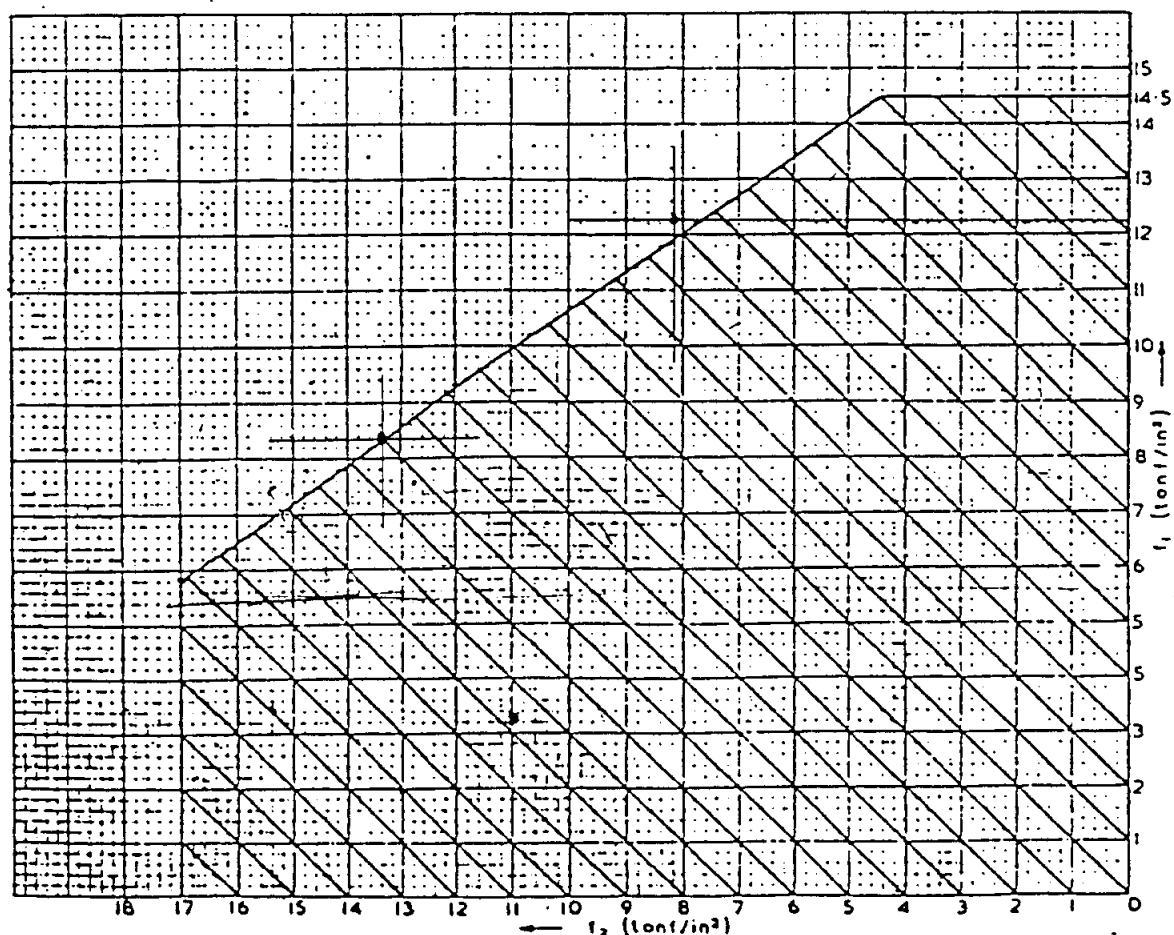
$$f_2 = 1.4 \times 0.5 \times 16.3 \text{ E3} / (1.3 \times 8.5^2)$$

$$f_2 = 122 \text{ MPa} = 7.9 \text{ tsi}$$

From plot of f_1 , f_2 Beam OK

Fig. 5. Values of f_1 and f_2 for steel to BS 15

mild steel
grade 43

Fig. 6. Values of f_1 and f_2 for steel to BS 968

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : BS 2853 - Runway beam

CALC BY : GJS DATE : 28-Jan-1998

CHECKED :

Runway beam design to BS 2853

(ver 1.21)

Hoist data

Trolley is 4 wheeled and weighs 3.0 kN.

Wheels at 300 mm c/c longitudinally.

Position of trolley wheels on flange (of breadth B) = $3/4 B$

SWL = 10.0 kN

Hoist is electric. DAF = 1.25

Beam data

Section 254x102UB25

Grade 43 Total mass 101.4

D = 257 Bf = 101.9 Tf = 8.4 tw = 6.1

Area = 3,230 mm²

rx = 102.9 ry = 21.5 mm

Zx = 266,148 Zy = 29,244 mm³

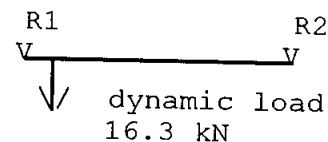
compression flange effective length factor = 1.00

 $k \cdot \text{span} / r_y = 1 \cdot 4000 / 21.5 = 186.2$

max/min reactions under dynamic loads and beam self weight (kN)

R1 = 16.1 R2 = 1.1

simply supported span = 4000 mm



max deflection under self wt & static load = 2.57 mm (span/1556)

Member stresses (MPa)

(including self weight)

maximum bending stress (f1) = 58.3 (≤ dynamic load at mid-span)

flange transverse bending (f2):
trolley remote from end = 124.0

(end stops used)

maximum shear stress (fv) = 10.3

Allowable stresses (MPa)

c (table 3) = 0.5

k1 (table 4) = 1.3

Pbc = 74.9

flange transverse (F2) = 223.7

shear (Fv) = 100.3

Stress ratios

f1 / Pbc = 0.78

f2 / F2 = 0.55

fv / Fv = 0.10

combination of f1 and f2 on fig 5 for load at midspan O.K

Section O.K use 254x102UB25

11.0 API - LRFD - beam columns

API RP2A – LRFD

Design loads, factored to LRFD

$$P = 1000 \text{ kN} \quad M_x = 500 \text{ kNm}$$

$$M_y = 50 \text{ kNm}$$

Member

$$457 \times 10 \text{ Fy} = 355 \text{ MPa}$$

$$A = 14043 \text{ mm}^2 \quad r = 158.1$$

$$\text{Plastic modulus} = 1.998 \text{ E6}$$

$$\text{Elastic modulus} = 1.54 \text{ E6}$$

$$L_x = 6000 \quad L_y = 5000$$

$$L_x/r = 38 \quad L_y/r = 31.6$$

Column buckling

$$F_{xe} = 2 \times 0.3 \times 200 \times 10^3 / 457$$

$$F_{xe} = 2625 \text{ MPa}$$

F_{xc}

$$D/t = 45/7 < 60$$

$$F_{xc} = F_y$$

$$F_{xc} = 355$$

$$\lambda = kl/\pi r (F_y/E)^{0.5}$$

$$\lambda = 38/\pi (355/200 \times 10^3)^{0.5}$$

$$\lambda = 0.51 < \sqrt{2}$$

$$F_{cn} = (1 - 0.25 \times 0.51^2) \times 355$$

$$F_{cn} = 332 \text{ MPa}$$

Beam bending

$$D/t = 47.5 = 16862/F_y$$

$$F_{bn} = (1.13 - 2.58 \times 355 \times 457 / (10 \times 200000) \times 1.998 \times 355 / 1.54$$

$$F_{bn} = 424 \text{ MPa}$$

Combined stresses

$$f_c = 1000/14 = 71 \text{ MPa}$$

$$f_{bx} = 500/1.54 = 235 \text{ MPa}$$

$$f_{by} = 50/1.54 = 32.5 \text{ MPa}$$

$$C_{mx} = C_{my} = 0.85$$

$$F_{ex} = 355/\lambda_x^2$$

$$F_{ex} = 355 / (38/\pi \times \sqrt{355/200000})^2$$

$$F_{ex} = 1365 \text{ MPa}$$

$$F_{ey} = 2012 \text{ MPa}$$

(D.3.2-1)

$$= 71 / (0.85 \times 332) + 1 / (0.95 \times 424) \{ [0.85 \times 32.5 / (1 - 71 / (0.85 \times 2012))]^2$$

$$+ [0.85 \times 235 / (1 - 71 / (0.85 \times 1365))]^2 \}^{0.5}$$

$$= 0.252 + 0.73$$

(D.3.2-2)

$$= 1 - \cos(90 \times 71 / (0.85 \times 355)) + (32.5^2 + 235^2)^{0.5} / (0.95 \times 424)$$

$$= 1 - 0.93 + 0.81$$

$$= 0.88$$

(D.3.2-3)

$$= 71 / (0.85 \times 355)$$

$$= 0.24$$

G. Simms

11-4-3

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - LRFD Beam column

CALC BY : GJS DATE : 25-May-1998

CHECKED :

Test API section

Code check to API RP2A LRFD (1st Ed) : July 1993 (ver 1.1.4)

Applied loads (limit state)

Axial load (Pu)	= 1,000.00	kN	Moment x-x (Mx)	= 500.00	kN-m
Shear (vect sum)	= 500.00	kN	Moment y-y (My)	= 50.00	kN-m

Effective lengths (mm)

Lb = 4000 Lcolx = 6000 Lcoly = 5000

Section 457x10 CHS rolled Grade 50 Fy = 355 MPa

Section data

Dia = 457	t = 10	D/t = 45.7	Area = 14,043	mm ²
Zx,y (elastic) = 1,535,725		Sx,y (plastic) = 1,998,423		mm ³
rx = 158.1	ry = 158.1			mm
Lcolx/rx = 38.0	Lcoly/ry = 31.6			

Limit state stresses (MPa)

Ø Fbn(x,y)	= 0.95	x 425.3	= 404.1	(D.2.3-2b)
Ø Fcn(x-x)	= 0.85	x 332.0	= 282.2	(D.2.2-2a)
Ø Fcn(y-y)	= 0.85	x 339.0	= 288.2	(D.2.2-2a)
Fxe	= 2625.8		Fxc	= 355.0

Actual stresses (MPa)

fb(x-x)	= 325.6	fb(y-y)	= 32.6
fa	= 71.2	fv	= 71.2

Capacity data (kN, kN-m)

ØMn(x,y)	= 807.5	ØVn	= 1367.2
ØPnx	= 3963.0	ØPny	= 4046.8

Code check results

Cm(x) = 0.85 Cm(y) = 0.85

(D.3.1-3) fc/Øc.Fxc = 0.24

(D3.2.-1) 0.25 + 0.73 = 0.99

(D.3.2-2) 1 - 0.93 + 0.81 = 0.88

(D.2.4-1) Shear fv/Øv.Fvn = 0.37

Section O.K. use 457x10 CHS

12.0 API – Load resistance factor design (LRFD) punching shear

The program carries out a punching shear code check to API -LRFD, Chapter E

Punching shear

$F_{yb} = F_{yc} = 355 \text{ MPa}$

$F_{ut} = 460 \text{ MPa}$

Therefore $F_{yi} = 2/3 * 460 = 307 \text{ MPa}$

Joint load	Pax	Mip	Mop	D	T
Chord	1000	400	300	1000	25
Brace	500	100	100	700	10

Geometry

$\theta = 90\text{deg}$

$\tau = 10/25 = 0.4$

$\beta = 700/1000 = 0.7$

$\gamma = 1000/2*25 = 20$

Qq values

$Q\beta = 0.3/(\beta(1 - 0.833 \beta)) = 1.03$

$Qu_{ax} = 3.4 + 19 * 0.7 = 16.7$

$Qu_{ip} = 3.4 + 19 * 0.7 = 16.7$

$Qu_{op} = (1.37 + 7\beta) Q\beta = 8.55$

Chord Stresses

1000x25, $A = 76576 \text{ mm}^2$ $Z = 18.26$ (elastic mod)

$f_a = 1000 / A = 13.0 \text{ MPa}$

$f_{bip} = 400 / Z = 22.0 \text{ MPa}$

$f_{bop} = 300 / Z = 16.5 \text{ MPa}$

Therefore the chord A value is;

$A = \sqrt{(13.0^2 + 22^2 + 16.5^2) / 0.95 * 307}$

$A = 0.10$

Therefore $Q_f = 1 - \lambda * \gamma * A^2 = 1 - 0.218 * \lambda$

$Q_{fax} = 1 - 0.218 * 0.03 = 0.99$

$Q_{fip} = 1 - 0.218 * 0.045 = 0.99$

$Q_{fop} = 1 - 0.218 * 0.021 = 0.99$

$P_u(ax) = 307 * 25^2 * 16.7 * 0.99 = 3172$

$M_u(ip) = 307 * 25^2 * 0. * 0.7 * 16.7 * 0.99 = 1776$

$M_u(op) = 307 * 25^2 * 0. * 0.7 * 8.55 * 0.99 = 909$

$\phi P_{uax} = 3013$

$\phi M_{uip} = 1687$

$\phi M_{uop} = 863$

Code check

E3.1

$= 355 * 20 * 0.4 / (307 * (11 + 1.5/\beta)) = 0.7$

E3.2

$= 500 / 3013 = 0.166$

E3.3 in-plane

$$= 100 / 1687 \qquad \qquad \qquad = 0.06$$

E3.3 out of plane

$$= 100 / 863 \qquad \qquad \qquad = 0.12$$

E3.4

$$= 1 - \cos(90 \times 0.166) + (0.06^2 + 0.12^2)^{0.5}$$

$$= 1 - 0.97 + 0.134 \qquad \qquad \qquad = 0.164$$

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - LRFD - Punching shear

CALC BY : GJS DATE : 28-Jan-1998

CHECKED :

Punch check to API RP2A LRFD (1st Ed) : 1993

ver 1.01

Member data

	Dia mm	t mm	Fy MPa	Pax kN	Mip kNm	Mop kNm
Chord	1000	25	345	1000	400	300
Brace	700	10	355	500	100	100

Chord Fy reduced to $2/3 * F_{ut}$ (see E.3-1) = 306.7**Joint geometry**

theta (deg) = 90.0	gap (mm) = 0.0	joint type = T/Y
tau (t/T) = 0.40	beta (d/D) = 0.70	gamma (D/2T) = 20.00

Q factorschord stress ratio $A = 0.10$

Qu(Ax) = 16.70 Qu(ip) = 16.70 Qu(op) = 8.53

Qf(Ax) = 0.99 Qf(ip) = 0.99 Qf(op) = 1.00

Q(beta) = 1.03 Q(gap) (K joints only) = 1.80

Connection resistance factors (Øj)

Ø axial = 0.95 Ø in plane = 0.95 Ø out of plane = 0.95

Joint capacities

Ø.Pu = 3020.9 kN

Ø.Mu ip = 1686.2 kN-m

Ø.Mu op = 866.0 kN-m

Code check results

Section E equations

E.3-1 (joint cap.) = 0.70

E.3-2 (axial load) = 0.17

E.3-3 (Moment in plane) = 0.06

E.3-3 (Moment out plane) = 0.12

E.3-4 (1 - axial + moment) = $1 - 0.97 + 0.13 = 0.16$ Joint O.K

13.0 API - Load resistance factor design (LRFD) hydrostatic check

The program carries out a hydrostatic design check to API –LRFD

Input data

Member, 1000x15 $F_y = 345\text{MPa}$
Area = 46417 $Z = 11.21\text{E6}$ (elastic mod) $S = 14.85\text{E6}$ (plastic mod)
 $r = 348.3$
 $L_x = L_y = 20000$
 $L/r = 57.4$
 $D/t = 66.7$

Design loads

$P = 1000\text{kN}$ $M_y = 200\text{kNm}$ $M_z = 300\text{kNm}$

Wave, $H_w = 8\text{m}$ $T = 12\text{ sec}$ $L = 1.56 \cdot T^2 = 225\text{m}$ $d = 70\text{m}$

$k = 2 \pi / L = 0.0279$

$k(d-z) = 0.559$

$k_d = 1.955$

$H_z = 50 + 8/2 \cdot (\cosh(1.395)/\cosh(1.953))$

$H_z = 50 + 4 \cdot (e^{0.559} + e^{-0.559}) / (e^{1.955} + e^{-1.995})$

$H_z = 51.29\text{m}$

$\gamma_h = 10.05 \cdot 51.29$

$\gamma_h = 515.5\text{ kPa}$

$P = 1.3 \cdot 10 \cdot 51.3 = 667\text{kPa}$

$f_h = 667\text{E6} / (2 \cdot 15) = 22.2$

Stresses

$f_a = 1000/A = 21.5\text{MPa}$

$f_{by} = 200 / Z = 17.8\text{MPa}$

$f_{bz} = 300 / Z = 26.2\text{MPa}$

$f_b(r) = 32.0$

Compression

$\lambda_x = \lambda_z = kl / \pi r (F_y/E)^{0.5} = 0.759 < \sqrt{2}$

$F_{xe} = 2 \cdot 0.3 \cdot 200000 \cdot 15 / 1000$

$F_{xe} = 1800$

$F_{xc} = (1.64 - 0.23 \cdot 66.7^{0.25}) \cdot 345$

$F_{xc} = 339$

$F_{cn} = (1 - 0.25 \cdot 0.759^2) \cdot 354$

$F_{cn} = 295$

Tension

$F_t \leq 0.9 \cdot 345 = 311\text{ MPa}$

Bending

$D/t = 66.7 = 23000/F_y$

$F_{bn} = (0.94 - 0.76 \cdot (345 \cdot 1000 / (200\text{E3} \cdot 15))) \cdot S/Z \cdot 345$

$F_{bn} = 382\text{MPa}$

Hydrostatic

$M = L/D \sqrt{2D/t}$ – no rings $L = 20\text{m}$ $M \gg 1.6D/t$

$Ch = 0.44 \cdot t/D$

$Ch = 6.6\text{E3}$

$F_{he} = 2 \cdot Ch \cdot E \cdot t/D$

$F_{he} = 39.6$

$F_{hc} = F_{he}$

Code check
(a) Compression

$$f_x = 21.5 + 32 + 0.5 * 22.2$$

$$f_x = 65 > 0.5 \phi_h F_{he} = 16$$

D.3.2-1

$$F_{ey} = F_{ez} = 345 / 0.759^2 = 599$$

$$= 21.5 / (0.85 * 295) + 1 / (0.95 * 382) \{ (0.85 * 17.6 / (1 - 21 / (0.85 * 599))^2 + (0.85 * 26.6 / (1 - 21 / (0.85 * 599))^2)^{0.5}$$

$$= 0.086 + 0.078$$

$$= 0.164$$

D.3.2-2

$$f_c = f_c + 0.5 f_h = 21.5 + 0 = 21.5$$

$$= 1 - \cos(90 * 32.5 / (0.85 * 339)) + 32 / (0.95 * 382)$$

$$= 1 - 0.984 + 0.088$$

$$= 0.11$$

D.3.4-1

$$= (65 - 0.5 * 0.8 * 39.6) / (0.85 * 1800 - 0.5 * 0.8 * 39.6) + (22.2 / (0.8 * 39.6))^2$$

$$= 0.032 + 0.49$$

$$= 0.52$$

if the axial load is applied as tension

D.3.3-1

$$A = (21.5 + 32 - 11) / (0.95 * 345) = 0.131$$

$$B = 22 / (0.8 * 39.6) = 0.69$$

$$\eta = 5 - 4 * 39.6 / 345 = 4.54$$

$$= 0.131 + 0.69^2 \eta + 2 * 0.3 * 0.131 * 0.69$$

$$= 0.017 + 0.034 + 0.054$$

$$= 0.106$$

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - LRFD Hydrostatic validation

CALC BY : GJS DATE : 04-Feb-1998

CHECKED :

Code check to API RP 2A-LRFD (1st Ed) : 1993, hydrostatic only. (ver 1.00)

Member properties (mm, mm², mm³, mm⁴)

Dia = 1000	tw = 15	ry = 348.3
Area = 46,417	Z = 11,261,343	S = 14,554,500
Ly = 20000	Lz = 20000	
Fy = 345.0 MPa		w = 364.37 kg/m

Applied loads

Still water depth = 70 m	Depth to member = 50 m
Wave height = 8 m	wave length = 225 m
Design head = 51.3 m	LRFD load factor (for D1) = 1.3
Axial = 1000 kN	My = 200 Mz = 300 kN-m

Member stresses (MPa)

fby = 17.8	fbz = 26.6	fb is resultant of fby & fbz
fa = 21.5	fb = 32.0	fh = 22.3 fx = 64.7

Critical stresses (MPa)

Fhe = 39.6	Fhc = 39.6	Fxe = 1800.0	Fxc = 339.1
Fcn = 291.1	Fbn = 380.2		

Resistance factors

Øc = 0.85	Øb = 0.95	Øh = 0.80
-----------	-----------	-----------

Ring stiffener properties (mm, mm⁴)

tubular is unstiffened

Code check results

Cmy = 0.85 Cmz = 0.85

(D.3.2-1)	0.09 + 0.08	= 0.17
(D.3.2-2)	1 - 0.98 + 0.09	= 0.10
(D.3.2-3)		= 0.11
(D.3.4-1)	0.03 + 0.50	= 0.53

Section O.K.

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : API - LRFD Hydrostatic validation

CALC BY : GJS DATE : 04-Feb-1998

CHECKED :

Code check to API RP 2A-LRFD (1st Ed) : 1993, hydrostatic only. (ver 1.00)

Member properties (mm, mm², mm³, mm⁴)

Dia = 1000	tw = 15	ry = 348.3
Area = 46,417	Z = 11,261,343	S = 14,554,500
Ly = 20000	Lz = 20000	
Fy = 345.0 MPa		w = 364.37 kg/m

Applied loads

Still water depth = 70 m	Depth to member = 50 m
Wave height = 8 m	wave length = 225 m
Design head = 51.3 m	LRFD load factor (for D1) = 1.3
Axial = -1000 kN	My = 200 Mz = 300 kN-m

Member stresses (MPa)

fby = 17.8	fbz = 26.6	fb is resultant of fby & fbz
fa = -21.5	fb = 32.0	fh = 22.3

Critical stresses (MPa)

Fhe = 39.6	Fhc = 39.6	Fxe = 1800.0	Fxc = 339.1
Fbn = 380.2			

Resistance factors

Øc = 0.85	Øb = 0.95	Øh = 0.80
-----------	-----------	-----------

Ring stiffener properties (mm, mm⁴)

tubular is unstiffened

Code check results

(D.3.3-1) tension

$$A^2 + B^{2n} + 2v|A|B = 0.02 + 0.04 + 0.05 = 0.11$$

Section O.K.

Kvaerner Oil & Gas

Plant/Area Ref:		Project No.		Document/Item Ref.	
Toolkit validation		C045			
Subject:				Sheet	
API- LRFD Hydrostatic				13.8 of	
Issue:	1	Date	2	Date	3
Made/Revised by:	GJS	02-Oct-1998			
Checked by:					
Approved - Process:					
Approved -					

Check ring stiffeners - External

Code check to API RP 2A-LRFD (1st Ed) : 1993, hydrostatic only. (ver 1.00)

Member properties (mm, mm², mm³, mm⁴)

Dia = 1000 tw = 15 ry = 348.3
 Area = 46,417 Z = 11,261,343 S = 14,554,500
 Ly = 0 Lz = 0
 Fy = 355.0 MPa w = 364.37 kg/m

Applied loads

Still water depth = 70 m Depth to member = 50 m
 Wave height = 8 m wave length = 225 m
 Design head = 51.3 m LRFD load factor (for D1) = 1.3
 Axial = 0 kN My = 0 Mz = 0 kN-m

Member stresses (MPa)

fby = 0.0 fbz = 0.0 fb is resultant of fby & fbz
 fa = 0.0 fb = 0.0 fh = 22.3 fx = 11.2

Critical stresses (MPa)

Fhe = 39.6 Fhc = 39.6 Fxe = 1800.0 Fxc = 348.9
 Fcn = 348.9 Fbn = 390.0

Resistance factors

Øc = 0.85 Øb = 0.95 Øh = 0.80

Ring stiffener properties (mm, mm⁴)

ring stiffeners are external at 20000 mm centers
 web depth = 100 web thickness = 15
 flange width = 100 flange thickness = 15
 tributary shell width = 134.7
 I of ring = 12.78E+06 I required = 87.90E+05
 I required/I of ring = 0.69

Code check results

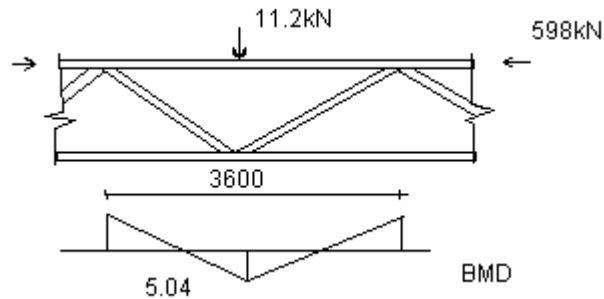
Cmy = 0.85 Cmz = 0.85

(D.3.2-1) 0.00 + 0.00 = 0.00
 (D.3.2-2) 1 - 1.00 + 0.00 = 0.00
 (D.3.2-3) = 0.04

Section O.K.

14.0 BS 5950:part 1:2000

The top chord of a lattice truss supports a purlin at midspan and is subject to factored loads of;
 $M=5.04\text{kNm}$ and axial load = 598kN



Check a $150 \times 150 \times 5$ RHS
 $F_y = 275\text{MPa}$ $e=1.0$
 Flange $b/t = 135/5 = 27$ (=web)
 Limit for class 1 = $28e$
 Flange is class 1

For web, $r_1 = F_c / (2 d t w p_{yw})$ $-1 < r_1 \leq 1$
 $r_1 = 598000 / (2 \times 135 \times 5 \times 275) = 1.6$
 $r_1 = 1$
 $b/t_{lim} = 64e / (1 + 0.6 \times r_1)$
 $b/t_{lim} = 40$
 Web is class 1

Shear
 Max shear $F_v = 11.2\text{kN} / 2 = 5.6\text{kN}$
 $P_v = 0.6 \times 275 \times A_D / (D+B)$
 $P_v = 238\text{kN}$
 $F_v / P_v = 5.6 / 275 = 0.024 \ll 1$

Flexure
 By inspection, we have low shear
 $M_{cx} = p_y \times S_x$
 $M_{cx} = 43.2\text{kNm}$
 Check elastic limit (4.2.5)
 $1.5 \times Z_x \times p_y$
 $= 55.5\text{kNm}$

$M_{cx} = 43.2\text{kNm}$

Compression
 $\lambda_x = K_x \cdot L / r_x$
 $\lambda_x = 0.85 \times 3600 / 59$
 $\lambda_x = 51.9$
 $\lambda_y = K_y \cdot L / r_y$
 $\lambda_y = 1.0 \times 1800 / 59$
 $\lambda_y = 30.5$

therefore x-x buckling governs
 From Table 24 $p_{cx} = 249\text{MPa}$

$$P_c = A_g \cdot p_{cx}$$

$$P_c = 719 \text{ kN}$$

Interaction ratios

(4.8.3.2) Yield

$$598000/2890 \cdot 275 + 5.04/43.2 + 0/43.2$$

$$= 0.81 + 0.12 + 0$$

$$= 0.93$$

(4.8.3.3) buckling

(4.8.3.3.1) simplified method

$$m_x = 0.8 \quad (4.8.3, \text{ table } 26)$$

$$m_{LT} = 0.44 \quad (\text{beta} = -1, \text{ table } 18)$$

$$= 598/719 + 0.8 \cdot 5.04/p_y \cdot Z_x + 0$$

$$= 0.83 + 0.109 + 0$$

$$= 0.94$$

LTB ($M_{ltb} = M_{cx}$)

$$= 598/719 + 0.44 \cdot 5.05/43.2 + 0$$

$$= 0.83 + 0.05$$

(4.8.3.3.3)

$$= 598/719 + 0.8 \cdot 5.04/43.2 \cdot (1 + 0.5 \cdot 598/719)$$

$$= 0.83 + 0.132$$

$$= 0.962$$



PROJECT : Validate Toolkit

Sheet of

SUBJECT : BS5950-1 2000

Job No :

Calc by : GJS

Date : 17-Oct-05

Checked :

Date :

Beam column example

Code check to BS5950-1:2000

(ver 1.0.0)

Design loads (limit state)

Axial load (Fc) = 598.00 kN

Moment x-x (Mx) = 5.04 kN-m

Shear load (Fv) = 5.80 kN

Moment y-y (My) = 0.00 kN-m

Section data

150x150x5 SHS

Grade = S 275

py = 275 MPa

w = 23 kg/m

D = 150

Bf = 150

Tf = 5

tw = 5

Area = 2,890 mm²J = 1.526729E+07 mm⁴

Ix = 10,090,000

Iy = 1.009E+07 mm⁴

Zx = 134,533

Zy = 134,533 mm³

Sx = 157,000

Sy = 157,000 mm³Iw = 3.514615E+07 mm⁶

Le = 3600

rx = 59.1 Lx = 3600

Lx/rx = 60.9

ry = 59.1 Ly = 1800

Ly/ry = 30.5

Web is unstiffened

Code check results

Shear interaction

Fv / (Pv,Vb) = 0.02

H.3.3.1. eqns 0.00, 0.00

4.8.3 Compression and moment

4.8.3.2(b) capacity

0.17 + 0.00 = 0.17

4.8.3.3 member buckling resistance

4.8.3.3.3 more exact CHS, RHS

major axis buckling

0.87 + 0.07 + 0.00 = 0.94

minor axis, (LTB check is required.)

0.78 + 0.12 + 0.00 = 0.89

interactive buckling.

0.56 + 0.00 = 0.56

Section O.K. use 150x150x5 SHS

15.0 Eurocode 3 Steel design – BS EN 1993-1-1: 2005

Beam-column

Section 254x254UC167 $F_y = 275\text{MPa}$
Area = $21.2\text{E}3\text{mm}^2$
 $W_{ely} = 20.69\text{E}5$ $W_{ply} = 24.2\text{E}5$
 $W_{elz} = 7.403\text{E}5$ $W_{plz} = 11.3\text{E}5$
 $i_y = 118.8$ $i_z = 68$
 $K_z L = 5000$ $K_y L = 5000$

Factored loads $N_{Ed} = 1000\text{kN}$ M_{yEd} (major axis) = 300kNm $M_{zEd} = 50\text{kNm}$ $V_{Ed} = 60\text{kN}$
 $C_1 = 1.13$ $C_2 = 0.46$ KL torsion = 5000
 $C_{mLT} = 1.0$ $C_{my} = 0.9$ $C_{mz} = 0.9$

Section compactness

Table 5.2 $e = \sqrt{235/F_y} = 0.92$

Web

$$d = 289 - 2 \cdot (31.7 + 12.7) = 200.2 \quad d/t = 200.2/19.2 = 10.4$$

$$\alpha = 0.5 \cdot (1 + \gamma_{m0} \sigma_w / F_y)$$

$$\sigma_w = 1000\text{E}3 / (19.2 \cdot 200.2)$$

$$\sigma_w = 260\text{MPa}$$

$$\alpha = 0.5 \cdot (1 + 1.05 \cdot 260 / 275)$$

$$\alpha = 0.996$$

Class 1 for $\alpha > 0.5$

$$d/tw_{lim} = 396 \cdot e / (13 \alpha - 1) = 30.5 > d/t \quad \text{web is class 1}$$

Flange

$$c / t_f = 264.5/2 / 31.7 = 4.17 < 9e = 8.2 \quad \text{flange is class 1}$$

Shear (6.2.6)

$$V_{pl,Rd} = A_v (F_y / \sqrt{3}) / \gamma_{m0}$$

$$V_{pl,Rd} = 289 \cdot 19.1 \cdot 275 / \sqrt{3} / 1.00$$

$$V_{pl,Rd} = 876\text{kN}$$

$$60/876 = 0.69$$

$$V_{Ed} = 60\text{kN} < 0.5 V_{pl,Rd} \quad \text{Low shear (6.2.8(2))}$$

Flexure

Get reduced moment capacity under axial load (6.2.9)

$$N_{pl,Rd} = 21200 \cdot 275 / 1.00 = 5830\text{kN}$$

$$0.5 \cdot h_w t_w f_y / \gamma_{m0}$$

$$= 0.5 \cdot 200.2 \cdot 19.1 \cdot 275 / 1.00$$

$$= 525.8 > N_{Ed} \quad \text{Must use reduced Moment capacity}$$

$$n = N_{Ed} / N_{pl,Rd}$$

$$n = 1000 / 5830$$

$$n = 0.17$$

$$a = (A - 2 b t_f) / A = (21200 - 2 \cdot 264.5 \cdot 31.7) / 21200$$

$$a = 0.2$$

$$M_{pl,y,Rd} = 275 \cdot 24.2\text{E}5 / 1.00$$

$$M_{pl,y,Rd} = 664\text{kNm}$$

$$M_{Ny,Rd} = 664 (1 - 0.17) / (1 - 0.5 \cdot 0.2)$$

$$M_{Ny,Rd} = 612$$

$$n < a$$

$$M_{Nz,Rd} = W_{pl,z} \cdot f_y / 1.00$$

$$M_{Nz,Rd} = 1.13 \cdot 275 / 1.00$$

$$M_{Nz,Rd} = 311$$

Biaxial interaction (eq 6.41)

For I and H, $a = 2$ $b = 5n, \geq 1$, Use $b = 1$

$$(300/612)^2 + (50/311)^1$$

$$= 0.24 + 0.16$$

$$= 0.40$$

Axial buckling (6.3)

$$\lambda_y = L_y / r_y = 5000 / 119 = 42$$

$$\lambda_z = L_z / r_z = 5000 / 67.9 = 73.6$$

$$\lambda_1 = 86.4$$

$$\lambda_{\text{bar}} = \lambda_{y,z} / \lambda_1$$

$$\lambda_{\text{bar},y} = 0.486$$

use buckling curve b, $a = 0.34$

$$\Phi = 0.5 * (1 + 0.34 * (0.485 - 0.2) + 0.485^2) = 0.66$$

$$X_y = 1 / (0.66 + (0.66^2 - 0.485^2)^{0.5}) = 0.89$$

$$N_{b,y,Rd} = 0.9 * 21.2 * 275 / 1.00$$

$$N_{b,y,Rd} = 5246 \text{ kN}$$

$$\lambda_{\text{bar},z} = 0.847$$

use buckling curve c, $a = 0.49$

$$\Phi = 0.5 * (1 + 0.49 * (0.847 - 0.2) + 0.847^2) = 1.01$$

$$X_z = 1 / (1.03 + (1.03^2 - 0.86^2)^{0.5}) = 0.63$$

$$N_{b,z,Rd} = 0.63 * 21.2 * 275 / 1.00$$

$$N_{b,z,Rd} = 3686 \text{ kN (MIN)}$$

6.3.2 Lateral torsional buckling of beams

$$\beta_{wT} = 1.0$$

$$W_{pl} * f_y = 2.42 * 275 = 665.5 \text{ kNm}$$

$$C_1 = 1.13 \quad C_2 = 0.46 \quad \text{KL torsion} = 5000$$

Using ENV 1993-1-1:1992 Appendix F, eqn (F.4) or from

<http://eurocodes.jrc.ec.europa.eu/doc/WS2008/SN003a-EN-EU.pdf>

$$M_{cr} = C_1 \frac{\pi^2 EI_z}{(kL)^2} \left\{ \sqrt{\left(\frac{k}{k_w} \right)^2 \frac{I_w}{I_z} + \frac{(kL)^2 GI_t}{\pi^2 EI_z} + (C_2 z_{\xi})^2} - C_2 z_{\xi} \right\}$$

$$M_{cr} = 2035$$

$$\lambda_{\text{bar},LT} = \sqrt{665.5 / 2035}$$

$$\lambda_{\text{bar},LT} = 0.571$$

$$\phi_{LT,0} = 0.4$$

$$\beta = 0.75$$

$$\phi_{LT} = 0.5 * (1 + 0.21 * (0.571 - 0.4) + 0.75 * 0.571^2) = 0.571$$

$$X_{LT} = 1 / (0.571 + (0.571^2 - 0.75 * 0.508^2)^{0.5}) = 0.955$$

$$M_{b,Rd} = 0.955 * 665.5 / 1.00$$

$$M_{b,Rd} = 635.56 \text{ kNm}$$

But $M_{yEd} / M_{cr} \leq \phi_{LT,0}^2$ so no LTB check required (6.3.2.2(4))

6.3.3 Bending and axial compression

Use Annex B, table B.1

$$k_{yy} = 0.95$$

$$k_{yz} = 0.7$$

$$k_{zy} = 0.97$$

$$k_{zz} = 1.17$$

$$(6.61)$$

$$= 0.19 + 0.45 + 0.11$$

$$= 0.75$$

$$(6.62)$$

$$= 0.27 + 0.46 + 0.19$$

$$= 0.92$$

PROJECT : BS EN 1993-1-1:2005

SUBJECT : Validation

Calc by : GJS

Date : 06-Jul-12

Checked :

Job No :

Revision :

Date :

Test beam-column - Compression

code check to BS EN 1993-1-1:2005

Design loads (limit state)

Axial load (N.Ed) = 1,000.00 kN

Shear load (Vy.Ed) = 60.00 kN

Moment y-y (My.Ed) = 300.00 kN-m

Moment z-z (Mz.Ed) = 50.00 kN-m

Section data

254x254UC167

Grade = S 275

Fy = 275 MPa

w = 166 kg/m

D = 289

Bf = 264.5

Tf = 31.7

tw = 19.2

Area = 21,200 mm²J = 6250000 mm⁴

Iy = 299,000,000

Iz = 9.79E+07 mm⁴

Wel.y = 2,069,204

Wel.z = 740,265 mm³

Wpl.y = 2,420,000

Wpl.z = 1,130,000 mm³Iw = 1.62E+12 mm⁶

Lb = 5000

iy = 118.8

Ly-y = 5000

Ly/iy = 42.1

iz = 68.0

Lz-z = 5000

Lz/iz = 73.6

Web unstiffened

Section Design Resistances (kN, kNm)

Nt.Rd = 5830.00

Nby.Rd = 5193.29

Nbz.Rd = 3686.28

Mply.Rd = 665.50

Mplz.Rd = 310.75

Mby.Rd = 635.55

Mcy.Rd = 665.50

Mcz.Rd = 310.75

V.Rd = 927.94

Code check results

NAD factors: GammaM0 = 1.00

GammaM1 = 1.00

Neta = 1.00

6.2.6 Shear

V.Ed / Vc.Rd = 0.06

6.2.1 General

(6.2) conservative approximation

0.17 + 0.45 + 0.16 = 0.78

6.2.9 Bending and axial force.

(6.41)

0.24 + 0.16 = 0.40

6.3.3 Bending and axial

CmLT = 1.00

Cmy = 0.90

Cmz = 0.90

(6.61)

0.19 + 0.45 + 0.11 = 0.75

(6.62)

0.27 + 0.46 + 0.19 = 0.92

Section O.K. use 254x254UC167

16.0 Standard section properties

This calculates the properties of standard shapes;

- Singly symmetric I

- Channel (C) section

- Circular (pipe) section

- Rectangular hollow section (RHS)

Singly symmetric I shape

Top flange = 200 x 20

Web = 950x20

Bottom flange = 300 x 30

$$\text{Area} = 200 * 20 + 950 * 20 + 300 * 30$$

$$\text{Area} = 32000$$

Elastic neutral axis (x-x)

$$X = [300*30^3/2 + 20*950*(950/2 + 30) + 200*20*(20/2 + 950 + 30)] / 32000$$

$$X = 427.8$$

I_{x-x}

$$\begin{aligned} I_{xx} = & 300*30^3/12 + 300*30*(427.8 - 30/2)^2 \\ & + 20*950^3/12 + 20*950*(427.8-950/2-30)^2 \\ & + 200*20^3/12 + 200*20*(427.8-990)^2 \end{aligned}$$

$$I_{xx} = 1.534E9 + 1.542E9 + 1.264E9$$

$$I_{xx} = 434E9$$

I_{y-y}

$$I_{yy} = 20*200^3/12 + 950*20^3/12 + 30*300^3/12$$

$$I_{yy} = 81.467E6$$

Elastic modulus

$$Z_{xx}(\text{top}) = I_{xx}/(1000-427.5) = 7.584E6$$

$$Z_{xx}(\text{bottom}) = I_{xx}/(427.8) = 10.14E6$$

$$Z_{yy}(\text{top}) = I_{yy}/(200/2) = 814.7E3$$

$$Z_{yy}(\text{bottom}) = I_{yy}/(300/2) = 543.1E3$$

Plastic modulus

$$\text{Areas flange(top)} = 4000$$

$$\text{Web} = 19000$$

$$\text{Flange(bottom)} = 9000$$

$$A1 = 200*20 + (950-x)*20$$

$$A1 = 23000 - 20x$$

$$A2 = 300*30 + 20x$$

$$\text{For } A1 = A2, x = 350$$

$$S_{xx} = 200*20*(990-380)$$

$$+ 20*600^2/2$$

$$+ 300*30*(380-15)$$

$$S_{xx} = 10.55E6$$

$$S_{yy} = 20*200^2/4 + 950*20^2/4 + 30*300^2/4$$

$$S_{yy} = 0.970E6$$

Torsion

$$J = \sum(bt^3)/3$$

$$J = 1/3*(200*20^3 + 950*20^3 + 300*30^3)$$

$$J = 5.767E6$$

Warping

Using BS5950 1990

$$H = h_s^2 t_1 t_2 b_1^3 b_2^3 / (12 (t_1 b_1^3 + t_2 b_2^3))$$

$$h_s = 1000 - 20/2 - 3/2 = 975$$

$$b_1 = 200 \quad t_1 = 20$$

$$b_2 = 300 \quad t_2 = 30$$

$$H = 975^2 \cdot 20 \cdot 30 \cdot 200^3 \cdot 300^3 / (12 \cdot (20 \cdot 200^3 + 30 \cdot 300^3))$$
$$H = 1.058E13$$

Radii

$$r = \sqrt{I/A}$$

$$r_x = \sqrt{I_{xx}/A} = 368$$

$$r_y = \sqrt{I_{yy}/A} = 50.5$$

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Standard sections

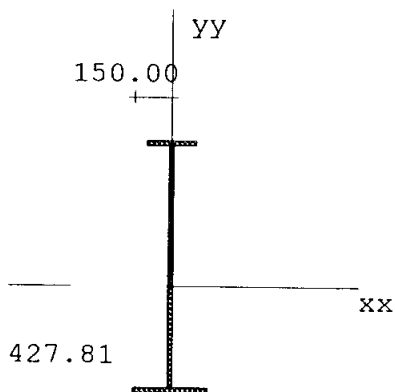
CALC BY : GJS DATE : 24-Jan-1998

CHECKED :

Singly symmetric I shape

Section Data

Depth		1000.000
top flange	B	200.000
top flange	T	20.000
web	tw	20.000
bottom flange	B	300.000
bottom flange	T	30.000
Area		32,000.0
I xx		4,340,913,541.7
I yy		81,466,666.7
Z xx top		7,586,522.8
Z xx bottom		10,146,766.5
Z yy left		543,111.1
Z yy right		543,111.1
S xx		10,550,000.0
S yy		970,000.0
r xx		368.3
r yy		50.5
x bar		427.813
y bar		150.000
I w		1.058428E+13
J tor.		5,766,666.8



Channel shape

Top flange = 150 x 15
Web = 270 x 10
Bottom flange = 150 x 15

Area = 150 * 15 + 270 * 10 + 150 * 150
Area = 72000

Elastic neutral axis (x-x)

X = 150

y-y

y = $[300 \cdot 10^2/2 + 2 \cdot 15 \cdot 140 \cdot (140/2 + 10)] / 7200$

X = 48.75

I_{x-x}

I_{xx} = $150 \cdot 300^3/12 - 140 \cdot 270^3/12$

I_{xx} = 107.865E6

I_{y-y}

I_{yy} = $300 \cdot 10^3/12 + 300 \cdot 10 \cdot (48.75 - 10/2)^2$
 $+ 2 \cdot 15 \cdot 140^3/12 + 2 \cdot 15 \cdot 140 \cdot (48.75 - 140/2 - 10)^2$

I_{yy} = 5.757E6 + 10.96E6

I_{yy} = 16.73E6

Elastic modulus

Z_{xx} = I_{xx}/(150) = 719.1E3

Z_{yy(left)} = I_{yy}/(48.75) = 343.2E3

Z_{yy(right)} = I_{yy}/(150-48.75) = 165.2E3

Plastic modulus

Areas flange(top) = 4000

Web = 19000

Flange(bottom) = 9000

S_{xx} = $10 \cdot 300^2/2 + 28140 \cdot 15 \cdot (300 - 15)/2$

S_{xx} = 823.5E3

S_{y-y} Find P_{na}

Area of full depth web = 3000mm²

Area of extending flanges = $2 \cdot 140 \cdot 15 = 4200 >$ web area

P_{na} is in flanges

$300 \cdot 10 + 2 \cdot 15x = 2 \cdot (140 - x) \cdot 15$

x = 20

S_{yy} = $300 \cdot 10^2/2 + 2 \cdot 15 \cdot 20^2/2 + 2 \cdot 15 \cdot 120^2/2$

S_{yy} = 75E3 + 6E3 + 216E3

S_{yy} = 297E3

Torsion

J = $\sum(bt^3)/3$

J = $1/3 \cdot (270 \cdot 10^3 + 2 \cdot 150 \cdot 15^3)$

J = 427.5E3

Warping

Using BS5950 1990

H = $hs^2 t_1 t_2 b_1^3 b_2^3 / (12(t_1 b_1^3 + t_2 b_2^3))$

hs = 300-15 = 285
b1 = 150 t1 = 15
b2 = 150 t2 = 15
 $H = 285^2 \cdot 15 \cdot 15 \cdot 150^3 \cdot 150^3 / (12 \cdot (2 \cdot 15 \cdot 150^3))$
H = 1.71E4

Radii

$r = \sqrt{I/A}$
rx = $\sqrt{I_{xx}/A}$ = 122
ry = $\sqrt{I_{yy}/A}$ = 48

G. Simms

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Standard sections

CALC BY : GJS DATE : 24-Jan-1998

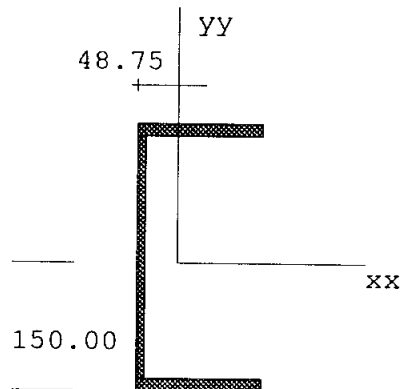
CHECKED :

Channel section

Section Data

Depth		300.000
top flange	B	150.000
top flange	T	15.000
web	tw	10.000
bottom flange	B	150.000
bottom flange	T	15.000

Area		7,200.0
I xx		107,865,000.0
I yy		16,728,750.0
Z xx top		719,100.0
Z xx bottom		719,100.0
Z yy left		343,153.8
Z yy right		165,222.2
S xx		823,500.0
S yy		297,000.0
r xx		122.4
r yy		48.2
x bar		150.000
y bar		48.750
I w		171,333,984,375.0
J tor.		427,500.0



Tube (circular) shape

$$D = 1000$$

$$T = 20$$

$$\text{Area} = \pi/4 (1000^2 - (1000 - 2 \cdot 20)^2)$$

$$\text{Area} = 61575$$

$$I_x - x = I_y - y$$

$$I = \pi/64 (1000^4 - (1000 - 2 \cdot 20)^4)$$

$$I = 7.395\text{E}9$$

Elastic modulus

$$Z = I/(D/2)$$

$$Z = 14.79\text{E}6$$

Plastic modulus

$$S = \pi/6 (1000^3 - (1000 - 2 \cdot 20)^3)$$

$$S = 60.35\text{E}6$$

Radius of gyration

$$r = \sqrt{I/A}$$

$$r = 346.6$$

G. Simms

16/10

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Standard sections

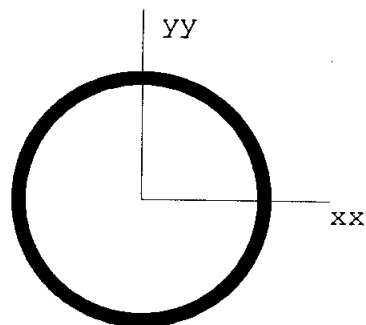
CALC BY : GJS DATE : 24-Jan-1998

CHECKED :

Tubular section

Section Data

Diameter	D	1000.000
thickness	tw	20.000
Area		61,575.2
I xx		7,395,183,552.1
I yy		7,395,183,552.1
Z xx top		14,790,367.1
Z xx bottom		14,790,367.1
Z yy left		14,790,367.1
Z yy right		14,790,367.1
S xx		19,210,666.7
S yy		19,210,666.7
r xx		346.6
r yy		346.6
x bar		500.000
y bar		500.000
I w	0	
J tor.		14,790,367,104.2



RHS (HSS) shape

D = 1000 B=300 T = 20 tw = 15
T = 20

Area = $1000 \times 300 - 270 \times 960$
Area = 40800

Ix-x
 $I_{xx} = 300 \times 1000^3 / 12 - 270 \times 960^3 / 12$
 $I_{xx} = 5.093E9$

Iy-y
 $I_{yy} = 300^3 \times 1000 / 12 - 270^3 \times 960 / 12$
 $I_{yy} = 0.675E9$

Elastic modulus
 $Z_{xx} = I_{xx} / (500) = 10.187E6$
 $Z_{yy} = I_{yy} / (150) = 4.5E6$

Plastic modulus
 $S_{xx} = 300 \times 1000^2 / 4 - 270 \times 960^2 / 4 = 12.792E6$
 $S_{yy} = 300^2 \times 1000 / 4 - 270^2 \times 960 / 4 = 5.02E6$

Radius of gyration
 $r_x = \sqrt{I_x / A}$
 $r_x = 353$
 $r_y = \sqrt{I_y / A}$
 $r_y = 128$

G. Simms

16.12

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Standard sections

CALC BY : GJS DATE : 24-Jan-1998

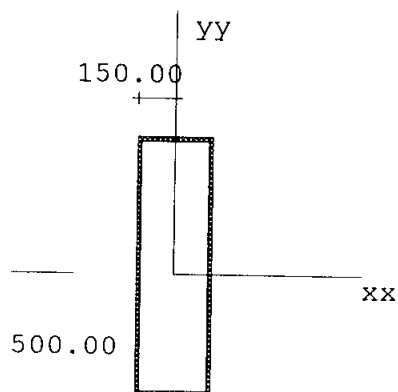
CHECKED :

Rectangular hollow section

Section Data

Depth		1000.000
top flange	B	300.000
top flange	T	20.000
web	tw	15.000
bottom flange	B	300.000
bottom flange	T	20.000

Area		40,800.0
I xx		5,093,440,000.0
I yy		675,360,000.0
Z xx top		10,186,880.0
Z xx bottom		10,186,880.0
Z yy left		4,502,400.0
Z yy right		4,502,400.0
S xx		12,792,000.0
S yy		5,004,000.0
r xx		353.3
r yy		128.7
x bar		500.000
y bar		150.000
I w		3.214937E+13
J tor.		1,974,898,481.0



17.0 Complex section properties

This calculates the properties of sections made up of component shapes.

To validate this, compare the composite (complex) section with standard sections or fabricated sections already checked in section 16.0

Note that rolled sections have radii and will therefore have slightly higher values of section properties.

G. Simms

17.2

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Complex sections

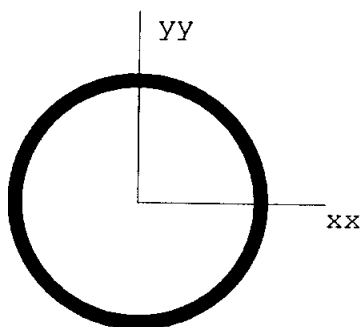
CALC BY : GJS DATE : 24-Jan-1998

CHECKED :

Tubular section - using standard section

Section Data

Diameter	D	1000.000
thickness	tw	20.000
Area		61,575.2
I xx		7,395,183,552.1
I yy		7,395,183,552.1
Z xx top		14,790,367.1
Z xx bottom		14,790,367.1
Z yy left		14,790,367.1
Z yy right		14,790,367.1
S xx		19,210,666.7
S yy		19,210,666.7
r xx		346.6
r yy		346.6
x bar		500.000
y bar		500.000
I w		0
J tor.		14,790,367,104.2



PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Complex sections

CALC BY : GJS DATE : 24-Jan-1998

CHECKED :

Tubular section using an arc of 360deg

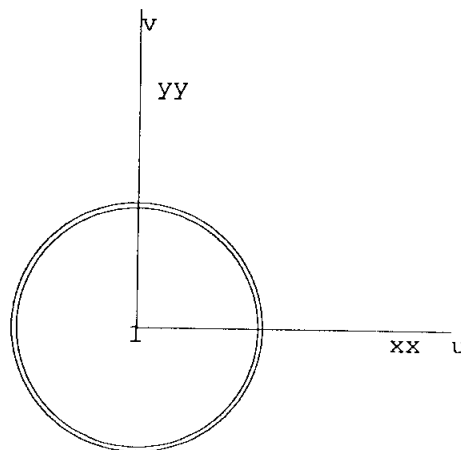
Element Data

x_o, y_o = distance from user origin to element centroid
 x_c, y_c = distance from section centroid to element centroid
 L_r, L_s are element dimensions in element r, s directions.
 The element r axis is at angle θ from the XX axis.

i	type	L_r/Dia	L_s/tw	θ	$x_o(i)$	$y_o(i)$	$x_c(i)$	$y_c(i)$	$\beta(i)$
1	A	1000	20	0.00	0	0	0.00	0.00	360.00

Section Data

Area 61,575.2
 I_{xx} 7,395,183,661.3
 I_{yy} 7,395,183,442.8
 I_{xy} 0
 Z_{xx} top 14,790,367.1
 Z_{xx} bottom 14,790,367.5
 Z_{yy} left 15,551,511.9
 Z_{yy} right 15,551,512.1
 r_{xx} 346.6
 r_{yy} 346.6
 I_u 7,395,183,661.3
 I_v 7,395,183,442.8
 r_u 346.6
 r_v 346.6
 x_o to centroid 0.000
 y_o to centroid 0.000
 θ from xx, yy to u, v axes. 0.000
 u, v are section principal axes.



G. Simms

17.4

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Complex sections

CALC BY : GJS DATE : 24-Jan-1998

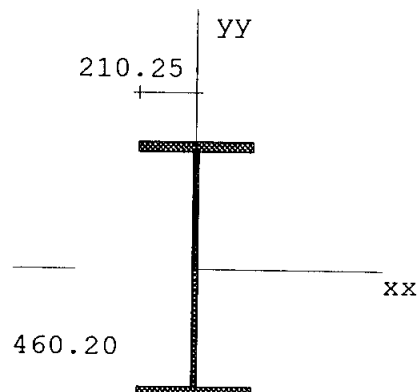
CHECKED :

Section table properties for 914x419UB 388

Section Data

Depth		920.400
top flange	B	420.500
top flange	T	36.600
web	tw	21.500
bottom flange	B	420.500
bottom flange	T	36.600

Area		49,500.0
I xx		7,190,000,000.0
I yy		454,000,000.0
Z xx top		15,623,641.9
Z xx bottom		15,623,641.9
Z yy left		2,159,334.1
Z yy right		2,159,334.1
S xx		17,700,000.0
S yy		3,340,000.0
r xx		381.1
r yy		95.8
x bar		460.200
y bar		210.250
I w		8.87E+13
J tor.		17,400,000.0



G. Simms

17.5

PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Complex sections

CALC BY : GJS DATE : 24-Jan-1998

CHECKED :

Computation of properties for 914x419UB 388

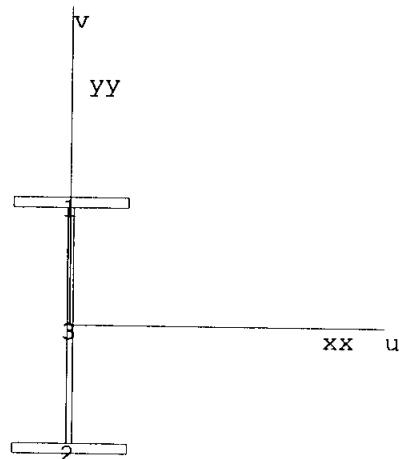
Element Data

x_o, y_o = distance from user origin to element centroid
 x_c, y_c = distance from section centroid to element centroid
 L_r, L_s are element dimensions in element r, s directions.
 The element r axis is at angle θ from the XX axis.

i	type	L_r/Dia	L_s/tw	θ	$x_o(i)$	$y_o(i)$	$x_c(i)$	$y_c(i)$	$\beta(i)$
1	R	420.5	36.6	0.00	0	441.9	0.00	441.90	0.00
2	R	420.5	36.6	0.00	0	-441.9	0.00	-441.90	0.00
3	R	21.5	847.2	0.00	0	0	0.00	0.00	0.00

Section Data

Area 48,995.4
 I_{xx} 7,103,605,925.9
 I_{yy} 454,254,431.5
 I_{xy} 0
 Z_{xx} top 15,435,910.3
 Z_{xx} bottom 15,435,910.3
 Z_{yy} left 2,160,544.3
 Z_{yy} right 2,160,544.3
 r_{xx} 380.8
 r_{yy} 96.3
 I_u 7,103,605,925.9
 I_v 454,254,431.5
 r_u 380.8
 r_v 96.3
 x_o to centroid 0.000
 y_o to centroid 0.000
 θ from xx, yy 0.000
 to u, v axes.
 u, v are section principal axes.



PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Complex sections

CALC BY : GJS DATE : 26-Jan-1998

CHECKED :

Model a 200x150x15 unequal angle

Element Data

(ver : 1.0.0)

xo, yo = distance from user origin to element centroid

xc, yc = distance from section centroid to element centroid

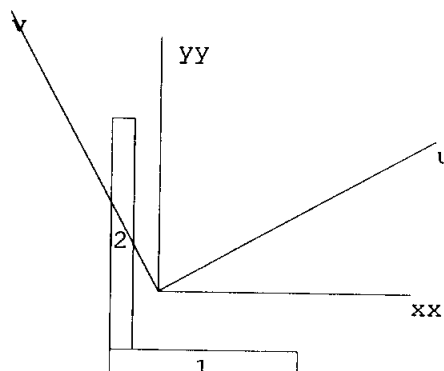
Lr, Ls are element dimensions in element r, s directions.

The element r axis is at angle theta from the XX axis.

i	type	Lr/Dia	Ls/tw	theta	xo(i)	yo(i)	xc(i)	yc(i)	beta(i)
1	R	150	18	0.00	0	0	36.18	-54.82	0.00
2	R	182	18	90.00	-66	100	-29.82	45.18	0.00

Section Data

Area 5,976.0
 I xx 23,916,956.8
 I yy 11,598,356.8
 I xy -9768795
 Z xx top 175,626.6
 Z xx bottom 374,760.7
 Z yy left 154,644.8
 Z yy right 104,319.9
 r xx 63.3
 r yy 44.1
 I u 29,306,091.3
 I v 6,209,222.3
 r u 70.0
 r v 32.2
 xo to centroid -36.181
 yo to centroid 54.819
 theta from xx, yy 28.884
 to u, v axes.
 u, v are section principal axes.



UNEQUAL ANGLES

DIMENSIONS

DESIGNATION SIZE			Mass per metre kg/m	Root radius r mm	Toe radius r ₂ mm	Area of Section cm ²	Distance to C of G		Second moment of area				Radius of gyration				Elastic modulus		Tensile Strength N/mm ²
A mm	B mm	Thick- ness t mm					Cx cm	Cy cm	x-x cm ²	y-y cm ²	u-u cm ⁴	v-v cm ⁴	x-x cm	y-y cm	u-u cm	v-v cm	x-x cm ²	y-y cm ²	
200 x 150	18	47.2	15.0	4.8	60.1	3.86	6.34	3.86	2390	1160	2920	623	6.30	4.38	6.97	3.22	175	104	0.549
200 x 150	15	39.7	15.0	4.8	50.6	6.22	3.75	2040	989	2500	531	6.34	4.42	7.02	3.24	148	87.8	0.551	
200 x 150	12	32.1	15.0	4.8	40.9	6.10	3.63	1670	812	2040	435	6.38	4.45	7.07	3.26	120	71.4	0.553	
200 x 100	15	33.9	15.0	4.8	43.1	7.17	2.23	1770	303	1880	197	6.41	2.65	6.60	2.13	138	39.0	0.260	
200 x 100	12	27.4	15.0	4.8	34.9	7.04	2.11	1450	252	1540	162	6.45	2.68	6.65	2.15	112	31.9	0.263	
200 x 100	10	23.1	15.0	4.8	29.4	6.95	2.03	1230	215	1310	138	6.48	2.70	6.68	2.17	94.5	26.9	0.265	
150 x 90	15	26.7	12.0	4.8	34.0	5.21	2.24	764	207	844	127	4.74	2.47	4.99	1.93	78.0	30.6	0.354	
150 x 90	12	21.6	12.0	4.8	27.6	5.09	2.12	630	172	698	104	4.78	2.50	5.03	1.95	63.6	25.0	0.359	
150 x 90	10	18.2	12.0	4.8	23.2	5.00	2.04	536	147	595	89.1	4.81	2.52	5.06	1.96	53.6	21.2	0.361	
150 x 75	15	24.9	11.0	4.8	31.7	5.53	1.81	715	120	756	79.2	4.75	1.95	4.89	1.58	75.5	21.1	0.254	
150 x 75	12	20.2	11.0	4.8	25.7	5.41	1.70	591	100	626	65.2	4.79	1.98	4.93	1.59	61.6	17.3	0.259	
150 x 75	10	17.0	11.0	4.8	21.7	5.32	1.62	503	86.3	534	55.7	4.82	2.00	4.96	1.60	52.0	14.7	0.262	
125 x 75	12	17.8	11.0	4.8	22.7	4.31	1.84	355	96.0	392	58.8	3.95	2.06	4.16	1.61	43.4	17.0	0.354	
125 x 75	10	15.0	11.0	4.8	19.2	4.23	1.76	303	82.5	336	50.2	3.98	2.08	4.19	1.62	36.7	14.4	0.358	
125 x 75	8	12.2	11.0	4.8	15.5	4.14	1.68	249	68.1	275	41.2	4.00	2.10	4.21	1.63	29.7	11.7	0.360	
100 x 75	12	15.4	10.0	4.8	19.7	3.27	2.03	189	90.3	230	49.5	3.10	2.14	3.42	1.59	28.1	16.5	0.540	
100 x 75	10	13.0	10.0	4.8	16.6	3.19	1.95	162	77.7	198	42.2	3.12	2.16	3.45	1.59	23.8	14.0	0.544	
100 x 75	8	10.6	10.0	4.8	13.5	3.10	1.87	133	64.2	163	34.7	3.14	2.18	3.48	1.61	19.3	11.4	0.547	
100 x 65	10	12.3	10.0	4.8	15.6	3.36	1.63	154	51.1	175	30.2	3.14	1.81	3.35	1.39	23.2	10.5	0.410	
100 x 65	8	9.95	10.0	4.8	12.7	3.28	1.56	127	42.3	144	24.9	3.17	1.83	3.38	1.40	18.9	8.56	0.414	
100 x 65	7	8.77	10.0	4.8	11.2	3.23	1.51	113	37.7	128	22.1	3.18	1.84	3.39	1.41	16.6	7.56	0.415	
80 x 60	8	8.32	8.0	4.8	10.6	2.55	1.56	65.8	31.5	80.2	17.1	2.49	1.72	2.75	1.27	12.1	7.09	0.544	
80 x 60	7	7.34	8.0	4.8	9.35	2.50	1.52	58.5	28.1	71.4	15.2	2.50	1.73	2.76	1.27	10.6	6.26	0.545	
80 x 60	6	6.34	8.0	4.8	8.08	2.46	1.48	50.9	24.5	62.2	13.2	2.51	1.74	2.77	1.28	9.19	5.41	0.546	
75 x 50	8	7.41	7.0	2.4	9.44	2.53	1.29	52.4	18.6	60.1	10.9	2.36	1.40	2.52	1.07	10.5	5.00	0.430	
75 x 50	6	5.67	7.0	2.4	7.22	2.44	1.21	40.9	14.6	47.1	8.48	2.38	1.42	2.55	1.08	8.10	3.87	0.436	
65 x 50	8	6.76	6.0	2.4	8.61	2.12	1.37	34.9	17.8	43.1	9.62	2.01	1.44	2.24	1.06	7.97	4.92	0.569	
65 x 50	6	5.18	6.0	2.4	6.59	2.04	1.30	27.4	14.1	34.0	7.49	2.04	1.46	2.27	1.07	6.14	3.80	0.575	
65 x 50	5	4.36	6.0	2.4	5.55	2.00	1.26	23.3	12.0	29.0	6.38	2.05	1.47	2.28	1.07	5.18	3.21	0.577	
60 x 30	6	4.00	6.0	2.4	5.09	2.20	0.724	18.3	3.05	19.3	2.01	1.90	0.774	1.95	0.629	4.82	1.34	0.252	
60 x 30	5	3.38	6.0	2.4	4.30	2.16	0.684	15.7	2.64	16.6	1.72	1.91	0.783	1.96	0.632	4.08	1.14	0.256	
40 x 25	4	1.92	4.0	2.4	2.45	1.36	0.621	3.86	1.15	4.32	0.692	1.26	0.685	1.33	0.532	1.46	0.612	0.380	

FOR EXPLANATION OF TABLES SEE NOTES 2 AND 3

18.0 Convert Units

The program itself is not reported here, rather, standard conversion factors are provided to enable users to check conversions where desired.

Conversion Factors

$$\begin{aligned}
 1 \text{ US BARREL} &= 42 \text{ US GALL.} \\
 &= 34.97 \text{ IMP. GALL.} \\
 &= 159 \text{ LITRES} \\
 &= 0.159 \text{ m}^3
 \end{aligned}$$

$$1000 \text{ kJ} = (4516/23.4) \cdot 2.477 \cdot 100 = 6.8951$$

To convert	Into	Multiply by	To convert	Into	Multiply by
A			B		
acres	sq feet	43,560.0	barrels (oil)	gallons (oil) (us.)	42.0
acres	sq meters	4,047.	bars	atmospheres	0.9869
acre-feet	sq miles	1.562×10^{-3}	bars	dynes/sq cm	10^4
	sq yards	4,840.	Btu	kgs/sq meter	1.020×10^4
amperes/sq cm	cu feet	43,560.0		pounds/sq ft	2,089.
	gallons	3.259×10^5		pounds/sq in.	14.50
amperes/sq in.	amps/sq in.	6.452		ergs	1.0550×10^{10}
amperes/sq in.	amps/sq meter	10^4		foot-lbs	778.3
amperes/sq meter	amps/sq cm	0.1550		gram-calories	252.0
	amps/sq meter	1,550.0		horsepower-hrs	3.931×10^{-4}
ampere hours	amps/sq cm	10^{-4}		joules	1,054.8
	amps/sq in.	6.452×10^{-4}		kilogram-calories	0.2520
ampere turns	coulombs	3,600.0		kilogram-meters	107.5
ampere-turns/cm	faradays	0.03731		kilowatt-hrs	2.928×10^{-4}
	gilberts	1.257		foot-pounds/sec	0.2162
ampere turns/in.	amp-turns/in.	2.540		gram-cal/sec	0.0700
	amp-turns/meter	100.0		horsepower	3.929×10^{-4}
ampere turns/meter	gilberts/cm	1.257		watts	0.2931
	amp/turns/cm	0.3937		foot-lbs/sec	12.96
	amp-turns/meter	39.37		horsepower	0.02356
	gilberts/cm	0.4950		kilowatts	0.01757
	amp-turns/cm	0.01		watts	17.57
	amp-turns/in.	0.0254		watts/sq in.	0.1221
	gilberts/cm	0.01257		cu ft	1.2445
ares	acres	0.02471		cu in.	2,150.4
atmospheres	sq meters	100.0		cu meters	0.03524
	cms of mercury	76.0		liters	35.24
	ft of water	33.90		pecks	4.0
	(at 4°C)			pints (dry)	64.0
	in. of mercury	29.92		quarts (dry)	32.0
	(at 0°C)				
	kgs/sq cm	1.0333			
	kgs/sq meter	10,332.			
	pounds/sq in.	14.70			
	tons/sq ft	1.058			
			C		
			centares (centiares)	sq meters	1.0
			Centigrade	Fahrenheit	$(C^\circ \times 9/5) + 32$

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Into	Multiply by
centigrams	grams	0.01	cubic feet/min	cu cms/sec	472.0
centiliters	liters	0.01		gallons/sec	0.1247
centimeters	feet	3.281×10^{-2}		liters/sec	0.4720
	inches	0.3937		pounds of water/ min	62.43
	kilometers	10^{-3}	cubic feet/sec	million gals/day	0.646317
	meters	0.01		gallons/min	448.831
	miles	6.214×10^{-4}	cubic inches	cu cms	16.39
	millimeters	10.0		cu feet	5.787×10^{-4}
	mils	393.7		cu meters	1.639×10^{-3}
centimeter-dynes	yards	1.094×10^{-2}		cu yards	2.143×10^{-3}
	cm-grams	1.020×10^{-3}		gallons (U.S. liq.)	4.329×10^{-3}
	meter-kgs	1.020×10^{-4}		liters	0.01639
centimeter-grams	pound-feet	7.376×10^{-4}		mil-feet	1.061×10^3
	cm-dynes	980.7		pints (U.S. liq.)	0.03463
	meter-kgs	10^{-3}		quarts (U.S. liq.)	0.01732
centimeters of mercury	pound-feet	7.233×10^{-3}	cubic meters	bushels (dry)	28.38
	atmospheres	0.01316		cu cms	10^4
	feet of water	0.4461		cu feet	35.31
	kgs/sq meter	136.0		cu inches	61,023.0
	pounds/sq ft	27.85		cu yards	1.308
	pounds/sq in.	0.1934		gallons (U.S. liq.)	264.2
centimeters/sec	feet/min	1.9685		liters	1,000.0
	feet/sec	0.03281		pints (U.S. liq.)	2,113.0
	kilometers/hr	0.036		quarts (U.S. liq.)	1,057
	knots	0.01943	cubic yards	cu cms	7.646×10^3
	meters/min	0.6		cu feet	27.0
	miles/hr	0.02237		cu inches	46,656.0
	miles/min	3.728×10^{-4}		cu meters	0.7646
centimeters/sec/ c	feet/sec/sec	0.03281		gallons (U.S. liq.)	202.0
	kms/hr/sec	0.036		liters	764.6
	meters/sec/sec	0.01		pints (U.S. liq.)	1,615.9
	miles/hr/sec	0.02237		quarts (U.S. liq.)	807.9
circular mils	sq cms	5.067×10^{-4}	cubic yards/min	cubic ft/sec	0.4 ^c
	sq mils	0.7854		gallons/sec	3.367
	sq inches	7.854×10^{-7}		liters/sec	12.74
coulombs	faradays	1.036×10^{-5}	D		
coulombs/sq cm	coulombs/sq in.	64.52			
	coulombs/sq meter	10^4	days	hours	24.0
coulombs/sq in.	coulombs/sq cm	0.1550		minutes	1,440.0
	coulombs/sq meter	1,550.		seconds	86,400.0
coulombs/sq meter	coulombs/cm	10^{-4}	deciliters	liters	0.1
	coulombs/sq in.	6.452×10^{-4}	decimeters	meters	0.1
cubic centimeters	cu feet	3.531×10^{-3}	degrees (angle)	minutes	60.0
	cu inches	0.06102		radians	0.01745
	cu meters	10^{-6}	degrees (terr. great circle)	seconds	3,600.0
	cu yards	1.308×10^{-4}	degrees/sec	miles (naut.)	60.0
	gallons (U.S. liq.)	2.642×10^{-4}		radians/sec	0.01745
	liters	0.001		revolutions/min	0.1667
	pints (U.S. liq.)	2.113×10^{-3}	dekagrams	grams	2.778×10^{-3}
	quarts (U.S. liq.)	1.057×10^{-3}	dekaliters	liters	10.0
cubic feet	bushels (dry)	0.8036	dekameters	meters	10.0
	cu cms	28,320.0	drams	grams	1.7718
	cu inches	1,728.0		grains	27.3437
	cu meters	0.02832		ounces	0.0625
	cu yards	0.03704	dynes	grams	1.020×10^{-3}
	gallons (U.S. liq.)	7.48052		joules/cm	10^{-7}
	liters	28.32		joules/meter	10^{-4}
	pints (U.S. liq.)	59.84		(newtons)	
	quarts (U.S. liq.)	29.92			

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Into	Multiply by
dynes/sq cm	kilograms	1.020×10^{-4}	hp-hrs		5.050×10^{-7}
	poundals	7.233×10^{-5}	joules		1.356
	pounds	2.248×10^{-4}	kg-calories		3.24×10^{-4}
	bars	10^{-4}	kg-meters		0.1383
E			kilowatt-hrs		3.766×10^{-7}
ergs	Btu	9.480×10^{-11}	Btu/min		1.286×10^{-3}
	dyne-centimeters	1.0	foot-pounds/sec		0.01667
	foot-pounds	7.367×10^{-8}	horsepower		3.030×10^{-5}
	gram-calories	0.2389×10^{-7}	kg-calories/min		3.24×10^{-4}
	gram-cms	1.020×10^{-3}	kilowatts		2.260×10^{-3}
	horsepower-hrs	3.7250×10^{-14}	Btu/hr		4.6263
	joules	10^{-7}	Btu/min		0.07717
	kg-calories	2.389×10^{-11}	horsepower		1.818×10^{-3}
	kg-meters	1.020×10^{-8}	kg-calories/min		0.01945
	kilowatt-hrs	0.2778×10^{-13}	kilowatts		1.356×10^{-3}
	watt-hours	0.2778×10^{-10}	rods		40.0
ergs/sec	Btu/min	5.688×10^{-9}	feet		660.0
	ft-lbs/min	4.427×10^{-4}	G		
	ft-lbs/sec	7.3756×10^{-4}	gallons (U.S.)	cu cms	3,785.412
	horsepower	1.341×10^{-10}		cu feet	0.1337
	kg-calories/min	1.433×10^{-9}		cu inches	231.0
	kilowatts	10^{-10}		cu meters	3.785×10^{-3}
F				cu yards	4.951×10^{-3}
farads	microfarads	10^6		liters	3,785.412
faradays	ampere-hours	26.80		pints	8.0
	coulombs	9.649×10^4		quarts	4.0
feet	feet	6.0	gallons	gallons (U.S. liq.)	1.20095
	centimeters	30.48	(liq. Br. Imp.)		
	kilometers	3.048×10^{-4}	gallons (U.S.)	gallons (Imp.)	0.83267
	meters	0.3048	gallons of water	pounds of water	8.3453
	miles (naut.)	1.645×10^{-4}	gallons/min	cu ft/sec	2.228×10^{-3}
	miles (stat.)	1.894×10^{-4}		liters/sec	0.06308
	millimeters	304.8		cu ft/hr	8.0208
	mils	1.2×10^4	gausses	lines/sq in.	6.452
feet of water	atmospheres	0.02950		webers/sq cm	10^{-4}
	in. of mercury	0.8826		webers/sq in.	6.452×10^{-4}
	kgs/sq cm	0.03048	gilberts	webers/sq meter	10^{-4}
	kgs/sq meter	304.8	gilberts/cm	ampere-turns	0.7958
	pounds/sq ft	62.43		amp-turns/cm	0.7958
feet/min	pounds/sq in.	0.4335		amp-turns/in.	2.021
	cms/sec	0.5080	gills	amp-turns/meter	79.58
	feet/sec	0.01667		liters	0.1183
	kms/hr	0.01829	grains (troy)	pints (liq.)	0.25
	meters/min	0.3048		grains (avdp)	1.0
	miles/hr	0.01136		grams	0.06480
feet/sec	cms/sec	30.48	grains/U.S. gal	ounces (avdp)	2.0833×10^{-3}
	kms/hr	1.097		pennyweight (troy)	0.04167
	knots	0.5921	grains/Imp. gal	parts/million	17.118
	meters/min	18.29	grams	pounds/million gal	142.86
	miles/hr	0.6818		parts/million	14.286
	miles/min	0.01136		dynes	980.7
feet/sec/sec	cms/sec/sec	30.48		grains	15.43
	kms/hr/sec	1.097		joules/cm	9.807×10^{-3}
	meters/sec/sec	0.3048		joules/meter	9.807×10^{-3}
	miles/hr/sec	0.6818		(newtons)	
feet/100 feet	per cent grade	1.0		kilograms	0.001
foot-pounds	Btu	1.286×10^{-3}		milligrams	1,000.
	ergs	1.356×10^7		ounces (avdp)	0.03527
	gram-calories	0.3238		ounces (troy)	0.03215
				poundals	0.07093
				pounds	2.205×10^{-3}

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Into	Multiply by
grams/cm	pounds/inch	5.600×10^{-3}		millimeters	25.40
grams/cu cm	pounds/cu ft	62.43		mils	1,000.0
	pounds/cu in.	0.03613		yards	2.778×10^{-3}
grams/liter	pounds/mil-foot	3.405×10^{-7}	inches of mercury	atmospheres	0.03342
	grains/gal	58.417		feet of water	1.133
	pounds/1,000 gal	8.345		kgs/sq cm	0.03453
	pounds/cu ft	0.062427		kgs/sq meter	345.3
	parts/million	1,000.0		pounds/sq ft	70.73
grams/sq cm	pounds/sq ft	2.0481		pounds/sq in.	0.4912
gram-calories	Btu	3.9683×10^{-3}	inches of water (at 4°C)	atmospheres	2.458×10^{-3}
	ergs	4.1868×10^7		inches of mercury	0.07355
	foot-pounds	3.0880		kgs/sq cm	2.540×10^{-3}
	horsepower-hrs	1.5596×10^{-4}		ounces/sq in.	0.5781
	kilowatt-hrs	1.1630×10^{-4}		pounds/sq ft	5.204
	watt-hrs	1.1630×10^{-3}		pounds/sq in.	0.03613
gram-calories/sec	Btu/hr	14.286			
gram-centimeters	Btu	9.297×10^{-4}	J		
	ergs	980.7	joules	Btu	9.480×10^{-4}
	joules	9.807×10^5		ergs	10^7
	kg-cal	2.343×10^{-4}		foot-pounds	0.7376
	kg-meters	10^{-3}		kg-calories	2.389×10^{-4}
H				kg-meters	0.1020
hectares	acres	2.471	joules/cm	watt-hrs	2.778×10^{-4}
	sq feet	1.076×10^{-3}		grams	1.020×10^4
hectograms	grams	100.0		dynes	10^7
hectoliters	liters	100.0		joules/meter (newtons)	100.0
hectometers	meters	100.0		poundals	723.3
hectowatts	watts	100.0		pounds	22.48
henries	millihenries	1,000.0	K		
horsepower	Btu/min	42.44	kilograms	dynes	980,665.
	foot-lbs/min	33,000.		grams	1,000.0
	foot-lbs/sec	550.0		joules/cm	0.09807
horsepower (metric)	horsepower	0.9863		joules/meter (newtons)	9.807
(542.5 ft lb/sec)	(550 ft lb/sec)			poundals	70.93
horsepower	horsepower (metric)	1.014		pounds	2.205
(550 ft lb/sec)	(542.5 ft lb/sec)			tons (long)	9.842×10^{-4}
horsepower	kg-calories/min	10.68		tons (short)	1.102×10^{-3}
	kilowatts	0.7457	kilograms/cu meter	grams/cu cm	0.001
	watts	745.7		pounds/cu ft	0.06243
horsepower (boiler)	Btu/hr	33.479		pounds/cu in.	3.613×10^{-5}
	kilowatts	9.803		pounds/mil-foot	3.405×10^{-10}
horsepower-hrs	Btu	2,547.		pounds/ft	0.6720
	ergs	2.6845×10^{13}	kilograms/meter	atmospheres	0.9678
	foot-lbs	1.98×10^4	kilograms/sq cm	feet of water	32.81
	gram-calories	641,190.		inches of mercury	28.96
	joules	2.684×10^4		pounds/sq ft	2,048.
	kg-calories	641.1		pounds/sq in.	14.22
	kg-meters	2.737×10^5	kilograms/sq meter	atmospheres	9.678×10^{-5}
	kilowatt-hrs	0.7457		bars	98.07×10^{-4}
	days	4.167×10^{-3}		feet of water	3.281×10^{-3}
hours	minutes	60.0		inches of mercury	2.896×10^{-3}
	seconds	3,600.0		pounds/sq ft	0.2048
	weeks	5.952×10^{-3}		pounds/sq in.	1.422×10^{-3}
I				kgs/sq meter	10^4
inches	centimeters	2.540	kilograms/sq mm	Btu	3.968
	feet	8.333×10^{-2}	kilogram-calories	foot-pounds	3,088.
	meters	2.540×10^{-2}		hp-hrs	1.560×10^{-3}
	miles	1.578×10^{-5}			

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Multiply by		
kilogram meters	joules	4,186.	L			
	kg-meters	426.9				
	kilojoules	4,186		league (marine)	miles (naut.)	3.0
	kilowatt-hrs	1.163×10^{-3}		lines/sq cm	gausses	1.0
	Btu	9.294×10^{-3}		lines/sq in.	gausses	0.1550
	ergs	9.804×10^7		lines/sq in.	webers/sq cm	1.550×10^{-4}
	foot-pounds	7.233			webers/sq in.	10^{-4}
joules	9.804			webers/sq meter	1.550×10^{-4}	
kg-calories	2.342×10^{-3}	links (engineer's)		inches	12.0	
kilowatt-hrs	2.723×10^{-4}	links (surveyor's)		inches	7.92	
		liters	bushels (U.S. dry)	0.02838		
kilolines	maxwells	1,000.0		cu cm	1,000.0	
kiloliters	liters	1,000.0		cu feet	0.03531	
kilometers	centimeters	10^5		cu inches	61.02	
	feet	3,281.	liters	cu meters	0.001	
	inches	3.937×10^4		cu yards	1.308×10^{-3}	
	meters	1,000.0		gallons (U.S. liq.)	0.2642	
	miles	0.6214		pints (U.S. liq.)	2.113	
	millimeters	10^6	liters/min	quarts (U.S. liq.)	1.057	
	yards	1,094.		cu ft/sec	5.886×10^{-4}	
kilometers/hr	cms/sec	27.78	lumens/sq ft	gals/sec	4.403×10^{-3}	
	feet/min	54.68	lux	foot-candles	1.0	
	feet/sec	0.9113		foot-candles	0.0929	
	knots	0.5396	M			
	meters/min	16.67		maxwells	kilolines	0.001
	miles/hr	0.6214			webers	10^{-4}
	kilometers/hr/sec	cms/sec/sec		27.78	megelines	maxwells
ft/sec/sec		0.9113		megohms	microhms	10^{12}
meters/sec/sec		0.2778			ohms	10^8
miles/hr/sec		0.6214		meters	centimeters	100.0
					feet	3.281
kilowatts	Btu/min	56.92			inches	39.37
	foot-lbs/min	4.426×10^4			kilometers	0.001
	foot-lbs/sec	737.6		miles (naut.)	5.396×10^{-4}	
	horsepower	1.341		miles (stat.)	6.214×10^{-4}	
	kg-calories/min	14.34		millimeters	1,000.0	
	watts	1,000.0		yards	1.094	
				varas	1.179	
kilowatt-hrs	Btu	3,413.	meters/min	cms/sec	1.667	
	ergs	3.600×10^{13}		feet/min	3.281	
	foot-lbs	2.655×10^6		feet/sec	0.05468	
	gram-calories	859,850.		kms/hr	0.06	
	horsepower-hrs	1.341		knots	0.03238	
	joules	3.6×10^6		miles/hr	0.03728	
	kg-calories	859.85	meters/sec	feet/min	196.8	
	kg-meters	3.671×10^5		feet/sec	3.281	
	pounds of water			kilometers/hr	3.6	
	evaporated from	3.53		kilometers/min	0.06	
	and at 212°F.			miles/hr	2.237	
	pounds of water	22.75	meters/sec/sec	miles/min	0.03728	
	raised from 62°			cms/sec/sec	100.0	
	to 212°F.			ft/sec/sec	3.281	
	feet/hr	6,080.2		kms/hr/sec	3.6	
	kilometers/hr	1.8532	meter-kilograms	miles/hr/sec	2.237	
	nautical miles/hr	1.0		cm-dynes	9.807×10^7	
	statute miles/hr	1.1516		cm-grams	10^5	
	yards/hr	2,027.	microfarad	pound-feet	7.233	
	feet/sec	1.689	micrograms	farads	10^{-4}	
			grams	10^{-4}		
			ohms	10^{-4}		

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Into	Multiply by
microliters	liters	10^{-6}	N		
miles (naut.)	degrees (terr. great circle)	0.016666	nepers	decibels	8.686
	feet	6,080.20	O		
	kilometers	1.853248	ohms	megohms	10^{-6}
	meters	1,853.248	ohms	microhms	10^{-6}
	miles (statute)	1.1516	ounces	drams	16.0
	yards	2,025.4		grains	437.5
miles (statute)	centimeters	1.609×10^3		grams	28.349527
	feet	5,280.		pounds	0.0625
	inches	6.336×10^4		ounces (troy)	0.9115
	kilometers	1.609		tons (long)	2.790×10^{-3}
	meters	1,609.		tons (metric)	2.835×10^{-3}
	miles (naut.)	0.8684		cu inches	1.805
	yards	1,760.		liters	0.02957
miles/hr	cms/sec	44.70	ounces (fluid)	grains	480.0
	feet/min	88.	ounces (troy)	grams	31.103481
	feet/sec	1.467		ounces (avdp.)	1.09714
	kms/hr	1.609		pennyweights (troy)	20.0
	kms/min	0.02682		pounds (troy)	0.08333
	knots	0.8684		pounds/sq in.	0.0625
	meters/min	26.82			
	miles/min	0.01667	P		
miles/hr/sec	cms/sec/sec	44.70	parts/million	grains/U.S. gal	0.0584
	feet/sec/sec	1.467		grains/imp. gal	0.07016
	kms/hr/sec	1.609		pounds/million gal	8.345
	meters/sec/sec	0.4470		grains	24.0
miles/min	cms/sec	2,682.	pennyweights (troy)	ounces (troy)	0.05
	feet/sec	88.		grams	1.55517
	kms/min	1.609		pounds (troy)	4.1667×10^{-3}
	miles (naut.)/min	0.8684		cu inches	33.60
	miles/hr	60.0	pints (dry)	cu cms.	473.2
mil-feet	cu inches	9.425×10^{-4}	pints (liq.)	cu feet	0.01671
milliers	kilograms	1,000.		cu inches	28.87
milligrams	grams	0.001		cu meters	4.732×10^{-4}
milligrams/liter	parts/million	1.0		cu yards	6.189×10^{-4}
millihenries	henries	0.001		gallons	0.125
milliliters	liters	0.001		liters	0.4732
millimeters	centimeters	0.1		quarts (liq.)	0.5
	feet	3.281×10^{-3}		dynes	13,826.
	inches	0.03937		grams	14.10
	kilometers	10^{-4}	poundals	joules/cm	1.383×10^{-3}
	meters	0.001		joules/meter (newtons)	0.1383
	miles	6.214×10^{-7}		kilograms	0.01410
	mils	39.37		pounds	0.03108
	yards	1.094×10^{-3}		drams	256.
million gals/day	cu ft/sec	1.54723		dynes	44.4823×10^4
mils	centimeters	2.540×10^{-3}		grains	7,000.
	feet	8.333×10^{-5}		grams	453.5924
	inches	0.001		joules/cm	0.04448
	kilometers	2.540×10^{-4}		joules/meter (newtons)	4.448
	yards	2.778×10^{-5}		kilograms	0.4536
miner's inches	cu ft/min	1.5×10^{-4}		ounces	16.0
minutes (angles)	degrees	0.01667		ounces (troy)	14.5833
	quadrants	1.852×10^{-4}		poundals	32.17
	radians	2.909×10^{-4}		pounds (troy)	1.21528
	seconds	60.0		tons (short)	0.0005
myriagrams	kilograms	10.0			
myriameters	kilometers	10.0			
myriawatts	kilowatts	10.0			

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Into	Multiply by
pounds (troy)	grains	5,760.	radians/sec	revolutions/sec	0.1592
	grams	373.24177	radians/sec/sec	revs/min/min	573.0
	ounces (avdp.)	13.1657		revs/min/sec	9.549
	ounces (troy)	12.0		revs/sec/sec	0.1592
	pennyweights (troy)	240.0	revolutions	degrees	360.0
	pounds (avdp.)	0.822857		quadrants	4.0
	tons (long)	3.6735×10^{-4}		radians	6.283
	tons (metric)	3.7324×10^{-4}	revolutions/min	degrees/sec	6.0
	tons (short)	4.1143×10^{-4}		radians/sec	0.1047
pounds of water	cu feet	0.01602		revs/sec	0.01667
	cu inches	27.68	revolutions/min/ min	radians/sec/sec	1.745×10^{-3}
	gallons	0.1198		revs/min/sec	0.01667
pounds of water/min	cu-ft/sec	2.670×10^{-4}	revolutions/sec	revs/sec/sec	2.778×10^{-4}
pound-feet	cm-dynes	1.356×10^7		degrees/sec	360.0
	cm-grams	13,825.		radians/sec	6.283
	meter-kgs	0.1383		revs/min	60.0
pounds/cu ft	grams/cu cm	0.01602	revolutions/sec/ sec	radians/sec/sec	6.283
	kgs/cu meter	16.02		revs/min/min	3,600.0
	pounds/cu in.	5.787×10^{-4}	rods	revs/min/sec	60.0
	pounds/mil-foot	5.456×10^{-9}		feet	16.5
pounds/cu in.	gms/cu cm	27.68	S		
	kgs/cu meter	2.768×10^4			
	pounds/cu ft	1,728.	seconds (angle)	degrees	2.778×10^{-4}
	pounds/mil-foot	9.425×10^{-4}		minutes	0.01667
pounds/ft	kgs/meter	1.488		quadrants	3.087×10^{-4}
pounds/in.	gms/cm	178.6		radians	4.848×10^{-4}
pounds/mil-foot	gms/cu cm	2.306×10^4	square centimeters	circular mils	1.973×10^3
pounds/sq ft	atmospheres	4.725×10^{-4}		sq feet	1.076×10^{-3}
	feet of water	0.01602		sq inches	0.1550
	inches of mercury	0.01414		sq meters	0.0001
	kgs/sq meter	4.882		sq miles	3.861×10^{-11}
pounds/sq in.	pounds/sq in.	6.944×10^{-3}		sq millimeters	100.0
	atmospheres	0.06804	square feet	sq yards	1.196×10^{-4}
	feet of water	2.307		acres	2.296×10^{-5}
	inches of mercury	2.036		circular mils	1.833×10^4
	kgs/sq meter	703.1		sq cms	929.0
	pounds/sq ft	144.0		sq inches	144.0
Q				sq meters	0.09290
quadrants (angle)	degrees	90.0		sq miles	3.587×10^{-4}
	minutes	5,400.0	square inches	sq millimeters	9.290×10^4
	radians	1.571		sq yards	0.1111
	seconds	3.24×10^5		circular mils	1.273×10^4
quarts (dry)	cu inches	67.20		sq cms	6.452
quarts (liq.)	cu cms	946.4		sq feet	6.944×10^{-3}
	cu feet	0.03342		sq millimeters	645.2
	cu inches	57.75		sq miles	10^4
	cu meters	9.464×10^{-4}	square kilometers	sq yards	7.716×10^{-4}
	cu yards	1.238×10^{-3}		acres	247.1
	gallons	0.25		sq cms	10^{10}
	liters	0.9463		sq ft	10.76×10^4
R				sq inches	1.550×10^4
adians	degrees	57.30		sq meters	10^4
	minutes	3,438.	square meters	sq miles	3.861×10^{-7}
	quadrants	0.6366		sq millimeters	10^4
	seconds	2.063×10^5		sq yards	1.196
radians/sec	degrees/sec	57.30			
	revolutions/min	9.549			

Conversion Factors (continued)

To convert	Into	Multiply by	To convert	Into	Multiply by
square miles	acres	640.0	watt-hours	Btu	3.413
	sq feet	27.88×10^4		ergs	3.60×10^9
	sq kms	2.590		foot-pounds	2,656.
	sq meters	2.590×10^6		gram-calories	859.85
	sq yards	3.098×10^4		horsepower-hrs	1.341×10^{-3}
square millimeters	circular mils	1,973.		kilogram-calories	0.8598
	sq cms	0.01		kilogram-meters	367.2
	sq feet	1.076×10^{-3}		kilowatt-hrs	0.001
	sq inches	1.550×10^{-3}	webers	maxwells	10^9
square mils	circular mils	1.273		kilolines	10^9
	sq cms	6.452×10^{-4}	webers/sq in.	gausses	1.550×10^7
	sq inches	10^{-4}		lines/sq in.	10^4
square yards	acres	2.066×10^{-4}		webers/sq cm	0.1550
	sq cms	8,361.		webers/sq meter	1,550.
	sq feet	9.0	webers/sq meter	gausses	10^4
	sq inches	1,296.		lines/sq in.	6.452×10^4
	sq meters	0.8361		webers/sq cm	10^{-4}
	sq miles	3.228×10^{-7}		webers/sq in.	6.452×10^{-4}
	sq millimeters	8.361×10^3			
T			Y		
temperature	absolute tempera-	1.0	yards	centimeters	91.44
(°C) + 273	ture (°C)			feet	3.0
temperature	temperature (°F)	1.8		inches	36.0
(°C) + 17.78				kilometers	9.144×10^{-4}
temperature	absolute tempera-	1.0		meters	0.9144
(°F) + 460	ture (°F)			miles (naut.)	4.934×10^{-4}
temperature	temperature (°C)	5/9		miles (stat.)	5.682×10^{-4}
(°F) — 32				millimeters	914.4
tons (long)	kilograms	1,016.			
	pounds	2,240.			
	tons (short)	1,120			
tons (metric)	kilograms	1,000.			
	pounds	2,205.			
tons (short)	kilograms	907.1848			
	ounces	32,000.			
	ounces (troy)	29,166.66			
	pounds	2,000.			
	pounds (troy)	2,430.56			
	tons (long)	0.89287			
	tons (metric)	0.9078			
tons (short)/sq ft	kgs/sq meter	9,765.			
	pounds/sq in.	2,000.			
tons of	pounds of	83.333			
water/24 hrs	water/hr				
	gallons/min	0.16643			
	cu ft/hr	1.3349			
W					
watts	Btu/hr	3.413			
	Btu/min	0.05688			
	ergs/sec	10^7			
	foot-lbs/min	44.27			
	foot-lbs/sec	0.7378			
	horsepower	1.341×10^{-3}			
	horsepower (metric)	1.360×10^{-3}			
	kg-calories/min	0.01433			
	kilowatts	0.001			

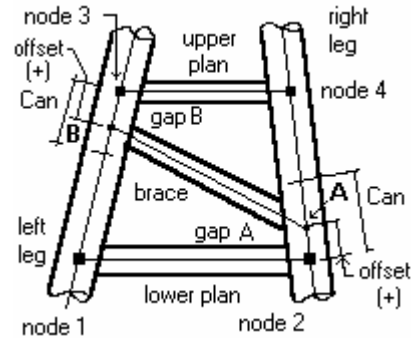
Some useful conversion factors

MULTIPLY	BY	TO OBTAIN	MULTIPLY	BY	TO OBTAIN
pressure			Density		
Atmospheres	760.	Millimeters of mercury	Grams per cc.	62.428	Pounds per cubic foot
	29.921	Inches of mercury		0.03613	Pounds per cubic inch
	33.93	Feet of water		8.345	Ponds per U.S. gallon
	10 332.	Kg. per square meter	Gram-moles of Ideal Gas & 0°C & 760 mm. Hg	22.4140	Liters
	14.696	Lbs. per square inch	Pounds per cubic inch	1 728.	Pounds per cubic foot
	2 116.2	Lbs. per square foot		27.68	Grams per cc.
	1.0133	Bars	Pound-moles of Ideal Gas & 0°C & 760 mm. Hg	359.05	Cubic feet
	1.0332	Kg. per square centimeter			
Centimeters of Hg	5.3524	Inches of water			
	0.4460	Feet of water			
	0.1934	Lbs. per square inch			
	27.845	Lbs. per square foot			
Feet of water	135.95	Kg. per square meter			
	0.02947	Atmospheres			
	0.4335	Lbs. per square inch			
Inches of Hg	62.378	Lbs. per square foot			
	0.03342	Atmospheres			
	13.60	Inches of water			
	1.133	Feet of water			
	0.4912	Lbs. per square inch			
	70.727	Lbs. per square foot			
Inches of water	345.32	Kg. per square meter			
	0.03609	Lbs. per square inch			
	5.1981	Lbs. per square foot			
Kg. per square centimeter	25.38	Kg. per square meter			
	0.9678	Atmospheres			
Kg. per square meter	14.22	Lbs. per square inch			
	0.00142	Lbs. per square inch			
	0.20482	Lbs. per square foot			
	0.00328	Feet of water			
	0.1	Grams per cmq.			
Pounds per square inch	70.31	Grams per cmq.			
	2.036	Inches of mercury			
	2.311	Feet of water			
TEMPERATURE			HEAT TRANSFER COEFFICIENT		
Degrees Fahrenheit = 1.8 (degrees Centigrade) + 32			BTU/(hr.) (ft.2) (°F)	0.001355	Cal/(sec.) (cmq.) (°C)
Degrees Kelvin = degrees Centigrade + 273.16				1.929 x 10 ⁻⁴	BTU/(sec.) (in.2) (°F)
Degrees Rankine = degrees Fahrenheit + 459.69				0.0005669	Watts/(cm.2) (°C)
THERMAL CONDUCTIVITY			Volume		
BTU/(hr.) (ft. 2) (°F/ft.)	0.00413	Cal/(sec.) (cm. 2) (°C/cm.)	Barrels	42.	Gallons (oil)
	12.	(°C/cm.)		31.5	Gallons
	0.0173	BTU/(hr.) (ft. 2) (°F/in.)	Cubic centimeters	0.001	Liters
		Watts/(cm. 2) (°C/cm.)		0.0610	Cubic inches
			Cubic feet	28 317.	Cubic centimeters
				1 728.	Cubic inches
				0.03704	Cubic yards
				7.481	Gallons
				28.32	Liters
			Cubic inches	16.387	Cubic centimeters
				0.01639	Liters
				4.329x10 ⁻³	Gallons
				0.01732	Quarts (liquid)
			Gallons, Imperial	277.4	Cubic inches
				1.201	U.S. Gallons
				4.546	Liters
			Gallons, U.S. (liquid)	231.	Cubic inches
				0.1337	Cubic feet
				3.785	Liters
				0.8327	Imperial gallons
				128.	Fluid ounces
			Ounces, fluid	29.57	Cubic centimeters
				1.805	Cubic inches
			Liters	0.2642	Gallons
				0.0353	Cubic feet
				1.0567	Quarts
				61.025	Cubic inches
				0.0334	Cubic feet
			Quarts, U.S. (liquid)	57.749	Cubic inches
				0.9463	Liters
VISCOSITY (Absolute)			MISCELLANEOUS PHYSICAL CONSTANTS		
Poise	1.0	gm/cm. sec.	CONSTANT	NUMERICAL	UNITS
	1.0	dyne sec./cm.2		VALUE	
	100.	Centipoise	Avogadro's Number	6.0228x10 ²³	Molecules/gm.-mole
Centipoise	0.000672	lb./ft. sec.	Gas-Law Constant R	1.987	Cal./(gm.-mole) (°K)
	0.0000209	lb. sec./ft.2		1.987	BTU/(lb.-mole) (°R)
	2.42	lb./ft.hr.		82.06	(cm.3) (atm.)/(gm.-mole) (°K)
				0.08205	(liter) (atm.)/(gm.-mole) (°K)
VISCOSITY (Kinematic)				10.731	(Ft.3) (lb.)/(in.2) (lb.-mole) (°R)
Stoke	1.0	cm.2/sec.		0.7302	(ft.3) (atm.)/(lb.-mole) (°R)
	0.155	in.2/sec.			
	0.001076	ft.2/sec.			
	density	Poise			
	(gm/cm.3)				

19.0 Frame geometry

This program calculates frame setting out points.

Frame geometry



Consider a frame of the general form shown above. Definitions of geometry are given below.

Node	X	Y	Z	Member	Diameter	
1	0	0	0	1-2	800	plan
2	23856	0	0	3-4	700	plan
3	1450	20000	0	1-3	1400	leg
4	22406	20000	0	2-4	1400	leg
				2-3	1000	brace

Side (leg) angles $\beta = \pm 4.145^\circ$

U and v are horizontal and vertical distances respectively from node 1

$$\Delta u_A = -700 / \cos(\beta) - (75 + 400) / \cos(\beta)$$

$$\Delta u_A = -702 - 34.43$$

$$\Delta u_A = -736.26$$

$$\Delta v_A = 400 + 75 \cos(\beta)$$

$$\Delta v_A = 474.8$$

$$\Delta u_B = +700 / \cos(-\beta) * \cos(0) + (350 / \cos(\beta) + 75) \sin(-\beta)$$

$$\Delta u_B = 702 - 30.8$$

$$\Delta u_B = 671.2$$

$$\Delta v_B = +700 / \cos(\beta) * \sin(0) - (350 / \cos(\beta) + 75) \cos(\beta)$$

$$\Delta v_B = 0 - 424$$

$$\Delta v_B = -424$$

Get the distances between leg wall to brace IPs.

$$L_u = u_2 - u_3 + \Delta u_A - \Delta u_B$$

$$L_u = 23.85 - 1.45 + (-0.736) - 0.671$$

$$L_u = 20.998\text{m}$$

$$L_v = v_2 - v_3 + \Delta v_A + \Delta v_B$$

$$L_v = 20.000 - 0.474 + (-0.424)$$

$$L_v = 19.102\text{m}$$

$$L = 28.368$$

$$\alpha_o = \text{ArcTan}(L_h/L_v) = 47.737\text{deg}$$

$$\alpha' = \text{ArcSin}(1000/28386) = 2.099\text{deg}$$

$$\alpha_H = \alpha_o + \alpha' = 49.73\text{deg}$$

Offset at A

$$A = +700 \tan(\beta) + 400/\cos(\beta) + 75 + 500 (\text{brace } D/2)/\sin(49.73 - \beta) - 700 \tan(90 - (49.7 - \beta))$$

$$A = 50.8 + 401 + 75 + 700 - 685$$

$$A = 542\text{mm}$$

Offset at B

$$B = +700 \tan(\beta) - 350/\cos(\beta) - 75 - 500 / \sin(49.73 - (-\beta)) + 700 \tan(90 - (49.7 + \beta))$$

$$B = 50.8 - 351 - 75 - 619$$

$$B = -483$$

Angles

At A

$$\text{Angle } 4-A-B = \alpha_N - \beta_{2-4}$$

$$\text{Angle } 4-A-B = 49.73 - 4.147$$

$$\text{Angle } 4-A-B = 45.58\text{deg}$$

$$\text{Angle } 1-B-A = \alpha_N - \beta_{1-3}$$

$$\text{Angle } 1-B-A = 49.73 + 4.147$$

$$\text{Angle } 1-B-A = 53.877\text{deg}$$

Enter node global coordinates

Direct nodes	X	Y	Z
node 1	0	0	0
node 2	23856	0	0
node 3	1450	20000	0
node 4	22406	20000	0

right leg diameter	1400
left leg diameter	1400
upper plan diameter	700
lower plan diameter	800
brace diameter	1000
A B	
gap (usually 75mm)	75 75

Read a node file

Node data source

- ☐ use data file nodes
☒ use direct nodes

Units (for cans)

- ☐ metres
☒ millimetres

Brace D > plan D

Angles, in plane of frame (degrees)

2-1-3 85.853	1-3-4 94.147
3-4-2 94.147	4-2-1 85.853
4-A-B 45.583	1-B-A 53.878

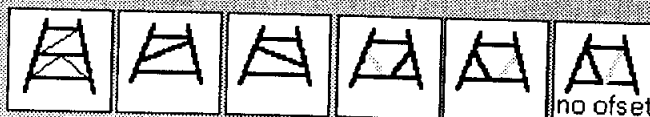
CL offsets :: Along CL's

2 - 540.917	** > D/4
3 (or) - 483.278	** > D/4

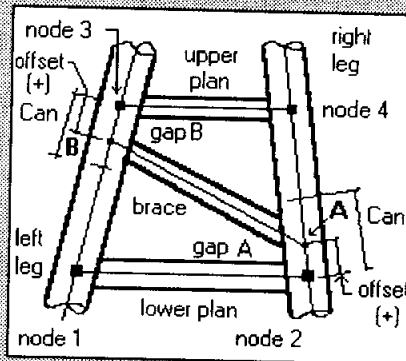
Along face of 'can'

1176.075
1044.928

Select configuration



u and v are local axes in plane of frame. Node 1 is origin



View...

plot

definitions

(check units)

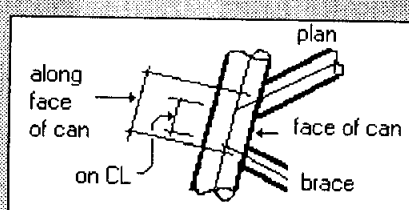
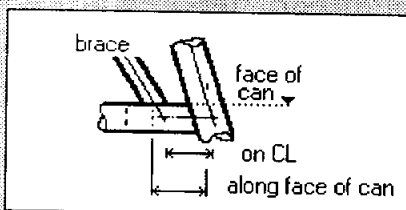
Can 'lengths'

At A - 2276.851

At B - 1963.187

Co-ordinates

	X	Y	Z
A	23816.888	539.501	0.000
B	1415.055	19517.987	0.000



PROJECT : Toolkit Validation

JOB No : 0000

SUBJECT : Frame geometry

CALC BY : GJS DATE : 25-May-1998

CHECKED :

Leg to leg bracing**Inter-nodal distances in plane of frame**

1 to 2 = 23846.000	1 to 3 = 20052.494
1 to 4 = 30033.795	2 to 3 = 30026.335
2 to 4 = 20051.773	3 to 4 = 20956.000

Inter-nodal angles in plane of frame(degrees)

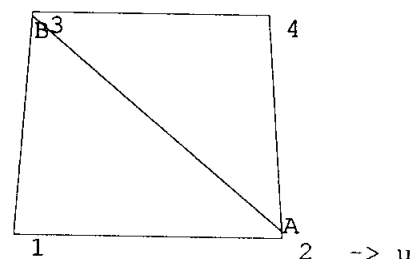
(1-2-3 is the included angle from node 1 to node 2 to node 3)

2 - 1 - 3 = 85.853
1 - 3 - 4 = 94.147
3 - 4 - 2 = 94.118
4 - 2 - 1 = 85.882
4 -A-B 45.598
1 -B-A 53.863

| v

Global node coordinates

node	X	Y	Z
1	0.000	0.000	0.000
2	23846.000	0.000	0.000
3	1450.000	20000.000	0.000
4	22406.000	20000.000	0.000

**Member diameters (or depths)**

(Members identified by node to node)

1 - 2 = 800.000
3 - 4 = 700.000
1 - 3 = 1400.000
2 - 4 = 1400.000
2 - 3 = 1000.000

Offsets on centre lines of members

Specified gaps A = 75 B = 75

(A is offset by node 2 B is by node 3 .)

A = 540.742 ** > D / 4
B = 483.141 ** > D / 4

offset of CL's of brace and other member, measured along face of the 'can'.
 Note that the 'can' is always the member to which the brace is attached.

A = 1175.872
B = 1045.028

Global co-ordinates of offsets

	X	Y	Z
A	23807.167	539.345	0.000
B	1415.067	19518.124	0.000

Can 'lengths'

(the can 'lengths' are for one side of the node only
 and are to the far side of brace + D/4 or 300mm)

Units are set as:- metres.

At A = 2276.109
At B = 1963.388

20.0 AISC

20.1 ASD 1989 (Green book)

20.1.1 Beam-columns

20.1.2 Single angle

20.2 ANSI/AISC 360-10

20.2.1 Beam-columns

Doubly symmetric

Singly symmetric

20.2.2 Tee sections

20.3 Web load capacities (includes ASD 1989)

20.1.1 Beam-column to AISC 1989 (ASD)

Design a beam-column with the following input data

P axial = 1000kN	Mx = 300kNm	My = 50kNm	Shear = 500kN
Lb = 4000mm	k.xLx = 6000	KyLy = 4000	
Steel grade 50.	Fy = 345MPa		

Try 610x305 UB 149

Depth = 610 Breadth = 305 Tf = 19.7 tw = 11.9

Area = 19000

Elastic moduli (UK nomenclature) Zx = 4.1e6 Zy = 0.611e6

Iy = 93.1e6 J = 2e6

rt = [Iy / (2.Zx)*(d^2 + 0.156 L^2 J / Iy)^0.5]^0.5 (commentary)

rt = 86mm

Section stresses

Fa = 1000e3/19e3 = 52 MPa

Fbx = Mx/Zx = 73MPa fby = My/Zy = 82MPa

Section compactness

Web fa/Fy = 52/345 = 0.153 < 0.16

d/tw(lim) = 1680/sqrt(345) * (1-3.74*0.153) = 38.8

d/tw = 610/11.9 = 51 > 38.8 therefore section is non-compact

Chapter E Compression

Cc = sqrt(2* π^2 *E/Fy)

Cc = sqrt(2*π^2*200e3/345)

Cc = 108

k.Lx/rx = 6000/257 = 23

k.Ly/ry = 4000/70 = 57

k Ly/ry / Cc = 0.53

Fa = 0.465 Fy = 160 MPa

Chapter F flexure

Lcrit = minimum(200*305/sqrt(345) , 137900/(610*345/(305*19.7))

Lcrit = 3284 < Lb

Therefore use F-3

Lb/rt = 47

1875*sqrt(Cb/Fy) = 101 (Cb = 1)

F1-6

Fbx = (2/3 – 345*47^2 / (10.55e6 * Cb)) Fy

Fbx = 0.59 Fy = 205MPa

Fby = 0.75 Fy = 259MPa

Chapter H Combined stresses

Fa/Fa = 52/160 = 0.33 > 0.15

H1-1

F'ex = 12 π^2 E/23(Kx.Lx/rx)^2 =1995MPa

F'ey = 12 π^2 E/23(KyLy/ry)^2 =325MPa

$$\frac{52}{160} + \frac{0.85 * 73}{(1-52/1995)*205} + \frac{0.85*82}{(1-52/325)*259}$$

$$0.33 + 0.31 + 0.32 = 0.96 < 1.0$$

H1-2

$$\frac{52}{0.6*345} + \frac{73}{205} + \frac{82}{259}$$

$$0.25 + 0.36 + 0.32 = 0.93 < 1.0$$

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Check beam-column

Code check to AISC Allowable stress design : 1989

(ver 2.0.11)

Applied loads

	kN		kN-m
Axial load (Fx)	= 1,000.00	Moment x-x (Mx)	= 300.00
Shear load (Vuy)	= 500.00	Moment y-y (My)	= 50.00

Effective lengths (mm)

Lb = 4000 Lx = 6000 Ly = 4000

Section

610x305UB149

Fy = 345 MPa

Section data

D = 609.6	Bf = 304.8	Tf = 19.7	tw = 11.9
Area = 19,000	mm ²	w = 149	kg/m
rx = 256.5	ry = 70.0	rt = 80.7	F1.3 mm
Elastic Mod x-x = 4,101,050		Elastic Mod y-y = 610,892	mm ³
Lx/rx = 23.4	Ly/ry = 57.1	Lb/rt = 49.5	Lcrit = 3274.8

Allowable stresses (MPa)

Allowable stress factor = 1.00

Fbx = 203.7	(F1-8)		
Fby = 258.8	(F2-1)		
Facx = 192.7	(E2-1)	Facy = 160.0	(E2-1)
Fv(y) = 138.0	(F4-1)		
Web unstiffened			
Mb(x-x) = 836	Mb(y-y) = 158	kN-m	

Actual stresses (MPa)

fac = 52.63 fbx = 73.15 fby = 81.85

Code check results

Cm(x) = 0.85 Cm(y) = 0.85 Cb = 1
 (H1-1) buckling
 $\frac{fa}{Fa} + \frac{Cmx.fbx}{[(\text{magn.}) Fbx]} + \frac{Cmy.fby}{[(\text{magn.}) Fby]}$
 0.33 + 0.31 + 0.32 = 0.97

(H1-2) yield
 $\frac{fa}{0.6 \cdot Fy} + \frac{fbx}{Fbx} + \frac{fby}{Fby}$
 0.25 + 0.36 + 0.32 = 0.93

Shear (y):: fv / Fv = 0.50

Section O.K. use 610x305UB149

20.1.2 Single angle code check to AISC-WSD 9th Ed

Try 200x150x18 RSA

Section properties

$$\theta = \tan^{-1}(0.549) = 28.8^\circ$$

$$A = 6010 \text{ mm}^2$$

$$I_{uu} = 2920 \text{ cm}^4 (29.2 \text{ e6 mm}^4)$$

$$I_{vv} = 623 \text{ cm}^4 (6.2 \text{ e3 mm}^4)$$

$$r_{uu} = 69.7 \text{ mm}$$

$$r_{vv} = 32.2 \text{ mm}$$

$$F_y = 345 \text{ MPa (N/mm}^2)$$

$$L_b = 2000 \text{ mm} \quad L_u = 3000 \text{ mm} \quad L_v = 3000 \text{ mm}$$

4 Compression

$$b/t \text{ max (at 1)} = 200/18 = 11$$

$$76/\sqrt{345/6.895} = 10.7 \quad (6.895 \text{ converts MPa stress units to ksi})$$

Therefore

$$Q = 1.34 - 0.00447 \cdot (b/t) \sqrt{F_y}$$

$$Q = 1.34 - 0.00447 \cdot 11 \cdot \sqrt{345/6.895}$$

$$Q = 0.99$$

$$C_c = \sqrt{2 \cdot \pi^2 \cdot E / (Q \cdot F_y)}$$

$$C_c = \sqrt{2 \cdot \pi^2 \cdot 200 \text{ e3} / (0.99 \cdot 345)}$$

$$C_c = 107$$

$$k \cdot L / r_{\min} = 3000 / r_{vv} = 93.9 < C_c$$

$$F_a = 0.99 \cdot (1 - 1/2 \cdot 0.87^2) \cdot F_y / (5/3 + 3/8 \cdot 0.87 - 1/8 \cdot 0.87^3)$$

$$F_a = 0.32 \cdot F_y$$

$$F_a = 110 \text{ MPa}$$

Check $(Kl/r)_{eq}$

$$(Kl/r)_{eq} = \pi \cdot \sqrt{E / F_e}$$

w_o and z_o are co-ordinates of the shear centre

$$\bar{r}_o^2 = z_o^2 + w_o^2 + (I_{uu} + I_{vv}) / A$$

$$w_o = -63.4$$

$$z_o = -38.6$$

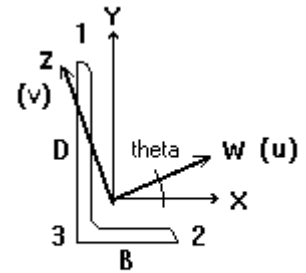
$$r_o = 99.2$$

$$\bar{r}_o^2 = 63.4^2 + 38.6^2 + (29.2 + 6.6) \cdot 1 \text{ e6} / 6010$$

$$\bar{r}_o^2 = 11466$$

$$H = 1 - (z_o^2 + w_o^2) / \bar{r}_o^2$$

$$H = 1 - (63.4^2 + 38.6^2) / 11466$$



Apply X, Y moments using the right hand rule.

$$H = 0.52$$

$$F_{ez} = \pi^2 * E / (L_z / r_z)^2$$

$$F_{ez} = \pi^2 * 200 * 10^3 / (3000 / 32.2)^2$$

$$F_{ez} = 227 \text{ MPa}$$

$$F_{ew} = \pi^2 * E / (L_w / r_w)^2$$

$$F_{ew} = \pi^2 * 200 * 10^3 / (3000 / 69.7)^2$$

$$F_{ew} = 1065 \text{ MPa}$$

$$\text{From Eq C4-2 } F_e = 219 \text{ MPa}$$

$$(Kl/r)_{eq} = \pi * \sqrt{200 * 10^3 / 219}$$

$$(Kl/r)_{eq} = 94.9 > 93.2 \quad \text{Recalculate } F_{ac} \text{ using } Kl/C_c = 0.89$$

$$F_{ac} = 0.31 * F_y$$

$$F_{ac} = 108 \text{ MPa}$$

5 Flexure

5.1.1 local buckling

$$\text{At 1 } b/t = 200/18 = 11.1$$

$$\sqrt{6.895} * 65 / F_y = 9.2$$

$$\sqrt{6.895} * 76 / F_y = 10.7$$

$$11.1 > 10.7 \text{ therefore } F_{bcu1}(\text{lim}) = 0.6 * Q * F_y$$

$$F_{bcu1}(\text{lim}) = 0.6 * 0.99 * 350 = 205 \text{ MPa}$$

$$\text{At 2 } b/t = 150/18 = 8.3 < 9.2$$

$$\text{Therefore } F_{bcu2}(\text{lim}) = 0.66 * F_y = 228 \text{ MPa}$$

5.1.2 Tension

$$F_{bt} = 0.66 F_y = 228 \text{ MPa}$$

5.1.3 Lateral buckling

To determine F_b , values of F_{ob} are required and these depend upon either 5.2 or 5.3

This calculation uses the geometric axes thus F_{ob} will be from clause 5.3

5.3.2 (a)

$$F_{ob} = 6.895 * 143100 / (Z_{uu}(1,2) * L^2) * I_{vv} * C_b * (\beta^2 + 0.52 * (L * t / r_v)^2)^{0.5} \pm \beta_w$$

$$\beta_w = 84 \text{ mm} \quad Z_{u1} = 212377 \text{ mm}^3 \quad Z_{u2} = 267429 \text{ mm}^3$$

$$F_{ob1} = 1328 \text{ MPa (using } -ve \beta_w)$$

$$F_{ob2} = 2015 \text{ MPa (using } +ve \beta_w)$$

For 5.1.3, $F_{ob} > F_y$

$$F_{bcu1}(LTB) = (0.95 - 0.5 \cdot \sqrt{350/1328}) \cdot 350$$

$$F_{bcu1}(LTB) = 0.7 F_y > 0.66 F_y$$

$$F_{bcu1,2}(LTB) = 0.66 F_y = 228 \text{ MPa}$$

Combined stresses

Use Chapter H with u and v instead of x and y

Applied loads

$$\text{Axial} = 200 \text{ kN}$$

$$M_x = 50 \text{ kNm}$$

$$M_y = 10 \text{ kNm}$$

$$F_v = 200 \text{ kN}$$

Transform moments to the principal axes using right hand rule. $\theta = 28.8^\circ$

$$M_u = M_x \cos(\theta) + M_y \sin(\theta)$$

$$M_v = -M_x \sin(\theta) + M_y \cos(\theta)$$

$$M_u = 50 \cos(28.8) + 10 \sin(28.8) = 48.6 \text{ kNm}$$

$$M_v = -50 \sin(28.8) + 10 \cos(28.8) = -15.3 \text{ kNm}$$

Moduli

$$U(i) = x(i)$$

$$u(i) = x(i) \cos(\theta) + y(i) \sin(\theta)$$

$$u(i) = -x(i) \sin(\theta) + y(i) \cos(\theta)$$

$$u_1 = -38.6 \cos(28.8) + 136.6 \sin(28.8) = 32$$

$$v_1 = 38.6 \sin(28.8) + 136.6 \cos(28.8) = 138.3$$

$$u_2 = 111.4 \cos(28.8) + (-63.4) \sin(28.8) = 67$$

$$v_2 = -111.4 \sin(28.8) + (-63.4) \cos(28.8) = -109$$

$$Z_{u1} = I_{uu}/v_1 = 211288 \quad Z_{u2} = I_{uu}/v_2 = 267890$$

$$Z_{v1} = I_{vv}/u_1 = 193750 \quad Z_{v2} = I_{vv}/u_2 = 92537$$

Buckling stresses

$$F'_{eu} = 12 \pi^2 E / 23 (L_u/r_u)^2 = 556 \text{ MPa}$$

$$F'_{ev} = 12 \pi^2 E / 23 (L_v/r_v)^2 = 119 \text{ MPa}$$

Member stresses

$$\text{Axial} \quad f_a = 200000/6010 = 33.3 \text{ (C)}$$

$$\text{Bending} \quad f_{bu1} = 48.6e6/Z_{u1} = 230 \text{ (T)}$$

$$f_{bv1} = -15.3e6/Z_{v1} = -79 \text{ (T)}$$

$$f_{bu2} = 48.6e6/Z_{u2} = 181 \text{ (C)}$$

$$f_{bv2} = -15.3e6/Z_{v2} = -164 \text{ (T)}$$

At point 1

H1-1

$$\frac{33.3}{108} + \frac{0.85 * 230}{(1-33.3/556)*228} + \frac{0.85*79}{(1-33.3/119)*228}$$

$$0.31 + 0.912 + 0.45 = 1.67 > 1.0$$

H1-2

$$\frac{33.3}{0.6*345} + \frac{230}{228} + \frac{79}{228}$$

$$0.16 + 1.009 + 0.35 = 1.52 > 1.0$$

At point 2

H1-1

$$\frac{33.3}{108} + \frac{0.85 * 181}{(1-33.3/556)*228} + \frac{0.85*164}{(1-33.3/119)*228}$$

$$0.31 + 0.718 + 0.849 = 1.88 > 1.0$$

H1-2

$$\frac{33.3}{0.6*345} + \frac{181}{228} + \frac{164}{228}$$

$$0.16 + 0.794 + 0.72 = 1.67 > 1.0$$

Shear.

This is assumed to be on the long leg and a 1.5 factor is applied to account for parabolic distribution. This is conservative as there is one flange which will reduce the 1.5 which is applicable for the case of a rectangular shape (a web with no flanges).

$$F_v = 0.4 F_y$$

$$F_v = 0.4 * 345 = 138 \text{ MPa}$$

$$F_v = 1.5 * 200e3 / (200 * 18) = 83 \text{ MPa}$$

$$I_R = 83 / 138 = 0.6$$

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Single angle beam-column

Code check single angle to AISC ASD : 1989

Design loads kN kN-m
Axial load (Fx) = 200.00 Moment x-x (Mx) = 50.00
Shear load (y) = 200.00 Moment y-y (My) = 10.00

Moments resolved about principal axes. Theta = 28.77
Mw-w = 48.64 Mz-z = -15.30

Effective lengths

Lb = 2000 Lw = 3000 Lz = 3000

Section data

200x150x18 RSA Fy = 345 MPa
D = 200.00 B = 150.00 tw = 18.00 Area = 6,010.000 mm²
Iw = 29199999.565 Iz = 6229999.907 mm⁴
rw = 70.03 rz = 32.23 mm
Lw/rw = 42.84 Lz/rz = 93.07

Points	1	2	3	
Sw	212,377.028	-267,428.506	-48.167	mm ³
Sz	195,316.197	93,340.320	-5.846	mm ³

Allowable stresses

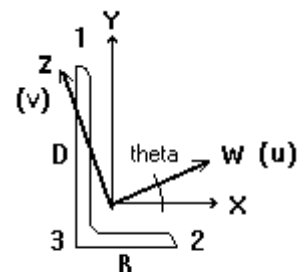
Allowable stress factor = 1.00

Stress	Fat	Fac	Fbcw	Fbcz	Fbt	Fv
Point 1	207.0	108.3	204.7	204.7	227.7	138.0
Point 2	207.0	108.3	227.7	227.7	227.7	138.0
Point 3	207.0	108.3	227.7	227.7	227.7	138.0

Actual stresses

Compression is +ve.

Stress	fa	fbw	fbz	fv
Point 1	33.3	-229.0	-78.3	83.3
Point 2	33.3	181.9	-163.9	
Point 3	33.3	61.6	159.7	



Apply X, Y moments using the right hand rule.

Code check results

Cb = 1 Cm(w) = 0.85 Cm(z) = 0.85
(fa/Fa > 0.15)

Point 1					
(H1-1)	buckling	0.31 +	0.91 +	0.41 =	1.62
(H1-2)	yield	0.16 +	1.01 +	0.34 =	1.51
Point 2					
(H1-1)	buckling	0.31 =	0.72 +	0.85 +	1.88
(H1-2)	yield	0.16 =	0.80 +	0.72 +	1.68
Point 3					
(H1-1)	buckling	0.31 =	0.24 +	0.83 +	1.38
(H1-2)	yield	0.16 =	0.27 +	0.70 +	1.13

Shear on long leg: fv / Fv = 0.60

Section FAILS

20.2.1 Beam-columns

Beam-column. W shape, doubly symmetric. US units

Consider W18x7.5x50 Fy=36ksi

Properties (inch units)

Depth = 17.992	Breadth = 7.48	
Flange T = 0.571	Web t = 0.354	
Radius = 0.394	Area = 14.663	
Ixx = 799.0	Iyy = 39.9	
rx = 7.38	ry = 1.65	
Elastic modulus X = 88.82	Plastic modulus X = 100.69	
Elastic modulus Y = 10.67	Plastic modulus Y = 16.53	
J = 1.25	Cw = 3022	
Cb=1	Cmx=0.85	Cmy=0.85
Lb=120	Kx.L=200	Ky.L=150
Kx.L/rx=200/7.38 = 27.1	Ky.L/ry=150/1.65 = 90.91	

Loads

Pr=100	Mnx=2000	Mny=50	Vr=50
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Chapter C

Assume B2=0	$P_{e1} = \pi^2 EI / (K.L)^2$
$P_{e1}(x) = \pi^2 \cdot 29000 \cdot 799.0 / 200^2 =$	5717kip
$P_{e1}(y) = \pi^2 \cdot 29000 \cdot 39.9 / 150^2 =$	507kip

LRFD

$B1x = 0.85 / (1 - 1 \cdot 100 / 5717) =$	0.865 < 1. Use 1.0
$B1y = 0.85 / (1 - 1 \cdot 100 / 507) =$	1.059

ASD

$B1x = 0.85 / (1 - 1.6 \cdot 100 / 5717) =$	0.865 < 1. Use 1.0
$B1y = 0.85 / (1 - 1.6 \cdot 100 / 507) =$	1.242

For LRFD, bending about x-x axis

$$M_{rx} = B1 \cdot M_{nx} = 2000$$

$$M_{ry} = M_{ny} = 50$$

For LRFD, bending about y-y axis

$$M_{rx} = M_{nx} = 2000$$

$$M_{ry} = B1 \cdot M_{ny} = 53.0$$

For ASD, bending about x-x axis

$$M_{rx} = B1 \cdot M_{nx} = 2000$$

$$M_{ry} = M_{ny} = 50$$

For ASD, bending about y-y axis

$$M_{rx} = M_{nx} = 2000$$

$$M_{ry} = B1 \cdot M_{ny} = 62.1$$

Chapter D Tension

$$P_n = F_y \cdot A_g$$

$$P_n = 36 \cdot 14.66 = 527.9 \text{ kip}$$

$$\phi P_n = P_c(t) = 475.0 \text{ kip}$$

$$P_n / \Omega = P_c(t) = 316.1 \text{ kip}$$

Chapter E Compression

Check compactness of section

Flange $b/t = \lambda = (7.48/2) / 0.571 = 6.55$

From table B4.1, case 3

$\lambda_r = 0.56 \cdot \sqrt{E/F_y} = 15.89, > \lambda$ therefore flange is compact

Web $h/t = \lambda = (17.99 - 2 \cdot (0.571 + 0.394)) / 0.354 = 16.06 / 0.354 = 45.37$

From table B4.1, case 10

$\lambda_r = 1.49 \cdot \sqrt{E/F_y} = 42, < \lambda$ therefore web is slender

To determine Q for slender stiffened element (E7.2(a)) need to get Fcr for Q=1

E3. Flexural buckling

$$F_e = \pi^2 E / (K \cdot L/r)^2$$

$$F_{ex} = \pi^2 \cdot 29000 / (27.1)^2 = 390.8 = 10.8 \cdot F_y > 0.44 F_y$$

$$F_{cr} = [0.658^{F_y/F_e}] \cdot F_y = 34.6 \text{ ksi}$$

$$F_{ey} = \pi^2 \cdot 29000 / (90.9)^2 = 34.6 = 0.96 \cdot F_y > 0.44 F_y$$

$$F_{cr} = [0.658^{F_y/F_e}] \cdot F_y = 23.3 \text{ ksi}$$

E4 Flexural-torsional buckling

Use (E4-4)

$$F_e = [\pi^2 E \cdot C_w / (K_z \cdot L)^2 + GJ] \cdot 1 / (I_x + I_y)$$

$$F_e = [\pi^2 \cdot 29000 \cdot 3022 / (120)^2 + 11200 \cdot 1.25] \cdot 1 / (799 + 39.9)$$

$$F_e = 88.3 = 2.45 F_y$$

$$F_{cr} = [0.658^{F_y/F_e}] \cdot F_y = 30.36 \text{ ksi}$$

The lowest Fcr is for y-y Flexural buckling, 23.3 ksi

E7.2(a)

(E7-17) using $f = F_{cr} = 23.3$

$$b_e = 1.92 \cdot t \cdot \sqrt{E/f} \cdot [1 - 0.34 / (b/t) \cdot \sqrt{E/f}]$$

$$b_e = 1.92 \cdot 0.354 \cdot \sqrt{29000/23.3} \cdot [1 - 0.34 / (45.37) \cdot \sqrt{29000/23.3}]$$

$$b_e = 17.64$$

This is greater than b (16.06) therefore there is no reduction in area

$$Q_a = 1$$

The Fcr values calculated above are valid

$$P_n(x) = \min(390.8, 30.36) \cdot \text{Area} = 445.2 \text{ kip}$$

$$P_n(y) = \min(23.3, 30.36) \cdot \text{Area} = 341.6 \text{ kip}$$

$$P_n(c) = 341.6 \text{ kip}$$

$$\phi P_n = P_c(c) = 307.5 \text{ kip}$$

$$P_n / \Omega = P_c(c) = 204.6 \text{ kip}$$

Chapter F flexure

Check compactness of section

Flange $b/t = \lambda = (7.48 / 2) / 0.571 = 6.55$

From table B4.1, case 1

$$\lambda_p = 0.38 \sqrt{E/F_y} = 10.79$$

$$\lambda_r = 1.00 \sqrt{E/F_y} = 28.3$$

$$\lambda < \lambda_p \quad \text{therefore flange is compact}$$

Web $h/t = \lambda = (17.99 - 2(0.571 + 0.394)) / 0.354 = 16.06 / 0.354 = 45.37$

From table B4.1, case 9

$$\lambda_p = 3.76 \sqrt{E/F_y} = 106.7$$

$$\lambda_r = 5.7 \sqrt{E/F_y} = 161$$

$$\lambda < \lambda_p \quad \text{therefore web is compact}$$

From Table F1.1, use section F2.

F2.1 Yield

$$\begin{aligned} M_n &= M_p = F_y \cdot Z_x \text{ (plastic modulus)} \\ &= 36 \cdot 100.69 \\ &= 3624 \text{ kip-in} \end{aligned}$$

F2.2 Lateral Torsional buckling

$$L_p = 1.76 \cdot r_y \cdot \sqrt{E/F_y} \quad (\text{F2-5})$$

$$L_p = 82.4$$

$$r_{st} = \sqrt{[I_y \cdot C_w] / S_x} \quad (\text{F2-7})$$

$$r_{st} = 1.98$$

$$h_o = 17.99 - 0.57$$

$$h_s = 17.4$$

$$L_r = 1.95 \cdot 1.98 \cdot 29000 / (0.7 \cdot 36) \cdot \sqrt{1.25 / (88.82 \cdot 17.4)} \cdot$$

$$\sqrt{1 + \sqrt{1 + 6.76 \cdot [0.7 \cdot 36 \cdot 88.82 \cdot 17.4 / (29000 \cdot 1.25)]^2}} \quad]$$

$$L_r = 251.7 \quad (\text{F2-6})$$

For $L_b = 120$, $L_p < L_b < L_r$ therefore use F2.2(b)

$$M_n = 1.0 \cdot [3624 - (3624 - 0.7 \cdot 36 \cdot 88.82) \cdot (120 - 82.4) / (251.7 - 82.4)]$$

$$M_n = 3316.2 < M_p \quad (\text{F2-2})$$

$$\phi M_n x = M_c(x) = 2984.6 \text{ kip-in}$$

$$M_n x / \Omega = M_c(x) = 1985.8 \text{ kip-in}$$

For $L_b = 300$, $> L_r$, use (F2-3)

$$F_{cr} = 1.0 \cdot \pi^2 \cdot 29000 / (300 / 1.98)^2 \cdot \sqrt{1 + 0.078 \cdot 1.25 \cdot 1.0 / (88.82 \cdot 17.4) \cdot (300 / 1.98)^2}$$

$$F_{cr} = 19.51 \text{ ksi}$$

$$M_n = F_{cr} \cdot S_x \text{ (elastic modulus)}$$

$$M_n = 19.51 \cdot 88.82$$

$$M_n = 1732.7 \text{ kip-in}$$

$$\phi M_n x = M_c(x) = 1559 \text{ kip-in}$$

$$M_n x / \Omega = M_c(x) = 1037.6 \text{ kip-in}$$

Minor axis

F6.1 Yielding

$$M_n = M_p = F_y Z_y \text{ (plastic mod.)} \leq 1.6 F_y S_y \text{ (elastic mod.)}$$

$$M_{ny} = 36 \times 16.53$$

$$M_{ny} = 595.1 \text{ kip-in}$$

$$1.6 F_y S_y = 614.6 \text{ kip-in}$$

$$M_{ny} = 595.1$$

$$\phi M_{ny} = M_c(y) = 535.6 \text{ kip-in}$$

$$M_{ny}/\Omega = M_c(y) = 356.3 \text{ kip-in}$$

Chapter G. Shear

G2.1 (a)

$$h/t_w = 45.37 < 2.24 \sqrt{E/F_y} = 63.6$$

Therefore $C_v = 1$ (G2-2) and $\phi = 1.0$, $\Omega = 1.5$

$$V_n = 0.6 F_y A_w C_v$$

$$V_n = 0.6 \times 36 \times 17.99 \times 0.354 \times 1.0$$

$$V_n = 137.6 \text{ kip}$$

$$\phi V_n = 137.6 \text{ kip}$$

$$V_n/\Omega = 91.7 \text{ kip}$$

$$\text{For LRFD, } V_r/V_c = 50/137.6 = 0.363 < 1 \text{ OK}$$

$$\text{For ASD, } V_r/V_c = 50/91.7 = 0.545 < 1 \text{ OK}$$

Chapter H. Combined forces

H1.1

Using design case of $L_b = 120$

Treating the loads as LRFD

$$P_r / P_c = 100 / 307.5 = 0.325 > 0.2 \text{ Use (H1-1a)}$$

$$\begin{aligned} P_r/P_c + 8/9 * (M_{rx} / M_{cx} + M_{ry} / M_{cy}) &= 0.325 + 8/9 * (2000/2984.6 + 50/535.6) \\ &= 0.325 + 0.596 + 0.083 \\ &= 1.004 \end{aligned}$$

Treating the loads as ASD

$$P_r / P_c = 100 / 204.6 = 0.489 > 0.2 \text{ Use (H1-1a)}$$

$$\begin{aligned} P_r/P_c + 8/9 * (M_{rx} / M_{cx} + M_{ry} / M_{cy}) &= 0.489 + 8/9 * (2000/1985.8 + 50/356.3) \\ &= 0.489 + 1.02 \\ &= 1.51 \end{aligned}$$

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Singly symmetric W LRFD

Code check to ANSI/AISC 360-05 : 2005

(ver 1.0.0)

Design loads

Axial load (Pr) = 100.00 kip
Shear load (Vry) = 50.00
Required capacity moments (Chapter C). B2 is taken as zero.
Mr(x) = 2,000.00

Moment x-x (Mx) = 2,000.00 kip-in
Moment y-y (My) = 50.00
Mr(y) = 50.00 kip-in

Effective lengths

Lb = 120 Lx = 200 Ly = 150

Section Data

W18x7.5x50	rolled	Grade : A36	Fy = 36.0 ksi
D = 18.0	Bf = 7.5	Tf = 0.6	tw = 0.4
Area = 15 in ²	J = 1.25 in ⁴		
Ix = 7.99E+02 in ⁴	Iy = 3.99E+01 in ⁴		
Elastic Mod x-x = 89		Plastic Mod x-x = 101 in ³	
Elastic Mod y-y = 11		Plastic mod y-y = 17 in ³	
rx = 7.4	ry = 1.6 in		
Lx/rx = 27.1	Ly/ry = 90.9		
Cw = 3021.634 in ⁶			
Web unstiffened			
Lp = 82.4	Lr = 251.3in		
Mn(x) = 3316.2	Mn(y) = 595.3kip-in		

Member resistance capacity (Ø.Rn or Rn/Omega)

Axial
Pc(t)=475.08 Pc(c)=307.43
Moment
Mc(x) = 2984.5 Eqn F2-2 Mc(y) = 535.8 Eqn F6-1
Shear
Vc = 137.7 Eqn G2-2

Code check results

Cb = 1
H1-1a - Compression. B2 = 0
 $Pr/Pc + 8/9(Mrx/Mcx + Mry/Mcy) = 0.33 + 0.60 + 0.08 = 1.00$

G2-2 Shear.

Vr/Vc = 0.36

Section fails

Consider 1000x300 20/4 PG $F_y = 345 \text{ MPa}$

Test flexural capacity using F5.

Properties (mm units)

Depth = 1000	Breadth = 300	
Flange T = 20	Web t = 4	
Radius = 0	Area = 15840	
$I_{xx} = 3176.5E6$	$I_{yy} = 90.0E6$	
$r_x = 447.8$	$r_y = 75.4$	
Elastic modulus X = $6.353E6$	Plastic modulus X = $6.801E6$	
Elastic modulus Y = $0.600E6$	Plastic modulus Y = $0.904E6$	
J = $1.62E6$	Cw = $21.6E12$	
$C_b = 1$	$C_{mx} = 0.85$	$C_{my} = 0.85$
Lb = 10000	$K_x.L = 0$	$K_y.L = 0$
$K_x.L/r_x = 0$	$K_y.L/r_y = 0$	

Loads

None applied

Chapter C

Assume $B_2 = 0$ $B_1 = 1$

Chapter D Tension

$P_n = F_y \cdot A_g$
 $P_n = 345 \cdot 15840 = 5464 \text{ kN}$

$\phi P_n = P_c(t) = 4918 \text{ kN}$
 $P_n/\Omega = P_c(t) = 3272 \text{ kN}$

Chapter F flexure

Check compactness of section

Flange $b/t = \lambda = (300/2) / 20 = 7.5$
From table B4.1, case 1
 $\lambda_p = 0.38 \cdot \sqrt{E/F_y} = 9.14$
 $\lambda_r = 1.00 \cdot \sqrt{E/F_y} = 24.1$
 $\lambda_p < \lambda < \lambda_r$ therefore flange is compact

Web $h/t = \lambda = (1000 - 2 \cdot (20)) / 4 = 960 / 4 = 240$
From table B4.1, case 9
 $\lambda_p = 3.76 \cdot \sqrt{E/F_y} = 90.5$
 $\lambda_r = 5.7 \cdot \sqrt{E/F_y} = 137$
 $\lambda > \lambda_r$ therefore web is slender

From Table F1.1, use section F5.

Get R_{pg}

$a_w = h \cdot t / (b_f \cdot t_f)$ (F4-11)
 $a_w = 960 \cdot 4 / (300 \cdot 20)$
 $a_w = 0.64 (< 10, \text{OK})$
 $R_{pg} = 1 - 0.64 / (1200 + 300 \cdot 0.64) \cdot (960/4 - 5.7 \cdot \sqrt{200000/345})$
 $R_{pg} = 0.953$

F5.1 Flange yield

$M_n = R_{pg} \cdot F_y \cdot S_{xc}$ (elastic mod)
 $M_n = 0.953 \cdot 345 \cdot 6.353E6 \text{ Nmm}$
 $M_n = 2088 \text{ kNm}$

F5.2 Lateral Torsional buckling

$h_o = 1000 - 20 = 980$

$$h = 1000 - 2 \cdot 20 = 960$$

$$r_t = 300 / \sqrt{12 \cdot (980/1000 + 0.64 \cdot 960^2 / (6 \cdot 980 \cdot 1000))}$$

$$r_t = 83.3$$

$$L_p = 1.1 \cdot 83.3 \cdot \sqrt{E/F_y} \quad (F4-7)$$

$$L_p = 2206$$

$$L_r = \pi \cdot 83.3 \cdot \sqrt{E/(0.7 \cdot F_y)} \quad (F5-5)$$

$$L_r = 7530$$

$$M_n = R_{pg} \cdot F_{cr} \cdot S_{xc} \text{ (elastic mod.)}$$

For $L_p < L_b < L_r$ use F5.2(b)

$$\text{Let } L_b = 5000$$

$$F_{cr} = 1.0 \cdot [345 - (0.3 \cdot 345) \cdot (5000 - 2206) / (7530 - 2206)]$$

$$F_{cr} = 290.6 \text{ MPa}$$

$$M_n = 0.953 \cdot 290.6 \cdot 6.353 \text{E6} \text{ Nmm}$$

$$M_n = 1759$$

$$\phi M_n = 1583 \text{ kNm}$$

For $L_b > L_r$ use F5.2(c)

$$\text{Let } L_b = 10000$$

$$F_{cr} = 1.0 \cdot \pi^2 \cdot 200000 / (10000/83.3)^2$$

$$F_{cr} = 137 \text{ MPa}$$

$$M_n = 0.953 \cdot 137 \cdot 6.353 \text{E6} \text{ Nmm}$$

$$M_n = 829$$

$$\phi M_n = 746 \text{ kNm}$$

← checking this value

F5.3 Flange local buckling
Flange is compact FLB not applicable

Chapter G. Shear

G2.1

$$h/t_w = 240 > 2.24 \cdot \sqrt{E/F_y} = 54 \text{ use G2.1(b)}$$

$$k_v = 5$$

$$1.1 \cdot \sqrt{k_v \cdot E/F_y} \quad (G2-3)$$

$$1.1 \cdot \sqrt{5 \cdot 200000 / 345} = 59.2$$

$$1.37 \cdot \sqrt{5 \cdot 200000 / 345} = 73.8$$

$$h/t > 73.8$$

$$C_v = 1.51 \cdot 200000 \cdot 5 / (240^2 \cdot 345)$$

$$C_v = 0.076$$

$$A_w = 1000 \cdot 4 = 4000$$

$$V_n = 0.6 \cdot F_y \cdot A_w \cdot C_v$$

$$V_n = 0.6 \cdot 345 \cdot 4000 \cdot 0.076 \text{ (N)}$$

$$V_n = 62.9 \text{ kN}$$

$$\phi V_n = 56.6 \text{ kN}$$

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Doubly symmetric slender web I – Test flexural capacity to F5

Code check to ANSI/AISC 360-05 : 2005

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Design loads

Axial load (Pr) = 0.00 kN
Shear load (Vry) = 0.00 kN-m
Required capacity moments (Chapter C). B2 is taken as zero.
Mr(x) = 0.00 Mr(y) = 0.00 kN-m
Moment x-x (Mx) = 0.00
Moment y-y (My) = 0.00

Effective lengths

Lb = 10000 Lx = 0 Ly = 0

Section Data

1000x300 20/4 PG rolled Fy = 345.0 MPa
D = 1000.0 Bf = 300.0 Tf = 20.0 tw = 4.0
Area = 15,840 mm² J = 1620480.05 mm⁴
Ix = 3.18E+09 mm⁴ Iy = 9.00E+07 mm⁴
Elastic Mod x-x = 6,353,024 Plastic Mod x-x = 6,801,600 mm³
Elastic Mod y-y = 600,034 Plastic mod y-y = 903,840 mm³
rx = 447.8 ry = 75.4 mm
Lx/rx = 0.0 Ly/ry = 0.0
Cw = 2.1609E+13 mm⁶
Web unstiffened
Lp = 2206.5 Lr = 7532.1mm
Mn(x) = 829.4 ← checking this value Mn(y) = 311.9kN-m

Member resistance capacity (Ø.Rn or Rn/Omega)

Axial
Pc(t)=4920.11 Pc(c)=2004.96
Moment
Mc(x) = 746.4 Eqn F5-4 Mc(y) = 280.7 Eqn F6-1
Shear
Vc = 56.6 Eqn G2-5

Code check results

Cb = 1
H1-1b - Compression. B2 = 0
Pr/2.Pc + (Mrx/Mcx + Mry/Mcy) = 0.00 + 0.00 + 0.00 = 0.00

G2-5 Shear.
Vr/Vc = 0.00

Section O.K. use 1000x300 20/4 PG

Consider 500x300 20/5 RHS (HSS) $F_y=275\text{MPa}$

Properties (mm units)

Depth = 500	Breadth = 300
Flange T = 20	Web t = 5
Radius = 0.0	Area = 16600
$I_{xx} = 772.7\text{E}6$	$I_{yy} = 190.0\text{E}6$
$r_x = 215.8$	$r_y = 107.0$

Elastic modulus X = $3.09\text{E}6$	Plastic modulus X = $3.41\text{E}6$
Elastic modulus Y = $1.267\text{E}6$	Plastic modulus Y = $1.58\text{E}6$
J = $374\text{E}6$	Cw = $4.4\text{E}12$

$C_b=1$	$C_{mx}=0.85$	$C_{my}=0.85$
$L_b=10000$	$K_x.L=10000$	$K_y.L=10000$

$K_x.L/r_x=10000/215.8 = 46.3$	$K_y.L/r_y=10000/107= 93.5$
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Loads

$P_r = 1000$	$M_{nx} = 500$	$M_{ny} = 10$	$V_r = 200$
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Chapter C

Assume $B_2=0$ $P_{e1} = \pi^2 EI / (K.L)^2$
 $P_{e1}(x) = \pi^2 * 200,000 * 772.7\text{E}6 / 10000^2 = 15239\text{kN}$
 $P_{e1}(y) = \pi^2 * 200,000 * 190.0\text{E}6 / 10000^2 = 3750\text{kN}$

LRFD

$B1x=0.85/(1-1*1000/15239)=$	$0.91 < 1. \text{ Use } 1.0$
$B1y=0.85/(1-1*1000/3750) =$	1.159

ASD

$B1x=0.85/(1-1.6*1000/15239)=$	$0.95 < 1. \text{ Use } 1.0$
$B1y=0.85/(1-1.6*1000/3750) =$	1.483

For LRFD, bending about x-x axis

$M_{rx}=B1*M_{nx}=500$

$M_{ry}=M_{ny}=10$

For LRFD, bending about y-y axis

$M_{rx}=M_{nx}=500$

$M_{ry}=B1*M_{ny}=11.6$

For ASD, bending about x-x axis

$M_{rx}=B1*M_{nx}=500$

$M_{ry}=M_{ny}=10$

For ASD, bending about y-y axis

$M_{rx}=M_{nx}=500$

$M_{ry}=B1*M_{ny}=14.8$

Chapter D Tension

$P_n=F_y*A_g$

$P_n=275*16600 = 4565\text{E}3 \text{ N} = 4565 \text{ kN}$

$\phi P_n = P_c(t) = 4108 \text{ kN}$

$P_n/\Omega = P_c(t) = 2733 \text{ kN}$

Chapter E Compression

Check compactness of section

$$\text{Flange} \quad b/t = \lambda_f = (300 - 2 \cdot 5) / 20 = 14.5$$

$$\text{Web} \quad h/t = \lambda_w = (500 - 2 \cdot 20) / 5 = 460 / 5 = 92$$

From table B4.1, case 12

$$\lambda_p = 1.12 \cdot \sqrt{E/F_y} = 30.2$$

$$\lambda_r = 1.4 \cdot \sqrt{E/F_y} = 37.8$$

$$\lambda_f < \lambda_p \quad \text{therefore flange is compact}$$

$$\lambda_w < \lambda_r \quad \text{therefore flange is slender}$$

To determine Q for slender stiffened element (E7.2(a)) need to get Fcr for Q=1

E3. Flexural buckling

$$F_e = \pi^2 E / (K \cdot L/r)^2$$

$$F_{ex} = \pi^2 \cdot 200000 / (46.3)^2 = 921 = 3.348 \cdot F_y > 0.44 F_y$$

$$F_{cr} = [0.658^{(F_y/F_e)}] \cdot F_y = 242 \text{ MPa}$$

$$F_{ey} = \pi^2 \cdot 200000 / (93.5)^2 = 225 = 0.82 \cdot F_y > 0.44 F_y$$

$$F_{cr} = [0.658^{(F_y/F_e)}] \cdot F_y = 165 \text{ MPa}$$

E4 Flexural-torsional buckling

Not applicable to this section

The lowest Fcr is for y-y Flexural buckling, 165MPa

E7.2(a)

(E7-17) using $f = F_{cr} = 165$

$$b_e = 1.92 \cdot t \cdot \sqrt{E/f} \cdot [1 - 0.34 / (b/t) \cdot \sqrt{E/f}]$$

$$b_e = 1.92 \cdot 5 \cdot \sqrt{200000/165} \cdot [1 - 0.34 / (92) \cdot \sqrt{200000/165}]$$

$$b_e = 291 (< 460)$$

$$Q_a = A_{eff}/Area$$

$$Q_a = [16600 - 2(\text{webs}) \cdot 5 \cdot (460 - 291)] / 16600$$

$$Q_a = 0.898$$

Using E7., the governing Fe is from y-y buckling

$$F_e = 225 \text{ MPa} > 0.44 \cdot 0.898 \cdot 276 = 108 \text{ MPa}$$

$$F_{cr} = Q[0.658^{(Q F_y/F_e)}] \cdot F_y$$

$$F_{crx} = 0.898 \cdot [0.658^{(0.898 \cdot 275 / 921)}] \cdot 275$$

$$F_{crx} = 220 \text{ MPa}$$

$$F_{cry} = 0.898 \cdot [0.658^{(0.898 \cdot 275 / 225)}] \cdot 275$$

$$F_{cry} = 156 \text{ MPa}$$

$$P_n(x) = 220 \cdot Area = 3652 \text{ kN}$$

$$P_n(y) = 156 \cdot Area = 2590 \text{ kN}$$

$$P_n(c) = 2590 \text{ kN}$$

$$\phi P_n = P_c(c) = 2331 \text{ kN}$$

$$P_n/\Omega = P_c(c) = 1551 \text{ kN}$$

Chapter F flexure

Major axis (x-x) bending

Check compactness of section

$$\text{Flange} \quad b/t = \lambda_f = (300 - 2 \cdot 5) / 20 = 14.5$$

$$\text{Web} \quad h/t = \lambda_w = (500 - 2 \cdot 20) / 5 = 460 / 5 = 92$$

From table B4.1, case 12

$$\lambda_p = 1.12 \cdot \sqrt{E/F_y} = 30.2$$

$$\lambda_r = 1.4 \cdot \sqrt{E/F_y} = 37.8$$

$$\lambda_f < \lambda_p \quad \text{therefore flange is compact}$$

From table B4.1, case 13

$$\lambda_p = 2.42 \cdot \sqrt{E/F_y} = 65.3$$

$$\lambda_r = 5.7 \cdot \sqrt{E/F_y} = 154$$

$$\lambda_w > \lambda_r \quad \text{therefore web is noncompact}$$

From Table F1.1, use section F7.

F7.1 Yield

$$\begin{aligned} M_n = M_p &= F_y \cdot Z_x \text{ (plastic modulus)} \\ &= 275 \cdot 3.41 \text{E6 (Nmm)} \\ &= 939 \text{ kNm} \end{aligned}$$

F7.2 Flange local buckling

(a) Flange is compact. FLB does not apply

F7.3 Web local buckling

(b) noncompact web

$$M_n = M_p - (M_p - F_y S_x (\text{elastic mod})) [0.305 \cdot h/t_w \cdot \sqrt{F_y/E} - 0.738]$$

$$M_{nx} = 939 - (939 - 275 \cdot 3.09 \text{E6}) \cdot (0.305 \cdot 92 \cdot \sqrt{275/200000} - 0.738)$$

$$M_{nx} = 912 \text{ kNm}$$

$$\phi M_{nx} = M_c(x) = 821 \text{ kNm}$$

$$M_{nx}/\Omega = M_c(x) = 546 \text{ kNm}$$

Minor axis (y-y) bending

Check compactness of section

$$\text{Flange} \quad b/t = \lambda_f = (500 - 2 \cdot 20) / 5 = 460 / 5 = 92$$

$$\text{Web} \quad h/t = \lambda_w = (300 - 2 \cdot 5) / 20 = 14.5$$

From table B4.1, case 12

$$\lambda_p = 1.12 \cdot \sqrt{E/F_y} = 30.2$$

$$\lambda_r = 1.4 \cdot \sqrt{E/F_y} = 37.8$$

$$\lambda_f < \lambda_r \quad \text{therefore flange is slender}$$

From table B4.1, case 13

$$\lambda_p = 2.42 \cdot \sqrt{E/F_y} = 65.3$$

$$\lambda_r = 5.7 \cdot \sqrt{E/F_y} = 154$$

$$\lambda_w > \lambda_r \quad \text{therefore web is compact}$$

F7.1 Yielding

$$M_n = M_p = F_y \cdot Z_y \text{ (plastic mod.)}$$

$$M_{ny} = 275 \cdot 1.58 \text{E6}$$

$$M_{ny} = 434.5 \text{ kNm}$$

F7.2 Flange local buckling

(c) Flange is slender

$$M_n = F_y \cdot S_{eff} \text{ (F7-3)}$$

$$b_e = 1.92 * 5 * \sqrt{200000/275} * (1 - 0.38/92 * \sqrt{200000/275})$$

$$b_e = 230 (< 460)$$

Get elastic section modulus for reduced top flange width

$$I_{elastic} (top) = 1.013E6 \text{ mm}^4$$

$$M_{ny} = 275 * 1.013E6$$

$$M_{ny} = 278 \text{ kNm}$$

$$\phi M_{ny} = M_c(y) = 250.7 \text{ kNm}$$

$$M_{ny}/\Omega = M_c(y) = 166.8 \text{ kNm}$$

Chapter G. Shear

G2.1 (a)

$$h/t_w = 92 > 2.24 * \sqrt{E/F_y} = 63.6$$

Therefore use G2.1(b)

$$\phi = 0.9, \Omega = 1.67$$

(i) $h/t_w < 260$, web unstiffened thus $k_v = 5$

$$1.1 * \sqrt{k_v E / F_y} = 66.3 \quad (\text{G2-3})$$

$$1.37 * \sqrt{k_v E / F_y} = 82.6 \quad (\text{G2-4})$$

$$h/t > 82.6$$

$$C_v = 1.51 * 200000 * 5 / ((92)^2 * 275)$$

$$C_v = 0.649$$

$$A_w = 2 * 500 * 5 = 5000 \text{ mm}^2$$

$$V_n = 0.6 * F_y * A_w * C_v$$

$$V_n = 0.6 * 275 * 5000 * 0.649$$

$$V_n = 535.2 \text{ kN}$$

$$\phi V_n = 481.7 \text{ kN}$$

$$V_n/\Omega = 320.5 \text{ kN}$$

$$\text{For LRFD, } V_r/V_c = 200/481.7 = 0.415 < 1 \text{ OK}$$

$$\text{For ASD, } V_r/V_c = 200/320.5 = 0.624 < 1 \text{ OK}$$

Chapter H. Combined forces

H1.1

Treating the loads as LRFD

$$P_r / P_c = 1000 / 2331 = 0.429 > 0.2 \text{ Use (H1-1a)}$$

$$P_r/P_c + 8/9 * (M_{rx} / M_{cx} + M_{ry} / M_{cy}) = 0.429 + 8/9 * (500/821 + 10/546)$$

$$= 0.429 + 0.541 + 0.016$$

$$= 0.987$$

Treating the loads as ASD

$$P_r / P_c = 1000 / 1551 = 0.489 > 0.2 \text{ Use (H1-1a)}$$

$$P_r/P_c + 8/9 * (M_{rx} / M_{cx} + M_{ry} / M_{cy}) = 0.645 + 8/9 * (500/546 + 10/166.8)$$

$$= 0.645 + 0.814 + 0.053$$

$$= 1.51$$

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RHS (HSS) section, slender for minor axis bending

Code check to ANSI/AISC 360-05 : 2005 (ver 1.0.0)

Design loads

Axial load (Pr) = 1,000.00 kN
Shear load (Vry) = 200.00 kN-m
Required capacity moments (Chapter C). B2 is taken as zero.
Mr(x) = 500.00 Mr(y) = 10.00 kN-m
Moment x-x (Mx) = 500.00
Moment y-y (My) = 10.00

Effective lengths

Lb = 10000 Lx = 10000 Ly = 10000

Section Data

500 x 300 20/5 RHS (HSS) rolled Fy = 275.0 MPa
D = 500.0 Bf = 300.0 Tf = 20.0 tw = 5.0
Area = 16,600 mm² J = 374776822.43 mm⁴
Ix = 7.73E+08 mm⁴ Iy = 1.90E+08 mm⁴
Elastic Mod x-x = 3,090,853 Plastic Mod x-x = 3,409,000 mm³
Elastic Mod y-y = 1,267,256 Plastic mod y-y = 1,578,500 mm³
rx = 215.8 ry = 107.0 mm
Lx/rx = 46.3 Ly/ry = 93.4
Cw = 4.399411E+12 mm⁶
Web unstiffened
Lp = 0.0 Lr = 0.0mm
Mn(x) = 915.0 Mn(y) = 278.5kN-m

Member resistance capacity (Ø.Rn or Rn/Omega)

Axial
Pc(t)=4110.00 Pc(c)=2351.54
Moment
Mc(x) = 823.5 Eqn F7-5 Mc(y) = 250.6 Eqn F7-3
Shear
Vc = 481.8 Eqn G2-5

Code check results

Cb = 1
H1-1a - Compression. B2 = 0
Pr/Pc + 8/9(Mrx/Mcx + Mry/Mcy) = 0.43 + 0.54 + 0.04 = 1.00

G2-5 Shear.
Vr/Vc = 0.42

Section fails

A general example for comparison

Consider W14x14.5x99

Fy= 345 MPa (50ksi)

Properties (mm units)

Depth = 360
Flange T = 19.8
Radius = 15
Ixx = 462.9E6
rx = 157

Breadth = 370
Web t = 12.3
Area = 18790
Iyy = 167.2E6
ry = 94.3

Elastic modulus X = 2.572E6
Elastic modulus Y = 0.9038E6
J = 2.237E6

Plastic modulus X = 2.838E6
Plastic modulus Y = 1.369E6
Cw = 4.836E12

Cb=1
Lb=10000

Cmx=0.85
Kx.L=15000
Cmy=0.85
Ky.L=10000

Kx.L/rx=15000/157 = 95.5

Ky.L/ry=10000/94.3 = 106

Loads

Pr=1000kN

Mnx=200kNm

Mny=50

Vr=500kN

Chapter C

Assume B2=0
 $Pe1 = \pi^2 EI / (K.L)^2$
 $Pe1(x) = \pi^2 * 200,000 * 462.9E6 / 15000^2 = 4061kN$

LRFD

$B1x = 0.85 / (1 - 1 * 1000 / 4061) = 1.128$

Therefore Mrx = 200 * 1.128 = 225.5kNm

Chapter D Tension

Pn=Fy*Ag

Pn= 345 * 18790 = 6482 kN

$\phi Pn = Pc(t) = 5834$ kN

$Pn/\Omega = Pc(t) = 3881$ kN

Chapter E Compression

Check compactness of section

Flange $b/t = \lambda = (370 / 2) / 19.8 = 9.34$

From table B4.1, case 3

$\lambda_r = 0.56 * \sqrt{E/Fy} = 13.5, > \lambda$ therefore flange is compact

Web $h/t = \lambda = (360 - 2 * (19.8 + 15)) / 12.3 = 290 / 12.3 = 23.6$

From table B4.1, case 10

$\lambda_r = 1.49 * \sqrt{E/Fy} = 35.9, > \lambda$ therefore web is noncompact

To determine Q for slender stiffened element (E7.2(a)) need to get Fcr for Q=1

E3. Flexural buckling

$Fe = \pi^2 E / (K.L/r)^2$

$Fex = \pi^2 * 200000 / (95.5)^2 = 216 = 0.63 * Fy > 0.44 Fy$

$Fcr = [0.658^{Fy/Fe}] * Fy = 177$ MPa

$Fey = \pi^2 * 200000 / (106)^2 = 176 = 0.51 * Fy > 0.44 Fy$

$Fcr = [0.658^{Fy/Fe}] * Fy = 151.7$ MPa

E4 Flexural-torsional buckling

Use (E4-4)

$Fe = [\pi^2 E * Cw / (Kz.L)^2 + GJ] * 1 / (Ix + Iy)$

$$F_e = [\pi^2 \cdot 200000 \cdot 4.836 \text{E}12 / (10000)^2 + 77200 \cdot 2.237 \text{E}6] \cdot 1 / (462.9 \text{E}6 + 167.2 \text{E}6)$$

$$F_e = 425.6 = 1.23 F_y$$

$$F_{cr} = [0.658^{(F_y/F_e)}] \cdot F_y = 246 \text{MPa}$$

The lowest F_{cr} is for y-y Flexural buckling, 151.7 MPa

$$P_n(x) = \min(177, 246) \cdot \text{Area} = 3325 \text{ kN}$$

$$P_n(y) = \min(151.7, 246) \cdot \text{Area} = 2850 \text{ kN}$$

$$P_n(c) = 2850 \text{ kN}$$

$$\phi P_n = P_c(c) = 2565 \text{ kN}$$

$$P_n / \Omega = P_c(c) = 1706 \text{ kN}$$

Chapter F flexure

Check compactness of section

$$\text{Flange} \quad b/t = \lambda = (370 / 2) / 19.8 = 9.34$$

From table B4.1, case 1

$$\lambda_p = 0.38 \cdot \sqrt{E/F_y} = 9.14$$

$$\lambda_r = 1.00 \cdot \sqrt{E/F_y} = 24.1$$

$$\lambda_p < \lambda < \lambda_r \quad \text{therefore flange is noncompact}$$

$$\text{Web} \quad h/t = \lambda = (360 - 2 \cdot (19.8 + 15)) / 12.3 = 290 / 12.3 = 23.6$$

From table B4.1, case 9

$$\lambda_p = 3.76 \cdot \sqrt{E/F_y} = 90.5$$

$$\lambda_r = 5.7 \cdot \sqrt{E/F_y} = 137$$

$$\lambda < \lambda_p \quad \text{therefore web is compact}$$

From Table F1.1, use section F3.

Get M_p

$$M_n = M_p = F_y \cdot Z_x \text{ (plastic modulus)}$$

$$= 345 \cdot 2.838 \text{E}6 \text{ (Nmm)}$$

$$= 979 \text{E}6 \text{ Nmm}$$

$$= 979.1 \text{ kNm}$$

F3.1 Lateral Torsional buckling, Use F2.2

$$L_p = 1.76 \cdot r_y \cdot \sqrt{E/F_y} \quad (\text{F2-5})$$

$$L_p = 3996$$

$$r_{st} = \sqrt{I_y \cdot C_w / S_x} \quad (\text{F2-7})$$

$$r_{st} = 105$$

$$h_o = 360 - 19.8$$

$$h_s = 340.2$$

$$L_r = 1.95 \cdot 105 \cdot 200000 / (0.7 \cdot 345) \cdot \sqrt{2.237 \text{E}6 / (2.572 \text{E}6 \cdot 340.2)} \cdot$$

$$\sqrt{1 + \sqrt{1 + 6.76 \cdot [0.7 \cdot 345 \cdot 2.572 \text{E}6 \cdot 340.2 / (200000 \cdot 2.237 \text{E}6)]^2}} \quad]$$

$$L_r = 13781 \quad (\text{F2-6})$$

For $L_b = 10000$, $L_p < L_b < L_r$ therefore use F2.2(b)

$$M_n = 1.0 \cdot [979 \text{E}6 - (979 \text{E}6 - 0.7 \cdot 345 \cdot 2.572 \text{E}6) \cdot (10000 - 3996) / (13781 - 3996)] \text{ (Nmm)}$$

$$M_n = 759 \text{ kNm} < M_p \quad (\text{F2-2})$$

F3.2 Flange local buckling

Flange is noncompact, use (F3-1)

$$\lambda = 9.34$$

$$\lambda_p = 0.38 \cdot \sqrt{E/F_y} = 9.14$$

$$\lambda_r = 1.00 \cdot \sqrt{E/F_y} = 24.1$$

$$M_n = 979.1 - (979.1 - 0.7 \cdot 354 \cdot 2.572) \cdot (9.34 - 9.14) / (24.1 - 9.14)$$

$$M_n = 974 \text{ kNm}$$

Governing M_n is LTB = 759 kNm

$$\phi M_{nx} = M_c(x) = 683 \text{ kNm}$$

$$M_{nx}/\Omega = M_c(x) = 454.5 \text{ kNm}$$

Minor axis

F6.1 Yielding

$$M_n = M_p = F_y \cdot Z_y \text{ (plastic mod.)} \leq 1.6 \cdot F_y \cdot S_y \text{ (elastic mod.)}$$

$$M_{ny} = 345 \cdot 1.369 \text{ E6}$$

$$M_{ny} = 472 \text{ kNm}$$

$$1.6 \cdot F_y \cdot S_y = 499 \text{ kNm}$$

$$M_{ny} = 595.1$$

$$\phi M_{ny} = M_c(y) = 424.8 \text{ kNm}$$

$$M_{ny}/\Omega = M_c(y) = 282.6 \text{ kNm}$$

Chapter G. Shear

G2.1 (a)

$$h/t_w = 23.6 < 2.24 \cdot \sqrt{E/F_y} = 54$$

Therefore $C_v = 1$ (G2-2) and $\phi = 1.0$, $\Omega = 1.5$

$$V_n = 0.6 \cdot F_y \cdot A_w \cdot C_v$$

$$V_n = 0.6 \cdot 345 \cdot 360 \cdot 12.3 \cdot 1.0 \text{ (N)}$$

$$V_n = 916.6 \text{ kN}$$

$$\phi V_n = 916.6 \text{ kN}$$

$$V_n/\Omega = 611 \text{ kN}$$

$$\text{For LRFD, } V_r/V_c = 500/916.6 = 0.55 < 1 \text{ OK}$$

$$\text{For ASD, } V_r/V_c = 500/611 = 0.82 < 1 \text{ OK}$$

Chapter H. Combined forces

H1.1

Treating the loads as LRFD

$$P_r / P_c = 1000 / 2565 = 0.39 > 0.2 \text{ Use (H1-1a)}$$

$$P_r/P_c + 8/9 \cdot (M_{rx} / M_{cx} + M_{ry} / M_{cy}) = 0.389 + 8/9 \cdot (225.5/683 + 50/424.8)$$

$$= 0.389 + 0.293 + 0.105$$

$$= 0.787$$

Treating the loads as ASD

$$P_r / P_c = 1000 / 1706 = 0.586 > 0.2 \text{ Use (H1-1a)}$$

$$P_r/P_c + 8/9 \cdot (M_{rx} / M_{cx} + M_{ry} / M_{cy}) = 0.586 + 8/9 \cdot (225.5/454.5 + 50/282.6)$$

$$= 0.586 + 0.441 + 0.157$$

$$= 1.184$$

20.2.1 Validation calculations for ANSI/AISC 360-10 for singly symmetric I shapes

Section				b/t or h/t			
D	1000	tw	10	98.00	Fy=	248.22	36ksi
BF1 (top)	300	TF1	10	15.00	E =	199955	29000ksi
BF2 (bot)	500	TF2	10	25.00	sqrt(E/Fy)=	28.38	
				ho =	990.00		
Plastic modulus (maj)=	6,261,000.00			hc1=	1,091.24	hp1=	1180 (to top)
Elast. Mod top=	4,840,612.87			hc2=	868.76	hp2=	780 (to bot)
Elast. Mod bot=	6,052,296.00			rx=	388.71	ry=	84.38
Cw=	1.81E+13	Jtorsion=	593,333.33	Area=	17800		
Ixx=	2.69E+09	Iyy=	1.27E+08	Pl mod (min)	874500		
Compression flange is always the top flange.				El mod (min)	506993.3		

Loading	Lb=	8,000.00	Klx =	6,000.00	kLy=	4000
	Pr=	200.00	Mx=	400.00	My=	20

F13 Proportions of beams and girders

F13.2	lyc=	22,500,000.00	lyc/ly=	0.18	<= 0.1 <=0.9	OK
	ly=	126,748,333.33				

B4 Classification of Section for local buckling

Check compactness using Table B4.1 and, for axial compression, with E7.1 as well

Flexure

Flanges

Rolled, Table B4.1, case 1

Lam_p=0.38*sq(E/Fy)	10.79	lam_r = 1*sq(E/Fy)=	28.38
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Fabricated, case 2	kc = 4/sqr(h/tw)=	0.40 (0.35<kc<0.76)	0.40
--------------------	-------------------	---------------------	------

Compression flange is always the top flange.	FL=	173.75	Sxt/Sxc =	1.25
--	-----	--------	-----------	------

Lam_pf =0.38*sq(E/Fy) =	10.79	rolled/fab	TableB4.1 case 2
lam_rf = 0.95*sq(kc*E/FL)=	20.49	fabricated	TableB4.1 case 2
comp flange bc/tc=	15.00	NC	Flexural compression flange checks, F4.3, F5.3
Max flange b/t=	25.00	SL	both flanges, for F6, minor axis bending

Web, case 11. Assume My, hc and hp all refer to the compression flange (My=Sxc*Fy)

Lam_p=hc/hp*sq(E/Fy) /[0.54*PL_mod/EL_mod (top or bot) -0.09]^2

Lam_pw 1(C is top)=	70.90
---------------------	-------

Lam_pw 2(C is bot)=	143.95
---------------------	--------

lam_rw=5.7sq(E/Fy)=	161.78
---------------------	--------

Web h/tw=	98.00	NC
-----------	-------	----

Web C or NC, use F4

Uniform compression

This uses B4.1 and E7.1

Flanges, fabricated (case 4)

Lam_pf =NA	lam_rf =0.64*sq(Kc*E/Fy) =	11.55
flange b/tmax=	25.00	SL in compression, use E7.1
0.64sq(E.kc/Fy)=	11.55	Table B4.1 case 4
1.17sq(E.kc/Fy)=	21.11	E7.1 (b)(iii)
Qs for b/tmax=	0.47	(E7-9)

Web (case 14)

Lam_p=NA	lam_r=1.49 *sq(E/Fy)=	42.29
Web h/tw=	98.00	SL in compression, use E7.2

E7.2 (a) b/t >= than limit, use (E7-17). Get iterated be rather than use Fcr, press button

be=	980.00
-----	--------

Qa=	1
-----	---

Q=Qs.Qa=	0.47
----------	------

KLy/ry =	47.40	KLx/rx=	15.44
Minor axis			
4.71sq(E/Q Fy)= Lim =	195.26	KL/r max=	47.40
(E3-4) Fe=	878.28	ro^2=	158,217.97 (E4-7)
(E4-5) Fe=	215.41	Fex=	8,282.97 (E4-9)
		Fey=	878.28 (E4-10)
		Fez=	215.41 (E4-11) for (E4-5)
Minimum Fe =	215.41	H=	1.00
(E3-2, E7-2) Fcr=	92.80 (KL/r<=lim)		
(E3-3, E7-3) Fcr=	188.92 (KL/r>lim)		
KL/r max Fcr =	92.80		
Pn =	1,651.91 kN		
LRFD, phi_c=	0.90	omega=	1.67
Pc = LRFD	1,486.72	ASD	989.17

Chapter F, flexure

Max Mp=Fy*PI mod = 1,554.11

F4. C or NC web

Get Rpc	Mp=	1,554.11	
	Myc=	1,201.54 (top C)	
hc/tw=	lam=	109.12	
	lam_pw	70.90 C=top (B4.1 11)	
	lam_rw	161.78 (B4.1 11)	
Rpc (F4-9b)	1.17 <= Mp/Myc	1.17	

1 Compression flange yield

(F4-1) Mn = 1,405.81

2 LTB

Get rt	aw for compression flange, top=	3.64
	ho =	990.00
	bfc=	300.00
	h =	980.00
(F4-10)	rt =	68.94

(F4-6)	FL=	173.75 Sxt/Sxc =	1.25
(F4-7)	Lp=	2,152.29	
(F4-8)	Lr =	7,557.45	
(F4-2)	Mn =	794.84 <=RpcMyc	794.84

(F4-5)	Fcr=	146.55	Cb=1	lyc/ly=	0.177517
(F4-3)	Mn =	709.37 <=RpcMyc	709.37	Fcr,J=0	146.5461

Mn to use (Lb,Lp etc) 709.37 Lb>Lr

3 Compression flange local buckling

Not applicable for compact flanges

bfc/2.tfc=	Lam =	15.00	
	lam_pf	10.79	
	lam_rf	20.49	
(F4-12)	Mn =	1,160.43 for NC flanges only	
(F4-13)	Mn=	1,564.37 for SL flange	
Mn to use (flg NC,SL)=	1,160.43	Comp flange is	NC

	Mp=	1,554.11		
hc/tw=	lam=	109.12		
(F4-15a)	Rpt(i)=	1.03		
(F4-15b)	Rpt(ii)=	1.02	<Mp/Myt	1.02
Rpt to use =		1.02		
(F4-14)				
Mn to use	Mn=	1,554.11		

Minimum Mn for F4 flexure

	Mnx =	709.37	omega=	1.67
Mcx = phi * Mnx =		638.44	ASD	424.77

F5. SL web

Get Rpg	aw =	3.64	<=10	3.64
Rpg (F5-6) =	1.08	(<=1)	1.00	

1. Compression flange yield (top flg in C)

(F5-1)=	Mn =	1,201.54 kN-m
---------	------	---------------

2. LTB (F5-2)

For Lb<=Lp LTB not considered

(F4-7)	Lp=	2,152.29		
(F5-5)	Lr =	7,347.00		
	Lb =	8,000.00	therefore use (F5-3)	
	Cb =	1.00		
(F5-3)	Fcr =	164.39	<=Fy	164.39 (F5-3)
(F5-4)	Fcr=	146.55	<=Fy	146.5461 (F5-4)
(F5-2)	Mn=	795.76		with (F5-3)
(F5-2)	Mn=	709.37		with (F5-4)
Mn to use (Lb,Lp etc)		709.37	Lb>Lr	

3. Compression flange local buckling

Not applicable for compact flanges

bfc/2.tfc=	Lam =	15.00		
	lam_pf	10.79		
	lam_rf	20.49		
(F5-8)	Fcr =	215.86	for NC flanges only	
(F5-9)	Fcr=	323.18	for SL flange	
(F5-7)	Mnx =	1,044.92	(F5-8)	
(F5-7)	Mnx =	1,564.37	(F5-9)	
Mn to use (flg NC,SL)=		1,044.92		

4. Tension flange yielding

If Sxt > Sxc then not applicable

(F5-10)	Mn=	1,502.30 (bott)
Mn to use	Mn=	1,554.11 Sxt>=Sxc

Minimum Mn for F5 flexure

Mnx =	709.37	omega=	1.67
Mcx= phi*Mnx =	638.44	ASD	424.77

F6 Minor Axis

1 Yielding

		FySy	1.6FyZy	(<= UK nomenclature)
(F6-1)	Mn =	201.35	217.07	201.35

2 Flange local yield

lam (mx)	25.00
lam_pf=	10.79
lam_rf=	20.49

(F6-3)Mn =111.92

Mn to use (flange b/t)111.92 flange SL

LRFD, phi_b =0.90omega=1.67

Mcy =100.73ASD67.02

Chapter H

Web C or NC, use F4

		LRFD		ASD	
		Pr/Pc= 0.13		Pr/Pc= 0.20	
		>= 0.2	< 0.2	>= 0.2	< 0.2
		(H1-1a)	(H1-1b)	(H1-1a)	(H1-1b)
F4					
Pr/Pc		0.13	0.07	0.20	0.10
Mrx/Mcx		0.56	0.63	0.84	0.94
Mry/Mcy		0.18	0.20	0.27	0.30
IR =		0.87	0.89	1.30	1.34
F5					
Pr/Pc		0.13	0.07	0.20	0.10
Mrx/Mcx		0.56	0.63	0.84	0.94
Mry/Mcy		0.18	0.20	0.27	0.30
IR =		0.87	0.89	1.30	1.34

PROJECT : Toolkit validation
SUBJECT : AISC ASD 1989 9th Ed
Calc by: GJS Date : 14-Oct-2012 Checked :

Sheet of
Job No : 0000
Revision :
Date :

Singly symmetric beam-column

Code check to ANSI/AISC 360-10 : 2010 (ASD)

Design loads (limit state)

	kN		kN-m
Axial load (Pu)	= 200.00	Moment x-x (Mx)	= 400.00
Shear load (Vuy)	= 0.00	Moment y-y (My)	= 20.00

Required capacity moments (Chapter C). B2 is taken as zero.
Mu(x) = 400.00 Mu(y) = 20.00 kN-m

Effective lengths

Lb = 6000 Lx = 6000 Ly = 4000

Section 1000 300x10 500x10 welded	Fy = 248.2 MPa
D = 1000.0 tw = 10.0	Bf top = 300.0 Tf top = 10.0
flex compression flange is top	Bf bot = 500.0 Tf bot = 10.0
Area = 17,800 mm ²	J = 593333.33 mm ⁴
Ix = 2.69E+09	Iy = 1.27E+08 mm ⁴
Elastic Mod x-x = 4,840,613	Plastic Mod x-x = 6,261,000 mm ³
Elastic Mod y-y = 506,993	Plastic mod y-y = 874,500 mm ³
rx = 388.7	ry = 84.4 mm
Lx/rx = 15.4	Ly/ry = 47.4 Cw = 1.813507E+13 mm ⁶

Web unstiffened

Lp = 2152.3	Lr = 7557.3 mm
Mn(x) = 709.3	Mn(y) = 111.9 kN-m

Member resistance capacity (Ø.Rn or Rn/Omega)

Axial	
Pc(t) = 2645.55	Pc(c) = 988.48
Moment	
Mc(x) = 424.8 Eqn F4-3	Mc(y) = 67.0 Eqn F6-3
Shear	
Vc = 564.7 Eqn G2-5	

Code check results

Cb = 1
H1-1a - Compression. B2 = 0
Pr/Pc + 8/9(Mrx/Mcx + Mry/Mcy) = 0.20 + 0.84 + 0.27 = 1.30
Shear. G2-5
Vr/Vc = 0.00

Section fails

20.2.2 Tee section

Spread sheet validation calculation. Units are metric (N, mm)

Input		Lengths			
Fy	350	Lb	5000		
D	300	KLx	4000		
B	100	Kly	4000		
Tf	15				
tw	10	E =	200000	(Young's mod)	
Properties					
Area	4350				
Ixx	41431131.47	Iyy	1273750		
rx	97.59	ry	17.11		
J	207500	Cw	0		
Plastic mod					
xx	371812.5	Elastic mod	391687.96	flange	
x axis to top	105.78	Elastic mod	213316.08	stem	
x axis to bot	194.22	Min	213316.08		
Applied loads					
	Axial	50	kN	fa=	11.49
	Mxx	20	kNm	fbx max=	93.76
	Fv	100	kN	fv=	33.33

Chapter E Compression

E7 (this is the same as E3 with Q=1)

Check slenderness

Flange. Use E7.1.(a)

	b/t (lim)	b/t =B/2/Tf	3.33
(i)	13.39		
(ii)	24.62		
Qs flge=	1.00		

	Stem. Use E7.1.(d)	d/t	30.00
(i)	17.93		
(ii)	24.62		
Qs stem =	0.44		

Qs = min()

Elastic buckling stresses

(E3-4)	Fex =	1175.03	Fey =	36.12
			Fcry=	31.68
(E4-2)	Fcrz =	195.94	yo=0, xo=	98.28

		ro_bar^2	19475.36
Fcr=	29.15	H =	0.50

Ref commentary table C-E4.2

flange B/Tf =	0.33	< 0.5	Flex-torsional buckling must be checked
stem D/tw =	1.50	>1.25	Flex-torsional buckling need not be checked

Min Fcr	min(Fe,Fcr)	29.15
---------	-------------	-------

Axial capacity	Pn =Fcr.Ag	126.82	kN
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Chapter F Flexure

F9 - loaded in plane of symmetry

1. Yielding

Mp (xx) = Fy Zx(pl)	130.13	kNm	My(xx)	74.66	(min EI mod value)
Mn(T) =min(Mp,1.6My)	119.46	kNm	(stem is always in tension)		
Mn (C) =My	74.66	kNm	(Stem is in compression)	Fyn	350

2. Lateral-Torsional Buckling

B = +- 0.34	(+ve for stem in tension, else -ve)
-------------	-------------------------------------

Mcr1 =	40859308.15	(Nmm)
Mcr (T) =	57.15	kNm (Tension in stem)
Mcr (C) =	29.21	kNm (Compression in stem)

If Lb = 0 then from commentary (C-F9-1)

Mcr =	60.87
-------	-------

Mn(LTB) =	29.21	kNm	(assumes stem in compression)
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3. Flange local buckling

Table B4.1 case 7

0.38sqrt(E/Fy)	9.08	Compact	flange b/t	3.33
1.0sqrt(E/Fy)	23.90	noncompact		
			Fcr	
Compactness	C		C	350.00
Fcr =	350		NC	392.10
			S	12420.00

Mn(FLB)	74.66	kNm
---------	-------	-----

Mn (xx)	29.21	kNm	(min of Mny, MnLTB, MnFLB)	Fbmin	136.94
				Mn/Z(el)min	

**Chapter
G2.(b)**

				h/tw	Cv
h/tw	30	kv = 1.2	(b)(i)	28.80	1
			(b)(ii)	35.88	0.96
Vn	604.90		(b)(iii)	35.88	1.15
Vc LRFD	544.41			Cv used	0.96
Vr/Vc LRFD	0.18				

Chapter H1.

Check applicability of H1.1 as $l_{yc}/l_y \leq 0.9$ is not normally met with Tee section

$l_{yc}/l_y = 0.98 > 0.9$ H1.1 is not applicable

LRFD, $\phi = 0.9$

Pc = 114.14
Mc = 26.29

(H1-1a) Pr/Pc 0.44 Pr/Pc = 0.44 Use (H1-1a)
8/9.Mr/Mc 0.68
Sum 1.11 <==

(H1-1b) Pr/2.Pc 0.22
Mr/Mc 0.76
Sum 0.98

Chapter H2.

fa/Fa 0.44
fbw/Fbw 0.76 Stem in bending compression
fbz/Fbz 0
1.20

fa/Fa 0.44
fbw/Fbw 0.39 Stem in bending tension
fbz/Fbz 0
0.83

PROJECT : Toolkit validation
 SUBJECT : ANSI/AISC 360-10 LRFD
 Calc by: GJS Date : 14-Oct-2012 Checked :

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 Job No : 0000
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Tee section beam-column

AISC 360-10 LRFD. Check Tee section

Design loads

	kN		kN-m
Axial load (Pr)	= 50.00	Moment x-x (Mrx)	= 20.00
Shear load (Vry)	= 100.00	Moment y-y (Mry)	= 0.00

Required capacity moments (Chapter C). B2 is taken as zero.

Mr(x) = 20.00	Mr(y) = 0.00	kN-m
---------------	--------------	------

Effective lengths

Lb = 4000	Lx = 4000	Ly = 4000
-----------	-----------	-----------

Section

Depth = 300.0	Breadth = 100.0	Fy = 350.0 MPa	
Area = 4,350 mm ²		T flange = 15.0	t stem = 10.0
Ix = 4.14E+07		J = 207500.00 mm ⁴	
		Iy = 1.27E+06 mm ⁴	

Elastic Mod x-x flange = 391,688

Elastic Mod x-x stem = 213,316

Elastic Mod y-y = 25,475

Plastic Mod x-x = 371,813 mm³

Plastic mod y-y = 44,625 mm³

rx = 97.6

ry = 17.1 mm

Lx/rx = 41.0

Ly/ry = 233.8

Distances to elastic neutral axis

Top (flange)	105.8
--------------	-------

Bottom (stem)	194.2
---------------	-------

Section elastic stresses

faxial = 11.49

fbx flange = -51.06

fbx stem = 93.76

Code check results

H2-1 - Stem in bending compression

$f_a/F_a + f_{bw}/F_{bw} + f_{bz}/F_{bz} = 0.45 + 0.77 + 0.00 = 1.22$

Shear. G2-3

Vr/Vc = 0.18

Section fails

20.3 Web load capacities. SI units

Spread sheet checks

	AISC ASD 1989	ANSI/AISC 360	360*phi	360/omega	914x419UB388 D = 920.4 Bf = 420.5 Tf = 36.6 tw = 21.5 Fy= 355 MPa E= 200000 MPa	h= 847
1 Flange local bending						
Resistance N	1783289.25	2972148.75	2674933.88	1779729.79		
In span (kN)	1783.29	2972.15	2674.93	1779.73		
At end (kN)	1783.29	1486.07	1337.47	889.86		
2 local web yielding					N = 173 k = 60.7 l = 1500 (x-6, -7) Cr= 6.62E+06 (x-6, -7)	dc = 799
Resistance (N)	2400344.93	3636886.25	3636886.25	2424590.83		
Span (kN)	2400.34	3636.89	3636.89	2424.59		
At end (kN)	1635.91	2478.65	2478.65	1652.44		
3 Web crippling (kN)						
span x-4	2521.98	5097.69	3823.26	2548.84		
end x-5(a)	1260.99	2548.84	1911.63	1274.42		
end x-5(b)		2537.83	1903.37	1268.91		
4 Web sideways buckling (kN)						
restr x-6	248906.60	1812232.76	1540397.84	1029677.70		
restr x-7	248357.48	1808877.83	1537546.16	1027771.50		
8 Web compression buckling (kN)						
Resistance	2380.42	2372.30	2135.07	1420.54		
ASD * 0.6	1428.25					

PROJECT : Toolkit validation
SUBJECT : ANSI/AISC 360-10 LRFD
Calc by: GJS Date : 17-Oct-2012 Checked :

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Web load capacities check AISC 360-10 LRFD

ANSI/AISC 360-10. Section J10. Flanges and webs with concentrated forces

Design method = LRFD

Units are; kN, mm, MPa

Section : 914x419UB388

D = 920.40

Bf = 420.50

Tf = 36.60

tw = 21.50

Input data

Flange yield Fyf 355.00

Web yield Fyw 355.00

Bearing length N 173.00

Distance k 60.70

Unbraced l 1500.00

Design force on flange 1000.00

Mu or Ma 0.00

Resistance factors

J10.1 $\phi = 0.9$

J10.2 $\phi = 1$

J10.3 $\phi = 0.75$

J10.4 $\phi = 0.85$

J10.5 $\phi = 0.9$

Interaction ratios.

J10.1. Flange local bending

Load is at beam end.

Resistance (J10-1) = 1337.39

IR = 0.75 **OK**

J10.2. Web local yielding

Load is at beam end.

Resistance (J10-3) = 2478.52

IR = 0.40 **OK**

J10.3. Web crippling

Load is at beam end.

Resistance (J10-5a) = 1911.28

IR = 0.52 **OK**

J10.4. Web sideway buckling

My = 3877.96

Cr = 6619008.18

Compression flange is not restrained.

Resistance (J10-7) = 1537229.56

IR = 0.00 **OK**

NB (h/tw)/(l/bf) > 1.7, check not required

J10.5. Web compression buckling

Load is at beam end

Resistance (J10-8) = 1067.34

IR = 0.94 **OK**

PROJECT : Toolkit validation
SUBJECT : AISC ASD 1989 9th Ed
Calc by: GJS Date : 17-Oct-2012 Checked :

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Job No : 0000
Revision :
Date :

Web load capacities check AISC 1989 ASD

AISC ASD 1989. Section K1. Webs and flanges under concentrated forces

Units are; kN, mm, MPa

Section : 914x419UB388

D = 920.40 Bf = 420.50 Tf = 36.60 tw = 21.50

Input data

Flange yield Fyf 355.00

Web yield Fyw 355.00

Bearing length N 173.00

Distance k 60.70

Unbraced l 1500.00

Design force on flange 0.00

Interaction ratios.

K1.2. Local Flange bending

Resistance (K1-1) = 1783.19

IR = 0.00 **OK**

K1.3. Local web yielding

Load is at beam end.

Resistance (K1-3) = 1635.82

IR = 0.00 **OK**

K1.4. Web crippling

Load is at beam end.

Resistance (K1-5) = 1271.99

IR = 0.00 **OK**

K1.5. Sideway web buckling

Compression flange is not restrained.

Resistance (K1-7) = 248739.55

IR = 0.00 **OK**

NB $(h/tw)/(l/bf) > 1.7$, check not required

K1.6. Compression buckling of web

Resistance (K1-8) = 1427.63

IR = 0.00 **OK**

21.0 NORSOK N-004 rev. 2 Oct 2004

Tubular section.

Other shapes are designed to NE 1993 (Eurocode 3) which is validated above

NORSOK
Tubular members

Tubular section 1000x15

Design loads

P = 1000kN compression	My = 500kNm	Mz = 200kNm
P = 1000kN Tension	My = 500kNm	Mz = 200kNm

Hydrostatic pressure = 500kPa, with compression loading

NORSOK N-004

Tubular		beam-col		
D	1000.00	kLy	20000	
tw	15.00	kLz	15000	
Area	46417.03			
I	5630676022.16	Axial (kN)	1000	1000000
				50000000
r	348.29	My (kNm)	500	0
				20000000
Wel	11261352.04	Mz	200	0
Wpl (Z)	14554500.00	Shear	500	500000
Eyoung	210000.00			
fy	235.00			
		Stresses	MPa	
Cmy	0.85	fcsd	69.36	
Cmz	0.85	fa.sd	21.54	
		fmy.sd	44.40	
		fmz.sd	17.76	

6.3.2

Nt.Rd	9485219.47	9485.219	kN
-------	------------	----------	----

6.3.3 Axial compression

fcle	1890.00	
fy/fcle	0.12	
fcl	235.00	
Lbar	0.61	
fc	210.40	
Nc.Rd	8492261.08	8492.261
Ney	29175586.05	29175.59
Nez	51867708.53	51867.71
Ncl.rd	9485219.47	

6.3.6.1 Hoop buckling

L	15000	p.sd (kPa)	500.00	0.5
mu	173.2050808	fpsd	16.67	(6.16)
Ch	0.0066	fq.sd	8.33	
fhe	41.58	fh	41.58	
		fh.rd	36.16	

6.3.7 Material Factor

Lamc	0.352616824	fp.sd/fh.rd	0.46	(6.15)
Lamh	2.37734214	B	0.46	
		fmh.rd	215.63	

Lams	0.486042076	neta	4.29
gammaM	1.15		

6.3.4 Bending

fyD/Et	0.07		
fm	284.75		
M.Rd	2788364971.43	2788.365	kNm

6.3.8 Combined load without hydrostatic

6.3.8.1

$(N_{sd}/N_{tsd})^{1.75}$	0.02		
$(M_{ysd}^2 + M_{zsd}^2)^{0.5} / M_{rd}$	0.19		
	0.21	(6.26)	

6.3.8.2

Nsd/Ncrd	0.12		
Cmy.Mysd/(1-Nsd/Ney)	4.4E+08		
	1.73E+0		
Cmz.Mzsd/(1-Nsd/Nez)	8		
$1/M_{rd} \{ \dots \}^2$	0.17		
	0.29	(6.27)	

Nsd/Nclr

d	0.11		
$[M_{ysd}^2 + M_{zsd}^2]^{0.5} / M_{rd}$	0.19		
	0.30	(6.28)	

6.3.9.2 Axial compression and hydro

6.45 fey	628.55		
6.46 fez	1117.43		
6.47,48	1.39	fch.rd (6.47)	176.55
6.49 eta	0.90	fch.rd (6.48)	491.91
fch.rd	176.55		

6.43

fa.sd/fch.rd	0.12		
$[C_{my} \cdot f_{my}.sd / (1 - f_{a}.sd / f_{ey})]^2$	1527.179		
$[C_{mz} \cdot f_{mz}.sd / (1 - f_{a}.sd / f_{ez})]^2$	236.9335		
$1/f_{mh}.rd [\dots]^{0.5}$	0.19		
	0.32	(6.43)	

6.44

$(f_{a}.sd + f_{q}.sd) / f_{cl}.rd$	0.15		
$\text{sqr}(f_{my}.sd^2 + f_{mz}.sd^2) / f_{mh}.rd$	0.22		
	0.37	(6.44)	

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PROJECT : Validate Toolkit

SUBJECT : NORSOK N-004

Calc by : gjs

Date : 28-Nov-07

Checked :

Date :

Vol. Sec

Sheet of

Job No : 1234

Beam-column Compression

Code check to NORSOK N-004 rev 2 2004

Design loads (limit state)

kN
Axial load (N.Sd) = 1,000.00
Shear (vect sum) = 500.00
Moment x-x (Mt.Sd) = 0.00

kN-m
Moment y-y (My.Sd) = 500.00
Moment z-z (Mz.Sd) = 200.00

Section data

1000CHS15	Grade = S235	Fy = 235 MPa	w = 364 kg/m
Dia = 1000	t = 15	D/t = 66.67	
Area = 46,417 mm ²		I _{y,z} = 5,630,671,266 mm ⁴	
Wel _{y,z} = 11,261,343		Wpl _{y,z} = 14,554,500 mm ³	
i _y = 348.3	Ly-y = 20000	Ly/i _y = 57.4	
i _z = 348.3	Lz-z = 15000	Lz/i _z = 43.1	

Section Design Resistances (kN, kNm)

Nt.Rd = 9485.21	Ncy.Rd = 8492.25	Ncz.Rd = 8926.67
M.Rd = 2788.36	Mt.Rd = 2657.23	V.Rd = 2738.14

Code check results

Material factor gamma_M (6.3.7) = 1.150

6.3.5 Shear, 6.3.8.3 Shear interaction

(6.13) $V.Sd / Vpl.Rd = 0.18$ (6.32)

M.Sd / M.Rd = 0.19

(6.14) Torsion $Mt.Sd / Mt.Rd = 0.00$

6.8.3.2 axial compression and bending without hydrostatic load

C_{my} = 0.85 C_{mz} = 0.85

(6.27) $0.12 + 0.17 = 0.29$

(6.28) $0.11 + 0.19 = 0.30$

Section O.K. use 1000CHS15

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PROJECT : Validate Toolkit

SUBJECT : NORSOK N-004

Calc by : gjs

Date : 28-Nov-07

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Job No : 1234

Beam-column Compression - Hydrostatic

Code check to NORSOK N-004 rev 2 2004

Design loads (limit state)

kN
Axial load (N.Sd) = 1,000.00
Shear (vect sum) = 500.00
Moment x-x (Mt.Sd) = 0.00

kN-m
Moment y-y (My.Sd) = 500.00
Moment z-z (Mz.Sd) = 200.00

N.Sd excludes the member end hydrostatic cap load of kN

Code check uses section 6.3.9, Method A

Section data

1000CHS15 Grade = S235 Fy = 235 MPa w = 364 kg/m

Dia = 1000 t = 15 D/t = 66.67
Area = 46,417 mm² I_{y,z} = 5,630,671,266 mm⁴
W_{el,y,z} = 11,261,343 W_{pl,y,z} = 14,554,500 mm³
i_y = 348.3 L_{y-y} = 20000 L_{y/i_y} = 57.4
i_z = 348.3 L_{z-z} = 15000 L_{z/i_z} = 43.1

6.3.6 Hydrostatic pressure, Ring spacing L_r = 0.00 mm

Section Design Resistances (kN, kNm)

N_t.Rd = 8257.70 N_{cy}.Rd = 8190.52 N_{cz}.Rd = 8606.51
M_t.Rd = 2427.51 M_t.Rd = 2657.23 V_t.Rd = 2738.14

Code check results

Material factor gamma_M (6.3.7) = 1.150

6.3.5 Shear

(6.13) V.Sd / V_{pl}.Rd = 0.18
(6.14) Torsion M_t.Sd / M_t.Rd = 0.00

6.3.9.2 axial compression and bending with hydrostatic loading. Method A.

C_{my} = 0.85 C_{mz} = 0.85

(6.43) 0.12 + 0.19 = 0.32
(6.44) 0.15 + 0.22 = 0.37

f_c.Sd > 0.5 * f_{he} / gamma_M & f_{cle} > 0.5 * f_{he}

(6.41) 0.04 + 0.21 = 0.25

6.3.6.1 hoop buckling

(6.15) f_p.Sd / f_h.Rd = 0.46

6.3.6.2 Ring stiffener design

No rings used

Section O.K. use 1000CHS15

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PROJECT : Validate Toolkit
SUBJECT : NORSOK N-004

Calc by : gjs Date : 28-Nov-07

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Beam-column Tension

Code check to NORSOK N-004 rev 2 2004

Design loads (limit state)

kN
Axial load (N.Sd) = -1,000.00
Shear (vect sum) = 500.00
Moment x-x (Mt.Sd) = 0.00

kN-m
Moment y-y (My.Sd) = 500.00
Moment z-z (Mz.Sd) = 200.00

Section data

1000CHS15	Grade = S235	Fy = 235 MPa	w = 364 kg/m
Dia = 1000	t = 15	D/t = 66.67	
Area = 46,417 mm ²		I _{y,z} = 5,630,671,266 mm ⁴	
W _{el,y,z} = 11,261,343		W _{pl,y,z} = 14,554,500 mm ³	
i _y = 348.3	Ly-y = 20000	Ly/i _y = 57.4	
i _z = 348.3	Lz-z = 15000	Lz/i _z = 43.1	

Section Design Resistances (kN, kNm)

Nt.Rd = 9485.21	Ncy.Rd = 8492.25	Ncz.Rd = 8926.67
M.Rd = 2788.36	Mt.Rd = 2657.23	V.Rd = 2738.14

Code check results

Material factor gamma_M (6.3.7) = 1.150

6.3.5 Shear, 6.3.8.3 Shear interaction

(6.13) $V.Sd / V_{pl.Rd} = 0.18$ (6.32)

M.Sd / M.Rd = 0.19

(6.14) Torsion $Mt.Sd / Mt.Rd = 0.00$

6.3.8.1 axial tension and bending without hydrostatic loading

(6.26) $0.02 + 0.19 = 0.21$

Section O.K. use 1000CHS15

NORSOK

6.4 tubular joints

Norsok N004

6.4 Tubular joint

T/Y

	Diam	T	Fy
Chord	1000	15	450
Brace	600	10	450

Loads	Axial	Mip (y)	Mop (z)			
Chord	1000	500	200	angle =	60	deg
Brace	600	300	200	gap =	75	mm

Geometry

Beta	0.60
gamma	33.33
tor	0.67

6.4.3.3 Qu

Qb	0.9996002	b>0.6
Qb	1	b<=0.6
Qg	1.6261387	Qg >=1

QuAxt	18
QuAxc	13.297341
Qumip	15.588457
Qumop	6.0154504

6.4.3.4 Qf

Chord stresses		Area	46417.0314
			6
			11261352.0
fa.sd	21.543816	Z	4
fmy.sd	44.399642		
fmz.sd	17.759857		

C1	25
C2	30

A^2	0.266422	(A	0.52
-----	----------	----	------

Lax	0.03
Lip	0.045
Lop	0.021

Qfax	0.9920073
------	-----------

Qfip	0.988011		
Qfop	0.9944051		
N.rd	1341053.9	1341.05	kN
	93946960		
M.rdy	0	939.47	kNm
	36487938		
M.rdz	1	364.88	kNm
	6.57		
N.sd/N.rd		0.45	
(My.sd/My.rd)^2		0.10	
Mz.sd/Mz.rd		0.55	
		1.10	(6.57)

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PROJECT : Validate Toolkit

SUBJECT : NORSOK N-004

Calc by : gjs

Date : 28-Nov-07

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Tubular joint T/Y

Norsok N-004 Rev 2 2004 : 6.4 Tubular joints

Member data

	Dia mm	t mm	Fy kN	Pax kN	Mip kNm	Mop kNm
Chord	1000	15	450	1000	500	200
Brace	600	10	450	600	300	200

Axial load N.Sd : compression is positive.

Joint geometry

theta (deg) = 60.0 gap (mm) = 75.0 joint type = T/Y
tau (t/T) = 0.67 beta (d/D) = 0.60 gamma (D/2T) = 33.33

Q factors

chord stress ratio A = 0.52
Qu(T) = 18.00 Qu(C) = 13.30
Qu(ip) = 15.59 Qu(op) = 6.02
Qf(Ax) = 0.99 Qf(ip) = 0.99 Qf(op) = 0.99
Q(beta) = 1.00 Q(gap) (K joints only) = 1.63

Joint capacities

Material factor gammaM = 1.150
Nt.Rd = 1815.3 kN
Nc.Rd = 1341.3 kN
My.Rd (ip) = 939.5 kN-m
Mz.Rd (op) = 364.9 kN-m

Code check results

6.4.3.6 strength check
(6.57)
 $0.45 + 0.10 + 0.55 = 1.10$

Joint O.K

22 Blast

These examples compare blast loads on ;

Simply supported beam

Propped cantilever (pin-fix)

The first page is an Excel example, followed by the Blast output.

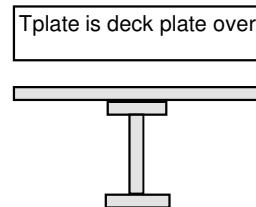
Check shear capacity and ductility requirements

Blast loading kPa	80	duration (s)	0.2
Max blast load F1 = area x blast loading (kN)			1440

Masses

total mass (kg)	2534	Wstat (kN)	24.86
Load mass factor (Klm)	0.78	Effec. mass	1976.52 kg
(mass factor alone =	0.5		

Section	610UB101	Fy (MPa) =	355
D (mm)	602	E (MPa)	206000
B (mm)	227.6	Ix (mm ⁴) =	746517618
Tf (mm)	14.8	Sx (mm ³) =	2846222
tw	10.6	Zx (mm ³) =	2480125
Tplate	0	Mc (kNm) =	1010.41
			0.00



Span (mm)	6000	Span capacity = Rm = nMc/L (kN)
		(Rm in tables 5.1..)
Rm n value	8	Rtot = 1347.21 kN

Beam stiffness kE = a.EI/L ³		
a (factor) =	77	Ke (kN/mm) = 54.82

Natural period		
T (s) =	0.0377	td/T = 5.30
DAF is calculated using Biggs table 2.8 (a)		1.10

Capacity check	(test to see if response is elastic/plastic)	
Wstat + F1 * DAF < Rtot =	1608.86 > Rtot	plastic

Dynamic reaction at supports

Shear calculation assumes two 30 radius ratholes in web	(tm/td (elas.) =	0.5)
From Biggs, fig 2.8 (b) or 2.26 (b) (value) =	0.5	(for td/T = 5.30)
Thus, at time tm/td, F = F1 (1-value) / 0.5 =	1440	(Rm/F1 = 0.92)

V = 0.39R + 0.11F or V = 0.38Rm + 0.12F, elastic or plastic respectively	(UDL, pinned)
Thus V (elastic) = 776.16 + Wstat/2 = 788.59	fv on web = 137.26 <= .6Fy OK
V (plastic) = 675.29 + Wstat/2 = 687.72	fv on web = 119.70 <= .6Fy OK

V = 0.71R - 0.21F or V = 0.75Rm - 0.25F, elastic or plastic respectively, fixed, point load	
(elastic) = 822.24 + Wstat/2 = 834.67	fv on web = 145.28 <= .6Fy OK
(plastic) = 631.76 + Wstat/2 = 644.19	fv on web = 112.13 <= .6Fy OK

V = 0.54R + 0.14F or V = 0.78Rm - 0.28F, elastic or plastic respectively, prop cant., point load	
(elastic) = 653.76 + 5Wstat/8 = 669.30	fv on web = 116.50 <= .6Fy OK
(plastic) = 588.56 + 5Wstat/8 = 604.10	fv on web = 105.15 <= .6Fy OK

Ductility ratios (for plastic response only)

RESPONSE IS PLASTIC

Rm = Rtot - Wstat		
Rm = 1322.35326	Rm / F1 =	0.92
From Biggs, table 2.26 (a) ym/yel (mu) =	2.2	(for td/T = 5.30)
yel = 24.1214 mm		
ystat = 0.4535 mm		
Maximum deflection is ym + ystat = yel.mu + ystat	53.5206 mm. (u.yel =	53.07 perm set)
Effective ductility ratio (mu demand) is therefore =	2.18	

FABIG

ref Tech note 4, June 1996 & SCI-P-112

A. Check strain limits criteria

Table 3.6, 3.7	mu capacity	
Pinned beam, UDL	13.66	mu demand/mu cap = 0.16 <= 1, OK

B. Non-compact local buckling criteria (FABIG 7.2)

buckling eqns (1), (2), (3)	1.15 > 1 XX
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PROJECT : Toolkit Validation

Job No :

SUBJECT : Blast application

Revision :

Calc by : GJS

Date :06-Jun-09

Checked :

Date :

610UB101, Simply supported

Equivalent SDOF oscillator.

Total mass on beam (kg) = 2534.0

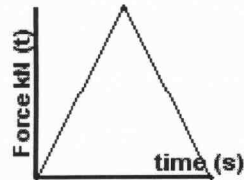
Equiv. SDOF mass (kg) = 1672.4

Stiffness (kN/m) = 55249.78

Period (s) = 0.0346

Applied loading

time (s)	F(t) (kN)
0	0
0.1	1440
0.2	0

**SDOF response.**

Displacements (mm)

Maximum (+ve) disp. = 41.86

Min (after max. +ve) disp. = 12.24

Max. plastic disp. = 17.539

Elastic limit +ve = 24.309

Elastic limit -ve = -25.209

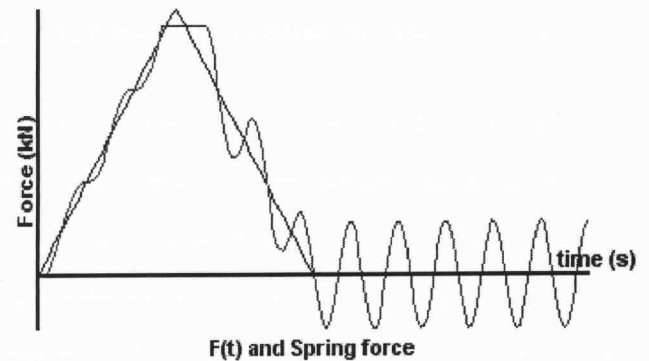
Damping % = 0.00

Combined with beam loading.

Static displacement = 0.45

Maximum total disp. = 42.31

Minimum total disp. = 12.69

Ductility, (max) μ = 1.71**Section data.**

Section : 610x229UB101

Plate : 0.0 x 0

Ix (mm⁴) = 75.80e+07Sx (mm³) = 28.90e+05

Fy static = 355.00

Fy used = 355.00

Beam response.

Static load (kN) = 24.86

Static loading : UDL

Blast loading : UDL

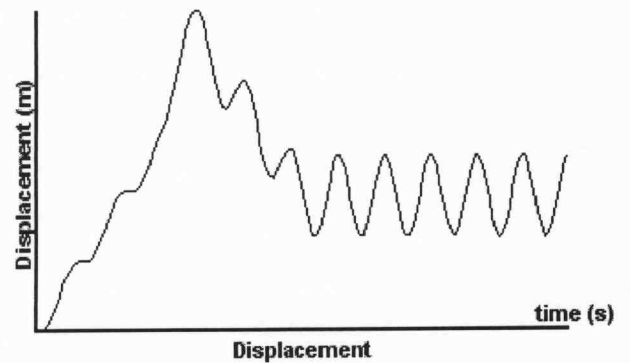
Blast direction : Down

Response : one is plastic

Supports : pin-pin

Span : 6000

Reactions (kN)	Max	Min
At 1 dynamic :	682.66	-111.36
At 1 static :	12.43	12.43
At 1 TOTAL :	695.09	-98.93
At 2 dynamic :	682.66	-111.36
At 2 static :	12.43	12.43
At 2 TOTAL :	695.09	-98.93



Blast app. ver 0.0.10
Run on 2009-Jun-06

Printout from menu 'Calculation details' for simply supported beam

Section : 610x229UB101
Depth : 602.2
Breadth : 227.6
T flange: 14.8
t web : 10.6
Cover plate
B input : 0
B effective : 0.00
T plate :0
Ix mm⁴ : 758,000,000
Sx mm³ : 2,890,000
Mp kNm: 1,026
Fy static : 355.00
Fy used : 355.00

Mass on beam : 2534
Blast loading : UDL
Blast direction : Down

Biggs, 5.2 Idealised systems. Transformation factors
Tables 5.1, 5.2, 5.3
KL elastic = 0.64
KL elastoplastic = 0.64
KL plastic = 0.50
KM elastic = 0.50
KM elastoplastic = 0.50
KM plastic = 0.33
Rm elastic = 1367933.33
Rm elastoplastic = 1367933.33
Rm plastic = 1367933.33
K elastic = 55249777.78
K elastoplastic = 55249777.78
Ke plastic = 55249777.78

Static data
Mass acts as gravity load = True
Static load (kN) = 24.86

SDOF Oscillator.
Run SDOF using elastic equivalent properties.
then check if response is plastic. If so, re-run using plastic
equivalent model.
Mass
Klm = KM/KL = 0.78 Mass = 1979.69
elastic Stiffness
Ke = 55249777.78
damp= 0.00%
T (sec) = 0.04

Oscillator response.
Max spring F =1343074.79

Min spring $F = -253302.14$
Rtot +ve = 1367933.33
Rtot -ve = -228443.60
elastic limit +ve = 1343074.79
elastic limit -ve = -1392791.87
response +ve = plastic
response +ve = 3
response -ve = elastic
response -ve = 1
response type = 3

SDOF response is plastic, 2st pass, plastic response
Change Biggs equivalent model to plastic.

Mass

$K_{lm} = K_M/K_L = 0.66$ Mass = 1672.44

Plastic Stiffness

$K_e = 55249777.78$

$T \text{ (sec)} = 0.03$

Beam ductility

SDOF max displacement = 0.04186

time at max displacement = 0.12035

SDOF min disp (after max.) = 0.01224

time at min displacement = 0.38363

SDOF delta displacement = 0.02963

SDOF post -ve yield disp diff = -0.01061

SDOF yield displacement (+ve) = 0.02431

SDOF yield displacement (-ve) = -0.02521

SDOF μ (+ve) = 1.722

SDOF μ (-ve) = -0.485

static displacement = 0.00045

beam eff μ (+ve) = 1.71

beam eff μ (-ve) = -0.46

Biggs dynamic reactions

Shear = $V = 0.38 \cdot R_m + 0.12 \cdot F$

$V_{max1} = 682657.86$ $V_{min1} = -111363.87$

$V_{max2} = 682657.86$ $V_{min2} = -111363.87$

Total reactions

Static reactions

$R1 = 12429.27$ $R2 = 12429.27$

Static + Max Dynamic

$R1 \text{ max} = 695087.13$ $R2 \text{ max} = 695087.13$

Static + Min Dynamic

$R1 \text{ min} = -98934.60$ $R2 \text{ min} = -98934.60$

PROJECT : Toolkit Validation

Job No :

SUBJECT : Blast application

Revision :

Calc by : GJS

Date : 06-Jun-09

Checked :

Date :

610UB101, Simply supported

Ductility check

Plastic hinge formation assumed. SDOF ductility demand on this hinge is 1.71

(a) Post yield compactness.

Ref. Steel Construction Institute, FABIG, Technical note 4, June 1996. Section 7.2.
Compactness ratio is 1.15 (7.2 (2)) FAIL

(b) Beam ductility.

Ref. Steel Construction Institute, FABIG, SCI-P-112, amendt. 1. Section 3.5.5.
The beam's ductility capacity is based on the plastic strain limit together with the loading pattern and boundary conditions.

For the beam analysed, the available ductility ratio = 8.60

(Beam ductility capacity) / (SDOF ductility demand) = 0.20 OK

N.B The max. allowed unrestrained length of compression flange is 1082.90 mm

Validation of Toolkit Blast app

Propped cantilever, UDL

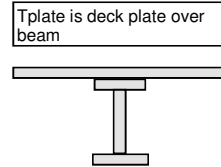
Check shear capacity and ductility requirements

Blast loading kPa 100 duration (s) 0.2
 Max blast load F1 = area x blast loading (kN) 2000

Masses

total mass (kg) 2534 Wstat (kN) 24.86
 Load mass factor (Klm) 0.66 Effec. mass 1672.44 kg
 (mass factor alone = 0.5

Section 610UB101 Fy (MPa) = 355
 D (mm) 602 E (MPa) 206000
 B (mm) 227.6 Ix (mm4) = 746517618
 Tf (mm) 14.8 Sx (mm3) = 2846222
 tw 10.6 Zx (mm3) = 2480125
 Tplate 0 Mc (kNm) = 1010.41 0.00



Span (mm) 6000 Span capacity = Rm = nMc/L (kN)
 (Tables 5.1, 5.2, 5.3)
 Rm n value 8 Rm = 1347.21 kN

Beam stiffness kE = a.EI/L^3
 a (factor) = 160 Ke (kN/mm) = 113.91

Natural period
 T (s) = 0.0241 td/T = 8.31
 DAF is calculated using Biggs table 2.8 (a) 1.10

Capacity check (test to see if response is elastic/plastic)
 Wstat + F1 * DAF < Rtot = 2224.86 > Rtot plastic

Dynamic reaction at supports

Shear calculation assumes two 30 radius ratholes in web (tm/td (elas.) = 0.5)
 From Biggs, fig 2.8 (b) or 2.26 (b) (value) = 0.5 (for td/T = 8.31)
 Thus, at time tm/td, F = F1 (1-value) / 0.5 = 2000 (Rm/F1 = 0.66)

V = 0.39R + 0.11F or V = 0.38Rm + 0.12F, elastic or plastic respectively (UDL, pinned)
 Thus V (elastic) = 1078.00 + Wstat/2 = 1090.43 fv on web = 189.80 <=.6Fy OK
 V (plastic) = 742.49 + Wstat/2 = 754.92 fv on web = 131.40 <=.6Fy OK

V = 0.71R - 0.21F or V = 0.75Rm - 0.25F, elastic or plastic respectively, fixed, point load
 (elastic) = 1142.00 + Wstat/2 = 1154.43 fv on web = 200.94 <=.6Fy OK
 (plastic) = 491.76 + Wstat/2 = 504.19 fv on web = 87.76 <=.6Fy OK

V = 0.54R + 0.14F or V = 0.78Rm - 0.28F, elastic or plastic respectively, prop cant., point load
 (elastic) = 908.00 + 5Wstat/8 = 923.54 fv on web = 160.75 <=.6Fy OK
 (plastic) = 431.76 + 5Wstat/8 = 447.30 fv on web = 77.86 <=.6Fy OK

V2 = 0.43R + 0.19F or V = 0.38Rm + 0.12F + Mp/L, elastic or plastic respectively, prop cant., UDL
 (elastic) = 1326.00 + 5Wstat/8 = 1341.54 fv on web = 233.51 >0.6Fy XX
 (plastic) = 910.90 + 5Wstat/8 = 926.43 fv on web = 161.25 <=.6Fy OK

168.4015

Ductility ratios (for plastic response only)

RESPONSE IS PLASTIC

Rm = Rtot - Wstat
 Rm = 1322.35326 Rm / F1 = 0.66
 From Biggs, table 2.26 (a) ym/yel (mu) = 70 (for td/T = 8.31)
 yel = 11.6084 mm
 ystat = 0.2182 mm
 Maximum deflection is ym + ystat = 812.8092 mm. (u.yel = 812.59 perm set)
 Effective ductility ratio (mu demand) is therefore = 68.73

FABIG

ref Tech note 4, June 1996 & SCI-P-112

A. Check strain limits criteria

Table 3.6, 3.7 mu capacity
 Pinned beam, UDL 13.66 mu demand/mu cap = 5.03 > 1, XX

B. Non-compact local buckling criteria (FABIG 7.2)

buckling eqns (1), (2), (3) mu > 5.0 *** >1 XX

PROJECT : Toolkit Validation
 SUBJECT : Blast application
 Calc by : GJS Date :06-Jun-09

Job No :
 Revision :
 Date :

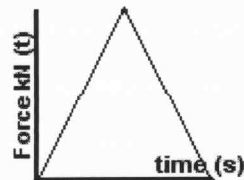
610UB101, Propped cantilever

Equivalent SDOF oscillator.

Total mass on beam (kg) = 2534.0
 Equiv. SDOF mass (kg) = 1672.4
 Stiffness (kN/m) = 115103.70
 Period (s) = 0.0240

Applied loading

time (s)	F(t) (kN)
0	0
0.1	2000
0.2	0



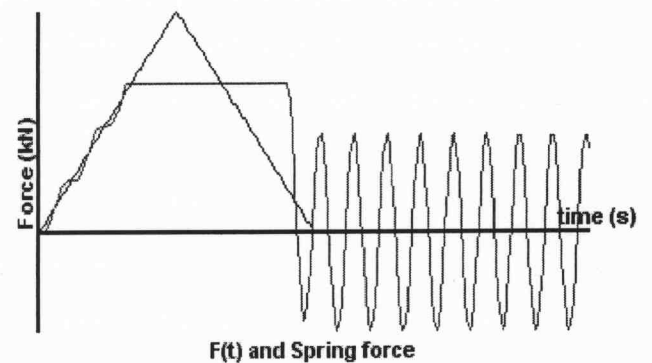
SDOF response.

Displacements (mm)
 Maximum (+ve) disp. = 859.93
 Min (after max. +ve) disp. = 840.55
 Max. plastic disp. = 848.259
 Elastic limit +ve = 11.668
 Elastic limit -ve = -12.100
 Damping % = 0.00

Combined with beam loading.
 Static displacement = 0.19
 Maximum total disp. = 860.12
 Minimum total disp. = 840.74
 Ductility, (max) μ = 72.55

Section data.

Section : 610x229UB101
 Plate : 0.0 x 0
 Ix (mm⁴) = 75.80e+07
 Sx (mm³) = 28.90e+05
 Fy static = 355.00
 Fy used = 355.00

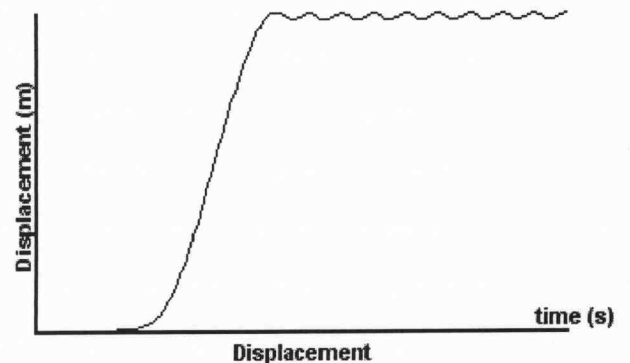


F(t) and Spring force

Beam response.

Static load (kN) = 24.86
 Static loading : UDL
 Blast loading : UDL
 Blast direction : Down
 Response : elasto-plastic
 Supports : pin-fix
 Span : 6000

Reactions (kN)	Max	Min
At 1 dynamic :	578.94	-508.12
At 1 static :	12.43	12.43
At 1 TOTAL :	591.37	-495.69
At 2 dynamic :	920.92	-166.14
At 2 static :	12.43	12.43
At 2 TOTAL :	933.35	-153.71



Displacement

Blast app. ver 0.0.10
Run on 2009-Jun-06

Printout from menu 'Calculation details' for propped cantilever

Section : 610x229UB101
Depth : 602.2
Breadth : 227.6
T flange: 14.8
t web : 10.6
Cover plate
B input : 0
B effective : 0.00
T plate : 0
I_x mm⁴ : 758,000,000
S_x mm³ : 2,890,000
M_p kNm: 1,026
F_y static : 355.00
F_y used : 355.00

Mass on beam : 2534
Blast loading : UDL
Blast direction : Down

Biggs, 5.2 Idealised systems. Transformation factors
Tables 5.1, 5.2, 5.3
KL elastic = 0.58
KL elastoplastic = 0.64
KL plastic = 0.50
KM elastic = 0.45
KM elastoplastic = 0.50
KM plastic = 0.33
R_m elastic = 1367933.33
R_m elastoplastic = 2051900.00
R_m plastic = 2051900.00
K elastic = 133088657.41
K elastoplastic = 55249777.78
K_e plastic = 115103703.70

Static data
Mass acts as gravity load = True
Static load (kN) = 24.86

SDOF Oscillator.
Run SDOF using elastic equivalent properties.
then check if response is plastic. If so, re-run using plastic
equivalent model.

Mass
K_{lm} = K_M/K_L = 0.78 Mass = 1966.03
elastic Stiffness
K_e = 133088657.41
damp= 0.00%
T (sec) = 0.02

Oscillator response.

Max spring F =1343074.79
Min spring F =-884117.94
Rtot +ve =1367933.33
Rtot -ve =-859259.40
elastic limit +ve =1343074.79
elastic limit -ve =-1392791.87
response +ve =elastoplastic
response +ve =2
response -ve =elastic
response -ve =1
response type =2

SDOF response is plastic, 2st pass, plastic response
Change Biggs equivalent model to plastic.

Mass

$K_{lm} = K_M/K_L = 0.66$ Mass = 1672.44

Plastic Stiffness

$K_e = 115103703.70$

T (sec) = 0.02

Oscillator response.

Max spring F =1343074.79

Min spring F =-887180.42

Rtot +ve =1367933.33

Rtot -ve =-862321.88

elastic limit +ve =1343074.79

elastic limit -ve =-1392791.87

response +ve =elastoplastic

response +ve =2

response -ve =elastic

response -ve =1

response type =2

Beam ductility

SDOF max displacement = 0.85993

time at max displacement = 0.18031

SDOF min disp (after max.) = 0.84055

time at min displacement = 0.38478

SDOF delta displacement = 0.01938

SDOF post -ve yield disp diff = -0.01530

SDOF yield displacement (+ve) = 0.01167

SDOF yield displacement (-ve) = -0.01210

SDOF μ (+ve) = 73.698

SDOF μ (-ve) = -69.465

static displacement = 0.00019

beam eff μ (+ve) = 72.55

beam eff μ (-ve) = -68.39

Biggs dynamic reactions

Shear = $V_1 = 0.38 \cdot R + 0.12 \cdot F - M_p/L$, $V_2 = 0.38 \cdot R_m + 0.12 \cdot F + M_p/L$

$V_{max1} = 578937.81$ $V_{min1} = -508120.23$

Vmax2 = 920921.14 Vmin2 = -166136.89

Total reactions

Static reactions

R1 = 12429.27 R2 = 12429.27

Static + Max Dynamic

R1 max = 591367.08 R2 max = 933350.41

Static + Min Dynamic

R1 min = -495690.96 R2 min = -153707.62

PROJECT : Toolkit Validation

Job No :

SUBJECT : Blast application

Revision :

Calc by : Date :06-Jun-09

Checked :

Date :

610UB101, Propped cantilever

Ductility check

Plastic hinge formation assumed. SDOF ductility demand on this hinge is 72.55

(a) Post yield compactness.

Ref. Steel Construction Institute, FABIG, Technical note 4, June 1996. Section 7.2.
The ductility demand is > 5. Section fails local compactness check.

(b) Beam ductility.

Ref. Steel Construction Institute, FABIG, SCI-P-112, amendt. 1. Section 3.5.5.
The beam's ductility capacity is based on the plastic strain limit together with the loading pattern and boundary conditions.

For the beam analysed, the available ductility ratio = 4.41

(Beam ductility capacity) / (SDOF ductility demand) = 16.44 FAIL

N.B The max. allowed unrestrained length of compression flange is 1082.90 mm

Validation of Toolkit Blast app

fixed ended, UDL

Check shear capacity and ductility requirements

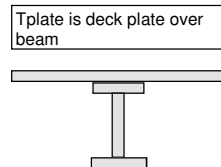
See note on cell C11,
 "This value (0.682) is taken from Blast, and is the iteration of K_{lm} (average) against μ "

Blast loading kPa 100 duration (s) 0.2
 Max blast load $F_1 = \text{area} \times \text{blast loading}$ (kN) 2000

Masses

total mass (kg) 5000 W_{stat} (kN) 49.05
 Load mass factor (K_{lm}) 0.682 Effec. mass 3410 kg
 (mass factor alone = 0.5

Section 533UB82 F_y (MPa) = 355
 D (mm) 528.3 E (MPa) 206000
 B (mm) 208.7 I_x (mm⁴) = 466692446
 T_f (mm) 13.2 S_x (mm³) = 2023587
 t_w 9.6 Z_x (mm³) = 1766771
 Tplate 0 M_c (kNm) = 718.37 0.00



Span (mm) 7000 Span capacity = $R_m = nM_c/L$ (kN)
 (Tables 5.1, 5.2, 5.3)
 R_m n value 16 R_m = 1642.00 kN

Beam stiffness $kE = aEI/L^3$
 a (factor) = 307 K_e (kN/mm) = 86.05

Natural period
 T (s) = 0.0396 t_d/T = 5.06
 DAF is calculated using Biggs table 2.8 (a) 1.10

Capacity check (test to see if response is elastic/plastic)
 $W_{stat} + F_1 \times DAF < R_{tot}$ = 2249.05 $> R_{tot}$ plastic

Dynamic reaction at supports

Shear calculation assumes two 30 radius ratholes in web (tm/ t_d (elas.) = 0.5)
 From Biggs, fig 2.8 (b) or 2.26 (b) (value) = 0.72 (for t_d/T = 5.06)
 Thus, at time t_m/t_d , $F = F_1$ (1-value) / 0.5 = 1120 (& R_m/F_1 = 0.80)

$V = 0.39R + 0.11F$ or $V = 0.38R_m + 0.12F$, elastic or plastic respectively (UDL, pinned)
 Thus V (elastic) = 981.20 + $W_{stat}/2$ = 1005.73 f_v on web = 223.71 $> 0.6F_y$ XX
 V (plastic) = 739.72 + $W_{stat}/2$ = 764.24 f_v on web = 170.00 $\leq 0.6F_y$ OK

$V = 0.71R - 0.21F$ or $V = 0.75R_m - 0.25F$, elastic or plastic respectively, fixed, point load
 (elastic) = 1326.80 + $W_{stat}/2$ = 1351.33 f_v on web = 300.58 $> 0.6F_y$ XX
 (plastic) = 914.71 + $W_{stat}/2$ = 939.23 f_v on web = 208.92 $\leq 0.6F_y$ OK

$V = 0.54R + 0.14F$ or $V = 0.78R_m - 0.28F$, elastic or plastic respectively, prop cant., point load
 (elastic) = 1031.20 + $5W_{stat}/8$ = 1061.86 f_v on web = 236.19 $> 0.6F_y$ XX
 (plastic) = 881.11 + $5W_{stat}/8$ = 911.77 f_v on web = 202.81 $\leq 0.6F_y$ OK

$V_2 = 0.43R + 0.19F$ or $V = 0.38R_m + 0.12F + M_p/L$, elastic or plastic respectively, prop cant., UDL
 (elastic) = 1158.80 + $5W_{stat}/8$ = 1189.46 f_v on web = 264.58 $> 0.6F_y$ XX
 (plastic) = 842.34 + $5W_{stat}/8$ = 873.00 f_v on web = 194.19 $\leq 0.6F_y$ OK

102.6248

Ductility ratios (for plastic response only)

RESPONSE IS PLASTIC

$R_m = R_{tot} - W_{stat}$
 R_m = 1592.9461 R_m / F_1 = 0.80
 From Biggs, table 2.26 (a) y_m/y_{el} (μ) = 6 (for t_d/T = 5.06)
 y_{el} = 18.5122 mm (& R_m/F_1 = 0.80)
 y_{stat} = 0.5700 mm
 Maximum deflection is $y_m + y_{stat} = y_{el} \cdot \mu + y_{stat}$ 111.6434 mm. ($u_{y_{el}}$ = 111.07 perm set)
 Effective ductility ratio (μ demand) is therefore = 5.85

FABIG

ref Tech note 4, June 1996 & SCI-P-112

A. Check strain limits criteria

Table 3.6, 3.7 μ capacity
 Pinned beam, UDL 13.57 μ demand/ μ cap = 0.43 ≤ 1 , OK

B. Non-compact local buckling criteria (FABIG 7.2)

buckling eqns (1), (2), (3) $\mu > 5.0$ *** > 1 XX

Blast app. ver 1.1.0
Run on 2010-Nov-10

Section : 533x210UB82
Depth : 528.3
Breadth : 208.7
T flange: 13.2
t web : 9.6
Cover plate
B input : 0
B effective : 0.00
T plate : 0
Ix mm⁴ : 475,000,000
Sx (plastic modulus) mm³ : 2,060,000
Fy elastic (static) : 355.00
Fy plastic : 355.00

Mp el kNm: 731
Mp pl kNm: 731

Mass on beam : 5000
Blast loading : UDL
Blast direction : Down

Biggs, 5.2 Idealised systems. Transformation factors
Tables 5.1, 5.2, 5.3
KL elastic = 0.53
KL elastoplastic = 0.64
KL plastic = 0.50
KM elastic = 0.41
KM elastoplastic = 0.50
KM plastic = 0.33
Rm elastic = 1253657.14
Rm elastoplastic = 1671542.86
Rm plastic = 1671542.86
K elastic = 109014577.26
Ke elastoplastic = 87154883.38
Static data
Mass acts as gravity load = True
Static load (kN) = 49.05

SDOF Oscillator.
Run SDOF using elastic equivalent properties
then check if response is plastic. If so, re-run using plastic
equivalent model.
Mass
 $K_{lm} = K_M / K_L = 0.77$ Equivalent Mass ($K_{lm} \cdot Mt$) = 3867.92
Elastic Stiffness
 $K_e = 109014577.26$

damp=
T (sec) = 0.037
Ductility (μ) = 62.63
td (Biggs) = 0.20
td/T (Biggs) = 5.34
Rm(el) (Biggs) = 1253657.14
Rm(SDOF) = Rm(el)+/-Wstatic = 1204607.14
Rm(SDOF)/F1 (Biggs) = 0.60
rise time/td (Biggs) = 0.50

SDOF response is plastic, 2st pass, plastic response
Change Biggs equivalent model to plastic.

Iterating value of Klm(av)

Klm_av = 0.681 μ = 5.52
Klm_av = 0.682 μ = 5.28
Klm_av = 0.682 μ = 5.26
Klm_av = 0.682 μ = 5.26
Ke (stiffness) = 87154883.38

Mass

Klm(pl) = 0.68 Mass = 3411.52
T (sec) = 0.039
Ductility (μ) = 5.26
td/T (Biggs) = 5.09
Rm(pl) (Biggs) = 1671542.86
Rm(SDOF) = Rm(pl)+/-Wstatic = 1622492.86
Rm(SDOF)/F1 (Biggs) = 0.81
rise time/td (Biggs) = 0.50

Oscillator response.

Max spring F = 1622492.86
Min spring F = -670847.67
Rtot +ve = 1671542.86
Rtot -ve = -621797.67
elastic load limit +ve = 1622492.86
elastic load limit -ve = -1720592.86
response +ve = plastic
response +ve = 3
response -ve = elastic
response -ve = 1
response type = 3

Beam ductility

SDOF max displacement = 0.09800
time at max displacement = 0.14676
SDOF min disp (after max.) = 0.07168
time at min displacement = 0.20703
SDOF delta displacement = 0.02632
SDOF post -ve yield disp diff = -0.01540
SDOF yield displacement (+ve) = 0.01862
SDOF yield displacement (-ve) = -0.01974

SDOF μ (+ve) = 5.264
SDOF μ (-ve) = -3.631
static displacement = 0.00045
beam eff μ (+ve) = 5.16
beam eff μ (-ve) = -3.53

Biggs dynamic reactions
Shear = $V = 0.38 \cdot R_m + 0.12 \cdot F$
 $V_{max1} = 855554.75$ $V_{min1} = -254922.12$
 $V_{max2} = 855554.75$ $V_{min2} = -254922.12$

Total reactions
Static reactions
 $R1 = 24525.00$ $R2 = 24525.00$
Static + Max Dynamic
 $R1_{max} = 880079.75$ $R2_{max} = 880079.75$
Static + Min Dynamic
 $R1_{min} = -230397.12$ $R2_{min} = -230397.12$

Design check
Beam shear
Maximum shear at end 1 (kN) = 880.08
Maximum shear at end 2 (kN) = 880.08
Web shear stresses (MPa)
at 1 = 173.53 $[0.49 \cdot F_y(355)]$
at 2 = 173.53 $[0.49 \cdot F_y(355)]$
Maximum ductility = 5.16
Maximum displacement (mm) = 98.45
Max displacement = span/71.10
Beam ductility IR
IR ductility = 1.07
IR Local buckling = 1.14
Maximum permitted $L_e = 995.07$ mm

23.0 BS EN ISO 19902:2007 Fixed steel offshore structures

Tubular section.

Other shapes are designed to BS EN 1993-1-1 (Eurocode 3) which is validated above

(a) Tubular beam-column

Excel validation check calculation

BS EN ISO 19902 : 2007

Section					
Diam	1000.00		kLy	20000	
tw	15.00		kLz	15000	
Area	46417.03				
I	5630676022.16		Axial (kN)		1000 1000000
r	348.29		My (kNm)	500	500000000
Ze	11261352.04		Mz	600	600000000
Zp	14554500.00		Shear	500	500000
Ip	11261352044.31		torsion	700	700000000
Eyoung	210000.00		Hz (m)	53.77	
fy	275.00		Lr (mm)	15000	
Cmy	0.85		Stresses	MPa	
Cmz	0.85		fdax	21.54	
			fdmy	44.40	
			fdmz	53.28	
			fdres	69.35	
			fvbeam	21.54	
			fvtor	31.08	
13.2.2 Tension					
Um	(13.2-2)	0.082			
13.2.3 Axial compression					
13.2.3.3	Local buckling		13.2.3.2	Column buckling	
	fxe	1890	Lambda_y	0.66	fc,y 241.55
	fy/fxe	0.145	Lambda_z	0.50	fc,z 256.19
	fyc	275	Lambda	0.50	fc 241.55
Um	(13.2-4)	0.105			
13.2.4 Bending					
	fyD/Et	0.09	13.2.5 Shear		
	fb	321.57	fv	158.77	
			13.2.5.1 Beam		
	(13.2-13)	355.42	Um	(13.2-17)	0.14
	(13.2-14)	321.57	13.2.5.2 Torsion		
	(13.2-15)	310.51	Um	(13.2-18)	0.21

13.2.6 Hydrostatic

30/08/2009

13.2.6.1	p	708.27	kPa				
	p	0.708	MPa				
13.2.6.2							
	sigma_h(13.2-22)	23.609	MPa				
	mu	173.205		>1.6*D/t	106.667	(13.2-27)	29.333
	Ch	0.007		>0.825D/t	55.000	(13.2-28)	0.007
	fhe	41.580		>1.5	1.500	(13.2-29)	0.004
	fh	41.580	41.580	<1.5		(13.2-30)	0.800
Um	(13.2-31)	0.710					
13.3	Combined, no hydro						
13.3.2	Tension						
Um	(13.3-2)	0.309					
13.3.3	Axial compression and bending						
	fey	628.553					
	fez	1117.428					
Um	(13.3-7)	0.303			0.105		0.198
Um	(13.3-8)	0.319			0.092		0.226
13.4	Combined with hydro						
	sigma_q (13.4-4)	11.805					
13.4.2	Tension and hydro						
	neta (13.4-11)	4.395		B	0.710	gR,h*sigma_h/fh	0.710
	fbh	252.491					
	fth	215.926					
Um	(13.4-12)	0.336	0.047	0.288			
13.4.3	Compression and hydro						
	fch(13.4-15)	245.251					
	fch(13.4-16)	1005.686					
	fch	245.251	1.402				
	sigma_x	90.898					
	(13.7-17 (1))	true					
	(13.7-17 (2))	true					
Um	(13.4-19)	0.432	0.143	0.288			
Um	(13.4-20)	0.355	0.104	0.252			
Um	(13.4-21)	0.551	0.047	0.504			

Check 1000x15 CHS. Compression, no hydro load

Code check to BS EN ISO 19902:2007

Design loads (limit state)

kN
Axial load = 1,000.00
Shear (vect sum) = 500.00

kN-m
Moment y-y = 500.00
Moment z-z = 600.00
Moment x-x = 700.00

Section data

1000x15 CHS
Dia = 1000
Area = 46,417 mm²
Z_{e y,z} = 11,261,343
i_y = 348.3
r_z = 348.3

Grade = S 275
t = 15
Ly-y = 20000
Lz-z = 15000

F_y = 275 MPa
D/t = 66.67
I_{y,z} = 5,630,671,266 mm⁴
Z_{p y,z} = 14,554,500 mm³
Ly/ry = 57.4
Lz/rz = 43.1

w = 364 kg/m

Section stresses under design loads (MPa)

f_{ax} = 21.54
f_{v, b} = 21.54
f_{my} = 44.40
f_{v, t} = 31.08

f_{mz} = 53.28

Code check results

13.2.5 Shear

(13.2-17) Um, b = 0.14
(13.2-19) Um, t = 0.21

13.3.3 Axial Compression and bending without hydro

C_{my} = 0.85 C_{mz} = 0.85

(13.3-7) 0.11 + 0.20 = 0.30
(13.3-8) 0.09 + 0.23 = 0.32

Section O.K. use 1000x15 CHS

PROJECT : Toolkit Validation

SUBJECT : BS EN ISO 19902:2007

Calc by : GJS

Date : 29-Aug-09

Checked :

Sheet of

Job No :

Revision

Date :

Check 1000x15 CHS. Tension, no hydro load

Code check to BS EN ISO 19902:2007

Design loads (limit state)

kN
Axial load = -1,000.00
Shear (vect sum) = 500.00

kN-m
Moment y-y = 500.00
Moment z-z = 600.00
Moment x-x = 700.00

Section data

1000x15 CHS
Dia = 1000
Area = 46,417 mm²
Z_{e y,z} = 11,261,343
i_y = 348.3
r_z = 348.3

Grade = S 275
t = 15
Ly-y = 20000
Lz-z = 15000

F_y = 275 MPa
D/t = 66.67
I_{y,z} = 5,630,671,266 mm⁴
Z_{p y,z} = 14,554,500 mm³
Ly/ry = 57.4
Lz/rz = 43.1

w = 364 kg/m

Section stresses under design loads (MPa)

f_{ax} = -21.54 f_{my} = 44.40
f_{v, b} = 21.54 f_{v, t} = 31.08

f_{mz} = 53.28

Code check results

13.2.5 Shear

(13.2-17) U_{m, b} = 0.14
(13.2-19) U_{m, t} = 0.21

13.3.2 Axial Tension and bending without hydro

(13.3-2) 0.08 + 0.23 = 0.31

Section O.K. use 1000x15 CHS

Check 1000x15 CHS. Compression, with hydro load

Code check to BS EN ISO 19902:2007

Design loads (limit state)

kN
Axial load = 1,000.00
Shear (vect sum) = 500.00

kN-m
Moment y-y = 500.00
Moment z-z = 600.00
Moment x-x = 700.00

Still water depth (m) = 50 Depth to member (m) = 50
Wave height (m) = 10.00 Length (m) = 400.00
Hydrostatic pressure (13.2-20) (kPa) = 702.57 Hz (m) = 53.77
Axial load excludes the member end hydrostatic cap load

Section data

1000x15 CHS Grade = S 275
Dia = 1000 t = 15
Area = 46,417 mm²
Ze y,z = 11,261,343
iy = 348.3 Ly-y = 20000
rz = 348.3 Lz-z = 15000
13.2.6.3 Ring stiffener, spacing Lr = 0.00 mm

Fy = 275 MPa
D/t = 66.67
Iy,z = 5,630,671,266 mm⁴
Zp y,z = 14,554,500 mm³
Ly/ry = 57.4
Lz/rz = 43.1

w = 364 kg/m

Section stresses under design loads (MPa)

fax = 21.54 fmy = 44.40 fmz = 53.28
fv, b = 21.54 fv, t = 31.08

Code check results

13.2.5 Shear

(13.2-17) Um, b = 0.14
(13.2-19) Um, t = 0.21

13.4.3 axial compression and bending with hydrostatic loading.
hydro end load is not in design axial load

Cmy = 0.85 Cnz = 0.85

(13.4-19) 0.14 + 0.29 = 0.43
(13.4-20) 0.10 + 0.25 = 0.35

$f_x > 0.5 * f_{he} / g_{R,h}$ & $f_{xe} / g_{R,c} > 0.5 * f_{he} / g_{R,h}$
(13.4-20) 0.05 + 0.50 = 0.55

13.2.6.2 hoop buckling

(13.2-22) $f_p / (g_{M,h} * f_{h,Rd}) = 0.70$

13.2.6.3 Ring stiffener design

No rings used

Section O.K. use 1000x15 CHS

Check 1000x15 CHS. Tension, with hydro load

Code check to BS EN ISO 19902:2007

Design loads (limit state)

kN
Axial load = -1,000.00
Shear (vect sum) = 500.00

kN-m
Moment y-y = 500.00
Moment z-z = 600.00
Moment x-x = 700.00

Still water depth (m) = 50 Depth to member (m) = 50
Wave height (m) = 10.00 Length (m) = 400.00
Hydrostatic pressure (13.2-20) (kPa) = 702.57 Hz (m) = 53.77
Axial load excludes the member end hydrostatic cap load

Section data

1000x15 CHS Grade = S 275
Dia = 1000 t = 15
Area = 46,417 mm²
Ze y,z = 11,261,343
iy = 348.3 Ly-y = 20000
rz = 348.3 Lz-z = 15000
13.2.6.3 Ring stiffener, spacing Lr = 0.00 mm

Fy = 275 MPa w = 364 kg/m
D/t = 66.67
Iy,z = 5,630,671,266 mm⁴
Zp y,z = 14,554,500 mm³
Ly/ry = 57.4
Lz/rz = 43.1

Section stresses under design loads (MPa)

fax = -21.54 fmy = 44.40 fmz = 53.28
fv, b = 21.54 fv, t = 31.08

Code check results

13.2.5 Shear

(13.2-17) Um, b = 0.14
(13.2-19) Um, t = 0.21

13.4.2 axial tension and bending with hydrostatic loading.

hydro end load is not in design axial load

(13.4-12) 0.05 + 0.29 = 0.33

13.2.6.2 hoop buckling

(13.2-22) fp / (gM,h * fh.Rd) = 0.70

13.2.6.3 Ring stiffener design

No rings used

Section O.K. use 1000x15 CHS

(b) Punching shear

14 Tubular joint

BS EN ISO 19902 : 2007

T/Y

	Diam	T	Fy		Tn
Chord	1000		40	345	15
Brace	800		30	345	

Loads	Axial	Mip (y)	Mop (z)			
Chord	20000		500	200	angle =	90 deg
Brace	600		300	200	gap =	75 mm

Geometry

Beta	0.80
gamma	12.50
tau	0.75

14.3.3 Qu

Qb	1.124 b>0.6
Qb	1.000 b<=0.6

Qg	1.626 Qg >=1
----	--------------

QuAxt	24.000
QuAxc	18.130
Qumip	12.728
Qumop	7.181

14.3.4 Qf

Area	120637.158	Py	41619.819 kN
Zp chord	36885333.3	Mp	12725.44 kNm

Pc/Py=	0.481	Mcip/Mp =	0.039	Mcop/Mp=	0.016
--------	-------	-----------	-------	----------	-------

(25, 11 for Y, 20, 22 for X and 14, 43 for K)					
Qf_axial	C1 =	25	C2=	11	
qA = sqrt(	5.773 +	0.017 +	0.003)		
qA =	2.527				

$$Qf_{ax} = 1 - 0.030 * qA^2 = 0.808$$

Qf_moment	C1 =	25	C2=	43	(C1, C2 are constant for moment)
qA = sqrt(	5.773 +	0.066 +	0.011		
qA =	2.540				

$$Qf_{ip} = 1 - 0.045 * qA^2 = 0.710$$

$$Qf_{op} = 1 - 0.021 * qA^2 = 0.865$$

14.3.2 strengths

Puj =	10709.78	Pd=	10199.79
Muj ip=	3989.36	Md ip =	3799.388
Muj op=	2741.48	Md ip =	2610.93

14.3.6 Strength check

(14.3-12)	Uj =	0.059	0.006	0.077 =	0.142
(14.3-13)	Let Ub (user input)=0.7			=	0.142 <= 0.598

PROJECT : Toolkit validation

Job No : 0000

SUBJECT : BS EN ISO 19902-2007 -Punch

Revision :

Calc by: GJS Date : 22-Nov-2013 Checked :

Date :

Check can punch calculation**BS EN ISO 19902:2007 : 14 Strength of tubular joints****Member data**

	Dia	t	Fy	Pax	Mip	Mop
	mm	mm	MPa	kN	kNm	kNm
Chord	1000	40	345	20000	500	200
Brace	800	30	345	600	300	200

Axial load P : compression is positive.

Joint geometry

θ (deg) = 90.0 gap (mm) = 75.0 joint type = T/Y
 τ (t/T) = 0.75 β (d/D) = 0.80 γ (D/2T) = 12.50

Q factors

$Q_u(T) = 24.00$ $Q_u(C) = 18.13$
 $Q_u(ip) = 12.73$ $Q_u(op) = 7.18$
 $Q_f(Ax) = 0.81$ $Q_f(ip) = 0.71$ $Q_f(op) = 0.86$
 $Q(\beta) = 1.12$ $Q(gap)$ (K joints only) = 1.64

Joint capacities

Joint resistance factor γ_{Rj} = 1.050
 Joint material factor γ_{Rq} = 1.050
 Joint partial resistance factor γ_{Zj} = 1.170

$P_d \quad T = 10199.8 \quad kN$
 $P_d \quad C = 7705.1 \quad kN$
 $M_d \quad ip = 3799.4 \quad kN-m$
 $M_d \quad op = 2610.9 \quad kN-m$

Code check results

14.3.6 strength check

 $U_j = 0.08 + 0.01 + 0.08 = 0.16$ 14.3-12 all joints: $U_j \leq 1$ **Joint O.K**14.3-13 all critical joints, $U_b = 1$ $U_j \leq U_b / \gamma_{Zj} = 0.85$ **Joint O.K**

24.0 Canadian steel code S16-09

Code check to CSA S16-09

Design a beam-column to resist the ULS design loads below

Design loads

Axial (compression) load	$C_f = 100.00$	kN
Axial (tension) load	$C_f = -100.00$	kN
Major axis bending	$M_{fx} = 100.00$	kNm (From a UDL)
Minor axis bending	$M_{fy} = 50.00$	kNm (From a mid span point load)
Shear	$V_f = 200.00$	kN

The lengths and column k factors are given are used as examples. This is not intended to represent a particular beam or column.

Length of unbraced beam segment $L = 4000$ mm

Column major axis buckling factor $K_x = 0.80$ Length $x = 5000.00$ mm

Column minor axis buckling factor $K_y = 0.80$ Length $y = 5000.00$ mm

Column flexural-torsional length $z = 5000.00$ mm

End supports are torsionally restrained

Try Section = 610x229UB101 $F_y = 235$ MPa

Section properties

$D = 602.20$ $B = 227.60$ $T_f = 14.80$ $t_w = 10.60$

Area = 12900 mm²

Moment of inertia $xx = 758.0e6$ $yy = 29.1e6$ mm⁴

Plastic moduli $xx = 2.890e6$ $yy = 401\ 000$ mm³

Elastic moduli $xx = 2.518e6$ $yy = 255\ 263$ mm³

Warping constant $C_w = 2.51e12$ mm⁶

St Venant torsional constant $J = 772\ 000$ mm⁴

11.1 Section compactness

Table 1. (I shape or channel)

Flange: $bel = B/2 = 113.80$ $bel/t = 7.69$ $bel/t(lim) = 200/F_y^{0.5} = 13.05 > 7.69$ OK

Web: $bel = 572.60$ $bel/t = 54.02$ $bel/t\ lim = 670/F_y^{0.5} = 43.706 < 54.02$ XX

Web bel exceeds limit. Use 13.3.5 (a) and reduce area by $(572.6 - 43.706 * 10.60) * 10.6 = 1158$ mm²

Effective area (A_e) = 12900 – 1158 = 11742 mm²

Table 1 classifications

Flange = 1 web = 1

Table 2.

I shape or channel

Flange: $bel = 113.80$ $bel/t = 7.69$ Class 1 limit = $145/F_y^{0.5} = 9.45 > 7.69$

Web, $h = 572.60$ $h/t = 54.02$

$C_y = A_e * F_y = 11742 * 235 = 2759.4$ kN

Class 1 limit
= $1100/F_y^{0.5} * (1 - 0.39 * C_f / \phi C_y)$
= $1100/235^{0.5} * (1 - 0.39 * 100 / (0.9 * 2759.4))$
= 70.6 > 54.02

Table 2 classifications

Flange x-x = 1 Web x-x = 1

Section classification x-x = 1

Flange y-y = 1 Web y-y = 1

Section classification y-y = 1

13.3 Axial compression

Calculate the various load capacities required for 13.8.2 (a), (b) and (c)

For (a) $C_r = \phi * A_e * F_y = 0.9 * 2759.4 = 2483.4 \text{ kN}$

For (b) $K_{x,y} = 1$

$$F_{ex} = \pi^2 E / (K_x L_x / r_x)^2 = \pi^2 200\,000 / (5000/242.4)^2 = 4639.4 \text{ MPa}$$

$$F_{ey} = \pi^2 E / (K_y L_y / r_y)^2 = \pi^2 200\,000 / (5000/47.5)^2 = 178.1 \text{ MPa}$$

$$\lambda_x = (F_y / F_{ex})^{0.5} = 0.225$$

$$\lambda_y = (F_y / F_{ey})^{0.5} = 1.149$$

$$C_r = \phi * A_e * F_y * (1 + \lambda^{2n})^{-1/n}$$

$$C_{rx} = 0.9 * 11742 * 235 * (1 + 0.225^{2*1.34})^{-1/1.34}$$

$$C_{rx} = 2449.9 \text{ kN}$$

$$C_{ry} = 0.9 * 11742 * 235 * (1 + 1.149^{2*1.34})^{-1/1.34}$$

$$C_{ry} = 1272 \text{ kN}$$

For (c) $K_{x,y} = 0.8$

Get the minimum C_r for buckling about minor axis or flexural-torsional buckling (13.3.2(a))

$$F_{ey} = \pi^2 E / (K_y L_y / r_y)^2 = \pi^2 200\,000 / (0.8*5000/47.5)^2$$

$$F_{ey} = 278.8 \text{ MPa}$$

$$F_{ez} = (\pi^2 E C_w / (K_z L_z)^2 + GJ) * 1 / (A r_o^2)$$

$$K_z = 1 \quad L_z = 5000$$

$$r_o^2 = 0^2 + 0^2 + 242.4^2 + 47.5^2 = 61\,014$$

$$F_{ez} = (\pi^2 200\,000 * 2510 \text{e}9 / (5000)^2 + 77000 * 772000) * 1 / (12900 * 61014)$$

$$F_{ez} = 327.3 \text{ MPa}$$

$$\lambda_y = (F_y / F_{ey})^{0.5} = 0.918$$

$$\lambda_z = (F_y / F_{ez})^{0.5} = 0.847$$

$$C_{ry} = 0.9 * 11742 * 235 * (1 + 0.918^{2*1.34})^{-1/1.34}$$

$$C_{ry} = 1604 \text{ kN}$$

$$C_{rz} = 0.9 * 11742 * 235 * (1 + 0.847^{2*1.34})^{-1/1.34}$$

$$C_{rz} = 1716 \text{ kN}$$

Therefore $C_{r,FTB} = C_{ry} = 1604 \text{ kN}$

13.4 Shear

$$\text{Shear area} = D * t_w = 602.2 * 10.6 = 6383.32 \text{ mm}^2$$

web unstiffened, $h/t_w = 54.0$

$$1014 / F_y^{0.5} = 66 > 54$$

$$F_s = 0.66 * F_y = 155.1 \text{ MPa}$$

$$V_r = 0.9 * 6383 * 155.1 = 891047.67 = 891.0 \text{ kN}$$

$$V_f / V_r = 200 / 891 = 0.225 < 1.0 \text{ OK}$$

13.5 and 13.6 Bending x-x

$M_{p.x} = F_y \cdot \text{Plastic modulus}(x) = 679.15 \text{ kNm}$

$M_{y.x} = F_y \cdot \text{Elastic modulus}(x) = 591.60 \text{ kNm}$

13.6 Bending x-x, Laterally unsupported

Using M_y .

$M_{\max} = 100$, $M_a = M_c = 0.75 \cdot M_{\max} = 75$ and $M_b = M_{\max}$

$\omega_2 = 4 \cdot 100 / (100^2 + 4 \cdot 100^2 + 7 \cdot 100^2 + 4 \cdot 100^2)^{0.5} \leq 2.5$

$\omega_2 = 1$

$M_u = \omega_2 \pi / L \cdot (E I_y G J + (\pi E / L)^2 I_y C_w)^{0.5}$

$M_u = 3.1416 / 4000 \cdot (200\,000 \cdot 29.1e6 \cdot 77000 \cdot 772000 + (3.1416 \cdot 200\,000 / 4000)^2 \cdot 29.1e6 \cdot 2510e9)$

$M_u = 1151.1 \text{ kNm} > 0.67 \cdot M_p = 454.9 \text{ kNm}$

Using 13.6 (a) (i)

$M_r = 1.15 \phi M_p \cdot (1 - 0.28 \cdot M_p / M_u) \leq \phi M_p$

$M_r = 1.15 \cdot 0.9 \cdot 679 \cdot (1 - 0.28 \cdot 679 / 1151.1)$

$M_{rx} = 586.6 < 0.9 \cdot 1151 = 1035$

13.5 - Bending y-y

$M_{p.y} = F_y \cdot \text{Plastic modulus}(y) = 94.23 \text{ kNm}$

$M_{y.y} = F_y \cdot \text{Elastic modulus}(y) = 60.09 \text{ kNm}$

For class 1

$M_{ry} = \phi M_{p.y}$

$M_{ry} = 0.9 \cdot 94.32 = 84.9$

13.8 Axial compression and bending

13.8.2

Interaction check = $C_f / C_r + 0.85 U_{1x} M_{fx} / M_{rx} + \beta U_{1y} M_{fy} / M_{ry} \leq 1$

$\beta = 0.6 + 0.4 \lambda_y \leq 0.85$

$\lambda_y = 1.149$

$\beta = 0.6 + 0.4 \cdot 1.149 = 1.06 > 0.85$

$\beta = 0.85$

13.8.4

$U_1 = \omega_1 / (1 - C_f / C_e)$ $\omega_{1x} = 1.0$ (UDL)

$\omega_{1y} = 0.85$ (point load)

$C_{e.x} = \pi^2 E I / L_x^2 = 59849 \text{ kN}$

$C_{e.y} = \pi^2 E I / L_y^2 = 2297.6 \text{ kN}$

$U_{1x} = 1 / (1 - 100 / 59849) = 1.002$

$U_{1y} = 0.85 / (1 - 100 / 2297.6) = 0.887$

13.8.5

Assume M_x is for a UDL. $\omega_{1,x}=1.0$

Assume M_y is for a point load. $\omega_{1,y}=0.85$

(a) cross-sectional strength (only applicable for braced frames)

(i) $C_r(\lambda=0) = \phi A_e F_y = 0.9 * 11742 * 235 = 2483 \text{ kN}$

(ii) $M_r = \phi M_p$ $M_{rx} = 611$ $M_{ry} = 84.9$

(iii) $U_{1x} = 1.00$ $U_{1y} = 1.00$ $\beta = 0.6$

Interaction check = $100/2483 + 0.85*1*100/611 + 0.6 * 1*50/84.9$

Interaction check = $0.04 + 0.14 + 0.35$

Interaction check = $0.53 \leq 1$ OK

(b) overall member strength

(i) $C_r = 1272 \text{ kN}$ (Cry for $K = 1$)

(ii) $M_r = \phi M_p$ $M_{rx} = 611$ $M_{ry} = 84.9$

(iii) For un-braced frame: $U_{1x} = 1.0$ $U_{1y} = 1.0$

(iv) For braced frame: $U_{1x} = 1.0$ $U_{1y} = 0.89$

$\beta = 0.85$

Interaction check = $100/1272 + 0.85*1*100/611 + 0.85 * 0.89*50/84.9$

Interaction check = $0.079 + 0.14 + 0.446$

Interaction check = $0.67 \leq 1$ OK (braced frame)

(c) Lateral torsional buckling

(i) $C_r = 1604 \text{ kN}$ (Cry)

(ii) $M_{rx} = 586.6$

(iii) $M_{ry} = 84.9$

(iv) For un-braced frame: $U_{1x} = 1.0$ $U_{1y} = 1.0$

(v) For braced frame: $U_{1x} = 1.0$ $U_{1y} = 0.89$

$\beta = 0.85$

Interaction check = $100/1604 + 0.85*1*100/586.6 + 0.85 * 0.89*50/84.9$

Interaction check = $0.06 + 0.145 + 0.446$

Interaction check = $0.651 \leq 1$ OK (braced frame)

In addition the member shall meet the following requirement

$M_{fx}/M_{rx} + M_{fy}/M_{ry} \leq 1.0$

$M_{rx} = 586.6$ $M_{ry} = 84.9$

$100/586.6 + 50/84.9 = 0.171 + 0.589 = 0.76 < 1.0$ OK

For tension axial load of 100kN

13.2 Axial tension

$$T_r = \phi * A_g * F_y$$

$$T_r = 0.9 * 12900 * 235$$

$$T_r = 2728.4 \text{ kN}$$

13.9.1

$$T_f/T_r + M_f/M_r \leq 1.0$$

For M_{fx}

$$100/2728 + 100/611 = 0.04 + 0.16 = 0.20 < 1 \text{ OK}$$

For M_{fy}

$$100/2728 + 50/84.9 = 0.04 + 0.59 = 0.63 < 1 \text{ OK}$$

13.9.2

$$M_f/M_r - T_f Z/M_r A \leq 1.0$$

For M_{fx}

$$100/611 - 100\,000 * 2.89e6 / (611e6 * 12900) = 0.164 - 0.0367 = 0.127 < 1 \text{ OK}$$

For M_{fy}

$$50/84.9 - 100\,000 * 401\,000 / (84.9e6 * 12900) = 0.59 - 0.0366 = 0.55 < 1 \text{ OK}$$

PROJECT : Canadian Steel code CSA S16-09

SUBJECT : Validation

Calc by : GJS

Date : 06-Jul-12

Checked :

Job No :

Revision :

Date :

Test beam-column - Compression

Code check to CSA S16-09

Design loads

	kN		kN-m
Axial load (Cf)	= 100.00	Moment x-x (Mfx)	= 100.00
Shear load (Vf)	= 200.00	Moment y-y (Mfy)	= 50.00

Lengths (mm)

Unbraced beam segment	L = 4000		
Column lengths	Lx = 5000	Ly = 5000	Lz = 5000
Effective length factors	kx = 0.8	ky = 0.8	kz = 1.0

Section 610x229UB101 rolled Grade : S 235 Fy = 235.0 MPa

Section data

D = 602.2	Bf = 227.6	Tf = 14.8	tw = 10.6
Area = 12,900	Ae = 11738 mm ²		J = 772000.00 mm ⁴
Ix = 7.58E+08		Iy = 2.91E+07 mm ⁴	
Elastic Mod x-x = 2,517,436		Plastic Mod x-x = 2,890,000 mm ³	
Elastic Mod y-y = 255,712		Plastic mod y-y = 401,000 mm ³	
rx = 242.4	ry = 47.5 mm		
Lx/rx = 20.6	Ly/ry = 105.3	Cw = 2.51E+12 mm ⁶	
Section classification x-x = 1.		Section classification y-y = 1	
Web unstiffened			

Code check results

13.8.2
w1(x) = 0.85 w1(y) = 0.85 w2 = 1 beta = 0.850

Frame is braced.

(a) Cross section strength 0.04 + 0.14 + 0.35 = 0.53
(Cr = 2482.6 Mrx = 611.2 Mry = 84.8)
(U1x = 1.0 U1y = 1.0)

(b) overall member strength 0.08 + 0.12 + 0.45 = 0.64
(Cr = 1272.1 Mrx = 611.2 Mry = 84.8)
(U1x = 0.9 U1y = 0.9)

(c) Lateral torsional buckling 0.06 + 0.14 + 0.45 = 0.65
(Cr = 1602.9 Mrx = 586.8 Mry = 84.8)
(U1x = 1.0 U1y = 0.9)

Additional moment check 0.17 + 0.59 = 0.76
(Mrx = 586.8 Mry = 84.8)

Shear. Vf/Vr = 0.22
(Vr = 891.05 kN)

Section O.K. use 610x229UB101

f1
f2
f3

PROJECT : Canadian Steel code CSA S16-09

SUBJECT : Validation

Calc by : GJS

Date : 06-Jul-12

Checked :

Job No :

Revision :

Date :

Test beam-column - Tension

Code check to CSA S16-09

Design loads

	kN		kN-m
Axial load (Cf)	= -100.00	Moment x-x (Mfx)	= 100.00
Shear load (Vf)	= 200.00	Moment y-y (Mfy)	= 50.00

Lengths (mm)

Unbraced beam segment	L = 4000		
Column lengths	Lx = 5000	Ly = 5000	Lz = 5000
Effective length factors	kx = 0.8	ky = 0.8	kz = 1.0

Section 610x229UB101 rolled Grade : S 235 Fy = 235.0 MPa**Section data**

D = 602.2	Bf = 227.6	Tf = 14.8	tw = 10.6
Area = 12,900	Ae = 12900 mm ²		J = 772000.00 mm ⁴
Ix = 7.58E+08		Iy = 2.91E+07 mm ⁴	
Elastic Mod x-x = 2,517,436		Plastic Mod x-x = 2,890,000 mm ³	
Elastic Mod y-y = 255,712		Plastic mod y-y = 401,000 mm ³	
rx = 242.4	ry = 47.5 mm		
Lx/rx = 20.6	Ly/ry = 105.3	Cw = 2.51E+12 mm ⁶	
Section classification x-x = 1.		Section classification y-y = 1	
Web unstiffened			

Code check results

Tr = Ø.A.Fy = 2728.35 kN

13.9.1 Moments x-x 0.04 + 0.16 = 0.20

13.9.1 Moments y-y 0.04 + 0.59 = 0.63

13.9.2 (a) Moments x-x 0.17 - 0.04 = 0.13

13.9.2 (a) Moments y-y 0.59 - 0.04 = 0.55

Shear. Vf/Vr = 0.22
(Vr = 891.05 kN)**Section O.K. use 610x229UB101**f1
f2
f3

25.0 BS EN 1993-6:2007 Crane supporting structure

This program checks 1993-6 for monorail (runway beam) hoists

BS EN 1993-6:2007 'Crane supporting structures'

Design a monorail beam to carry a safe working load of 5 tonne.

The beam will span 5m between supports (span1) and have a 1.5m cantilever (span2).

Assume;

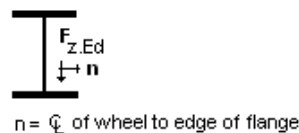
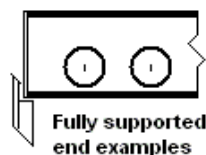
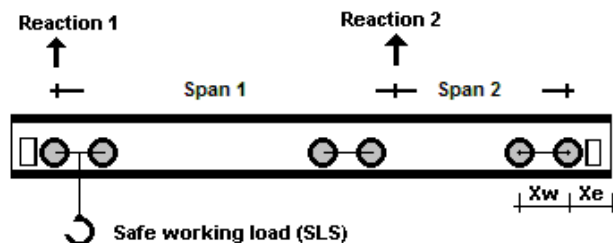
Steel $F_y = 375 \text{ MPa}$

Trolley weighs 1 tonne and has 4 wheels. Hoisting velocity= 0.1m/s and hoist class is HC1

$X_w = 400 \text{ mm}$ $X_e = 250 \text{ mm}$ $n=20 \text{ mm}$

Design loads (SLS) are; trolley = 10kN

SWL = 50kN



Try 457x152UB67

Loading factors (EN 1991-3)

EN 1991-3 Tables 2.4 and 2.5 sets ϕ dynamic factors

EN 1991-3 Annex A sets γ_G as 1.35

EN 1991-3 clause 2.5 sets horizontal load as 5% of the vertical load

Dynamic factors

$$\phi_{2 \min} = 1.05 \quad \beta_2 = 0.17 \quad \phi_2 = \phi_{2 \min} + \beta_2 \cdot v_h = 1.067$$

$$\text{Total ULS vertical load } F_{z.tot.Ed} = 1.35 \cdot (\text{Trolley} + 1.067 \cdot \text{SWL})$$

$$F_{z.tot.Ed} = 85.52 \text{ kN}$$

$$\text{Individual wheel load } F_{z.Ed} = F_{z.tot.Ed} / 4 = 21.38 \text{ kN}$$

$$\text{Total ULS transverse load } F_y = 5\% \text{ of } 1.35 \cdot (\text{Trolley} + \text{SWL}) = 4.05 \text{ kN}$$

Design check (BS EN 1993-6)

5.8 Local bending stresses in bottom flange.

Use SLS as these stresses are used in 7.5

Edge distance, $n = 20$

Clause 5.8 (3) requires $X_w/b \geq 1.5$ to keep the flange stressed areas separate, however (8) permits the superposing of flange stresses for $X_w/b < 1.5$.

To account for case of $X_w < 1.5b$ ($X_w/b < 1.5$) use multiplier k ($1 \leq k \leq 2$) to linearly superimpose stresses.

stress superposition. $X_w/b = 2.63 \geq 1.5$ therefore $k = 1.000$

$$\text{ratio } \mu (5.7) = 2 \cdot 20 / (151.9 - 9.1) = 0.280 \quad F_{z.Ed.ser} = (10 + 50) / 4 = 15 \text{ kN}$$

$$k \cdot c_{x0} = 0.232 \quad k \cdot c_{x1} = 1.821 \quad k \cdot c_{x2} = 0.829$$

$$k \cdot c_{y0} = -1.509 \quad k \cdot c_{y1} = 1.135 \quad k \cdot c_{y2} = 0.000$$

$$c_{x1} = 2.23 - 1.49\mu + 1.39e^{-(18.33\mu)} = 1.82 \text{ (check)}$$

$$c_{y0} = -2.11 + 1.977\mu + 0.0076e^{(6.530\mu)} = -1.5091 \text{ (check)}$$

$$\sigma_{x.Ed.0} = 15.46 \quad \sigma_{x.Ed.1} = 121.39 \quad \sigma_{x.Ed.2} = 55.29$$

$$\sigma_{y.Ed.0} = -100.59 \quad \sigma_{y.Ed.1} = 75.65 \quad \sigma_{y.Ed.2} = 0.00$$

Maximum induced stresses

$$\sigma_{ox.Ed.ser} = k \cdot c_{x1} \cdot F_z / t^2 = 1 \cdot 1.82 \cdot 15000 / 15^2 = 121.39$$

$$\sigma_{oy.Ed.ser} = k \cdot c_{y0} \cdot F_z / t^2 = -100.59$$

$$\sigma_{oy.end.Ed.ser} = (5.8) = 309.01 \text{ (not applicable as } X_e > \text{ limit of table 6.2)}$$

7.5 Reversible behaviour

Stress state check (SLS)

The flange local stresses from wheel loads are calculated above.

Check stress state at mid-span of span 1 and also at R2 for cantilevers.

$M_{y.Ed.ser}$ includes the beam self weight and the minor axis moment ($M_{z.Ed.ser}$) is assigned entirely to the bottom flange.

The combined stresses are checked at points 0, 1, 2 of fig 5.6.

The stresses to be combined include local flange stresses and the global stresses from beam bending, major and minor axes.

Point	Wheel load on flange		Major axis	Minor axis		(7.2d)	
	$\sigma_{x.Ed}$	$\sigma_{y.Ed}$	$M_y/W_{el.y}$	$M_z/W_{el.z}$	$\Sigma \sigma_x$		
Span1							
0	15.46	-100.59	56.8	0	72	150.4	At face of web
1	121.39	75.65	56.8	43.9	222	195.6	At wheel load location
2	55.29	0	56.8	59.6	191	171.7	At edge of beam
Span2							
			62.95	67.4		130.4	At support, no wheel loads (trolley at cantilever end)

For Span 1

$$IR = (7.2d) / F_y = 195.6/375 = 0.52$$

Span 2.

$$IR = (7.2d) / f_y = 130.4/375 = 0.35$$

6.7 Resistance of bottom flanges to wheel loads

$$m = 43.24 \quad n = 20 \quad X_w = 400 \quad X_e = 250$$

$$t_f = 15.00$$

Load at point of max beam moment (middle of span1)

Wheel remote (table 6.2 (b)) $l_{eff} = 357.74 \text{ mm}$

$\sigma_{f.Ed}$ from M_{yy} (beam self weight+trolley+load) = 77.64 MPa

$F_{f.Rd}$ (span) equation (6.2)

$$F_{f.Rd} = 357.74 \cdot 15^2 \cdot 375 / (4 \cdot 43.24) \cdot (1 - (77.64/375)^2) = 167.035 \text{ kN}$$

Load at beam end

$X_e > 2 \cdot \sqrt{2} \cdot (m+n)$. Check not required

IRs for flange local loading

At span $F_{z.Ed}/F_{f.Rd} = 0.128$

At end $F_{z.Ed}/F_{f.Rd} = 0.000$

Annex A, Assessment of LTB

Ignore the torsion component as the structural model is to use the bottom flange to take the lateral load, see 5.6.2 (4). Users need to ensure that the supports and web can transfer the 5% from the bottom flange.

span 1 compression flange buckling length = $k.LTB1 * span\ 1 = 1 \times 5000 = 5000.0$

span 2 compression flange buckling length = $k.LTB2 * span\ 2 = 2 \times 1500 = 3000.0$

Maximum compression flange buckling length = 5000.0

Interaction checks

Resistance moments

$Mb.Rd\ (1993-1-1, 6.3.2.3) = 330.4$

$Mz.Rd\ (1993-1-1) = 68.63$

Design moments (kNm)

Span 1

$My.Ed = 98.35$

$Mz.Ed = 4.66$

$My.Ed/My.Rd\ (major\ axis\ bending) = 0.30$

$Mz.Ed/0.5 * Mz.Rd\ (minor\ axis\ bending) = 0.14$

Eq (A.1) total = 0.44 ≤ 1.0 OK

Span 2

$My.Ed = 330.4$

$Mz.Ed = 6.08$

$My.Ed/My.Rd\ (major\ axis\ bending) = 0.39$

$Mz.Ed/0.5 * Mz.Rd\ (minor\ axis\ bending) = 0.18$

Eq (A.1) total = 0.57 ≤ 1.0 OK

7.3 Limits on displacements

Using serviceability limit state loads for trolley and SWL the displacements are;

Trolley mid span 1.

Displacement = 2.67 mm $\leq L/500$ (table 7.2 c) OK

Trolley at span 2 tip, load at (span2 - $X_w/2$).

Displacement = 5.57 mm $\leq L/250$ (table 7.2 c) OK

Beam reactions ULS (kN)

Trolley in span 1 at Reaction 1 (left end).

Reaction 1. Beam weight = 2.17	Load = 82.10	Total = 84.27 kN
--------------------------------	--------------	------------------

Reaction 2. Beam weight = 4.03	Load = 3.42	Total = 7.45 kN
--------------------------------	-------------	-----------------

Trolley at span 2 tip, load at (span2 - $X_w/2$).

Reaction 1. Beam weight = 2.17	Load = 22.24	Total = 24.41 kN
--------------------------------	--------------	------------------

Reaction 2. Beam weight = 4.03	Load = 107.76	Total = 111.79 kN
--------------------------------	---------------	-------------------

PROJECT : Runway beam BS EN 1993-6:2007
 SUBJECT : Validation
 Calc by: GJS Date : 27-Apr-2014 Checked :

Sheet of
 Job No : 0000
 Revision :
 Date :

Test combined spans

Monorail Runway beam - BS EN 1993-6:2007

Hoist data

SWL = 50.0 kN
 Trolley is 4 wheeled and weighs 10.0 kN. Wheels at 400 mm c/c longitudinally.
 Wheel flange edge distance n (mm) = 20
 Wheel end distance X_e (mm) = 250 Flange ends are not supported (fig 6.2)
 Hoist speed = 0.1 m/s. Hoist class = HC1. $\phi 2 = 1.07$
 Total vertical load (trolley+hook load, ULS). $F_z(\text{total}) = 85.52$ kN
 Transverse load (ULS) (1991-3 2.5.1.2) $F_y.Ed = 5\% * 1.35 * (\text{Trolley} + \text{SWL}) = 4.05$ kN

Beam data

Section 457x152UB67 F_y (MPa) 375
 $D = 457.3$ $B_f = 151.9$ $T_f = 15$ $tw = 9.1$
 Compression flange buckling lengths (k.LTB * span).
 Span 1 = 5000.0 Span 2 = 3000.0
 ULS max/min reactions under dynamic loads and beam self weight (kN)
 $R_1 = 84.3$ $R_2 = 111.8$
 span 1 = 5000 mm
 span 2 = 1500 mm



Max deflection under static load (SLS)
 Span 1 = 2.67 mm (span/1876) Span 2 = 5.57 mm (span 2/269)

6.7 Resistance of flange to wheel loads.

$F_{f.Rd}$ remote from beam end (kN) = 166.9
 Interaction ratio(s)
 $F_z.Ed / F_{f.Rd}$ remote = 0.128 End check not required as $X_e > 2 * \sqrt{2} * (m+n)$.

7.5 Stress check

Flange local stresses due to wheel loads. Note $\gamma_{M.ser}=1$
 $\sigma_{ox}.Ed = 121.4$ $\sigma_{oy}.Ed = -100.6$
 Check stress state at midspan of span 1 and also at R2 for cantilevers.
 Span 1. $\sigma_x.Ed.ser = 0.00$ $\sigma_y.Ed.ser = 100.59$ $\tau.Ed.ser = 14.4$
 (7.2d) = 0.00 $IR = (7.2d)/f_y = 0.52$ $IR = (7.2b)/f_y = 0.07$
 Span 2. $\sigma_x.Ed.ser = 130.35$ $\sigma_y.Ed.ser = 100.59$
 (7.2d) = 130.35 $IR = (7.2d)/f_y = 0.35$

Annex A Lateral Torsional Buckling check

Ignore the torsion component as the structural model is to use the bottom flange to take the lateral load, see 5.6.2 (4).
 The value of $M_{z.Rd}$ used in IRs below is halved to account for this.

Resistance moments for beam (from 1993-1-1)
 $M_{b.Rd} = 330.40$ $M_{z.Rd} (100\%) = 68.63$
 Design moments. Span 1 $M_y.Ed = 98.35$ $M_z.Ed = 4.66$
 Design moments. Span 2 $M_y.Ed = 128.28$ $M_z.Ed = 6.08$

Span 1. (A.1) $0.30 + 0.14 = 0.43$
 Span 2. (A.1) $0.39 + 0.18 = 0.57$

Section 457x152UB67 OK

f1
 f2
 f3

26.0 Stiffened plate DNV-RP-C201

Code check Angle stiffener to DNV-RP-C201, 2010

Design premise.

Stiffener is continuous

Stiffeners are 150x75 RSA at 700mm c/c. $F_y = 355$ MPa

Span= 5000mm

l_t (7.5.2) = 2300 $l_k = 2300$, $L_g = 4600$

The plate is 8 mm thick and $F_y = 420$ MPa

Design pressures are (MPa);

$\tau.S_d = 30$ $\sigma_x.S_d = 4.0$ $\sigma_y1 = 4.0$ $\sigma_y2 = 2.0$ $p.S_d = 0.004 = 4$ kPa

7.2 Forces in the idealised stiffened plate

(7.1)

$$N.S_d = \sigma_x.S_d(A_s + s.t) + \tau.t.f.s.t$$

Get τ_{crg} and τ_{crl}

$$k_g = 5.34 + 4 \cdot (5000/7000)^2 = 7.38 \quad (7.5) \quad (l < L_g)$$

$$\tau_{crg} = 7.38 \cdot 0.904 \cdot 210000 (8/5000)^2 = 3.58 \text{ MPa} \quad (7.4)$$

$$k_l = 5.34 + 4 \cdot (700/5000)^2 = 5.418 \quad (7.7) \quad (l > S)$$

$$\tau_{crl} = 5.42 \cdot 0.904 \cdot 210000 (8/700)^2 = 134.4 \text{ MPa} \quad (7.6)$$

$$\tau_{crl}/\gamma_M = 134.4/1.15 = 116.9 \text{ MPa} \quad (7.2)$$

$$\tau.S_d = 30 < 116.9 \quad \text{therefore } \tau_{tf} = 0$$

$$N.S_d = 4 \cdot (2170 + 700 \cdot 8)$$

$$N.S_d = 31,080 \text{ N}$$

(7.8) equivalent lateral line load

$$q.S_d = (p.S_d + p_0)s$$

$$\psi = 2/4 = 0.5$$

$$k_c = 2(1 + \nu [1 + 10.9 \cdot I_s / (t^3 s)]) = 52.17 \quad (7.12)$$

$$m_e = 13.3$$

$$C_0 = W_{es} \cdot f_y \cdot m_e / (k_c E t^2 s)$$

$$C_0 = 154,194 \cdot 355 \cdot 13.3 / (52.17 \cdot 210000 \cdot 64 \cdot 700) = 0.00175 \quad (7.11)$$

$$p_0 = (0.6 + 0.4 \cdot 0.5) C_0 \cdot 4 = 0.0056 \quad (7.9)$$

$$q.S_d = (p.S_d + p_0) s = 6.73 \text{ kN/m} \quad (7.8)$$

7.3 Effective plate width

$$S_e/S = C_{xs} \cdot C_{ys} \quad (7.13)$$

$$\lambda_p = 0.525 \cdot s/t \cdot \sqrt{f_y/E} \quad (7.15)$$

$$s/t = 700/8 = 87.5$$

$$E = 210000 \text{ MPa}$$

$$\lambda_p = 2.05 > 0.673$$

$$C_{xs} = (\lambda_p - 0.22) / \lambda_p^2$$

$$C_{xs} = 0.435$$

Get C_{ys} using (6.6)

$$\lambda_c = 1.1 \cdot s/t \cdot \sqrt{f_y/E} = 4.3 \quad (6.8)$$

$$\mu = 0.21(\lambda_c - 0.2) = 0.86 \quad (6.9)$$

$$\begin{aligned}
k_p &= 1.0 & (6.10) \\
\kappa &= 0.10 & (6.7) \\
S_{y,R} &= 49.34 & (6.6) \quad \sigma_{y,Rd} = \sigma_{y,R}/\gamma_M = 42.9 \\
S_{y,Sd} &= 3.86 & (\text{Ch 6.8, fig 6-6}) \\
c_i &= 0.27 & (7.16) \\
C_{ys} &= 1.004 & (7.16) \\
\text{Effective plate width per bulb flat} &= C_{xs}.C_{ys} * 700 = 303.8\text{mm}.
\end{aligned}$$

Calculate section properties NOTE I_{yy} is the bending axis

$$\begin{aligned}
A_e &= 4577 & \text{mm}^2 \\
I_s (I_{yy}) &= 20,655,982 & \text{mm}^4 \\
I_e (I_{yy}) &= 16,490,852 & \text{mm}^4 \\
W_{es} (\text{Wel.y bulb}) &= 323,035 & \text{mm}^3 \\
W_{ep} (\text{Wel.y plate}) &= 154,192 & \text{mm}^3
\end{aligned}$$

7.4 Resistance of plate between stiffeners

$$\begin{aligned}
\tau_{Rd} &= 420 / \sqrt{3} \cdot \gamma_M = 210.9 \text{ MPa} & (7.18) \\
\tau_{Sd} / \tau_{Rd} &= 30 / 210.9 = 0.14 < 1.0 \text{ OK} & (7.18) \\
k_{sp} &= 0.99 & (7.20) \\
\sigma_{y,Sd} / (k_{sp} \cdot \sigma_{y,Rd}) &= 0.09 < 1.0 \text{ OK} & (7.20)
\end{aligned}$$

7.5 Characteristic buckling strength of stiffeners

7.5.1 General

For column buckling use an average (by area) F_y as the plate and stiffener yields are different
 $F_{y_average} = 391 \text{ MPa}$

$$f_E = 1411.6 \text{ MPa} \quad (7.24)$$

$$Z_p = 47.05 \quad Z_t = 106.95$$

Plate side, $f_r = F_{y_average}$

$$\lambda = \sqrt{(391/1411)} \quad (7.23)$$

$$\mu = 0.13 \quad (7.25)$$

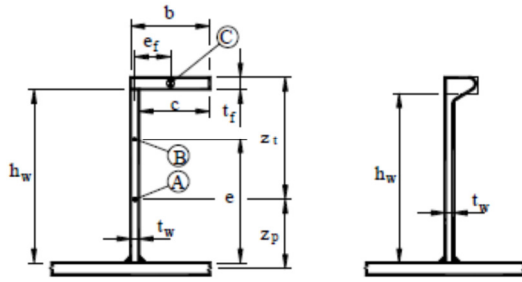
$$f_{kp} = 333.6 \text{ MPa} \quad (7.21)$$

Stiffener side. $F_r = f_t$. Use 7.5.2 to get f_t

7.2.5 Torsional buckling of stiffeners

$$\lambda_T = \sqrt{(f_y / f_{ET})}$$

For the stiffener, represented by the inverted definition diagram below;



$$f_{ET} = \beta \frac{A_w + \left(\frac{t_f}{t_w}\right)^2 A_f}{A_w + 3A_f} G \left(\frac{t_w}{h_w}\right)^2 + \frac{\pi^2 EI_z}{\left(\frac{A_w}{3} + A_f\right) l_T^2} \quad (7.32)$$

$$I_z = \frac{1}{12} A_f b^2 + e_f^2 \frac{A_f}{1 + \frac{A_f}{A_w}} \quad (7.33)$$

The values are;

$\beta =$	1.60	$t_f =$	10	$A_w =$	1400	$A_f =$	750
$t_w =$	10	$h_w =$	140	$b =$	75	$e_f =$	38
$l_z =$	1,038,335	$L_T =$	2300				

$$F_{ET} = 737.8$$

$$\lambda_T = \sqrt{(355/737.8)}$$

$$\lambda_T = 0.758 > 0.6 \text{ use} \quad (7.28)$$

$$\mu = 0.35(\lambda_T - 0.6) \quad (7.29)$$

$$\mu = 0.045$$

$$f_T/f_y = (1 + \mu + \lambda_T^2 - \sqrt{[(1 + \mu + \lambda_T^2)^2 - 4\lambda_T^2]})/(2\lambda_T^2) \quad (7.28)$$

$$f_T = 0.92 f_y$$

$$f_T = 326.5 \text{ MPa}$$

Check column buckling, Stiffener side.

$$\lambda = \sqrt{(325/1411)} \quad (7.23)$$

$$\mu = 0.136 \quad (7.26)$$

$$f_{ks} = 279.3 \text{ MPa} \quad (7.21)$$

7.6 Resistance of stiffened panels to shear stresses

$$\tau_{Rdy} = 420/(\sqrt{3} \cdot \gamma M) = 210.9 \quad (7.45)$$

$$\tau_{Rdl} = \tau_{crl}/\gamma M = 116.9 \quad (7.46)$$

$$\tau_{crs} = 222.8$$

$$\tau_{Rds} = \tau_{crs}/\gamma M = 193.7 \quad (7.47)$$

$$\tau_{Rd} = 116.9$$

7.7 Interaction formulae

7.7.3 Resistance parameters

$$A_e = 4577 \text{ mm}^2$$

$$N_{Rd} = A_e \cdot f_y / \gamma_m = A_e \cdot 355 = 1412.9 \text{ kN}$$

$$N_{ks,Rd} = A_e \cdot f_{ks} / \gamma_m = A_e \cdot 279.3 / 1.15 = 1111.6 \text{ kN}$$

$$N_{kp,Rd} = A_e \cdot f_{kp} / \gamma_m = A_e \cdot 333.6 / 1.15 = 1327.7 \text{ kN}$$

$$N_E = \pi^2 E A_e / (L_k / i_e)^2 = 6461 \text{ kN}$$

$$M_{s1,Rd} = W_{es,fr} / \gamma_m = 154,192 \cdot 326.5 / 1.15 \text{ Nmm} = 43.77 \text{ kNm}$$

$$M_{s2,Rd} = W_{es,fr} / \gamma_m = 154,192 \cdot 326.5 / 1.15 \text{ Nmm} = 43.77 \text{ kNm}$$

$$M_{st,Rd} = W_{es,fy} / \gamma_m = 154,192 \cdot 355 / 1.15 \text{ Nmm} = 47.6 \text{ kNm}$$

$$M_{p,Rd} = W_{ep,fy} / \gamma_m = 323,035 \cdot 420 / 1.15 \text{ Nmm} = 118.1 \text{ kNm}$$

(Note $M_{p,Rd}$ uses the minimum of plate top $\cdot f_{yp}$ or the stiffener top $\cdot f_{ys}$)

7.7.1 (z^* taken as zero)

$$q_{Sd} = 6.73 \text{ kN/m}$$

$$M_{1,Sd} = q_{Sd} \cdot 5^2 / 12 = 6.73 \cdot 25 / 12 = 14.02 \text{ kNm}$$

$$M_{2,Sd} = q_{Sd} \cdot 5^2 / 24 = 7.01 \text{ kNm}$$

$$1 - N_{Sd} / N_E = 1 - 31.08 / 6461 = 0.995$$

$$u = (\tau_{Sd} / \tau_{Rd})^2 = (30 / 116.9)^2 = 0.066$$

$$(7.50) \quad 31.08 / 1111.6 + 14.02 / 43.77 (0.995) + 0.066 = 0.416$$

$$(7.51) \quad 31.08 / 1327.7 - 2 \cdot 31.08 / 1412 + 14.02 / 118.1 (0.995) + 0.07 = 0.165$$

$$(7.52) \quad 31.08 / 1111.6 - 2 \cdot 31.08 / 1412 + 7.01 / 47.6 (0.995) + 0.07 = 0.198$$

$$(7.53) \quad 31.08 / 1327.7 + 7.01 / 118.1 (0.995) + 0.066 = 0.149$$

7.8 Check for shear force

The web is welded to the supporting member's web and is not vertically stiffened.

The shear area is the web of the web of the stiffener, $= h_w \cdot t_w$.

Allow for 50mm loss of web depth for ratholes etc.

For a 150x10 RSA;

$$h_w = 150 - 10 = 140 \text{ mm}$$

$$\text{Shear area} = (140 - 50) \cdot 10 = 900 \text{ mm}^2$$

$$V_{Rd} = A_{net} \cdot f_y / (\sqrt{3} \cdot \gamma_M)$$

$$V_{Rd} = 900 \cdot 355 / (\sqrt{3} \cdot 1.15)$$

$$V_{Rd} = 160.4 \text{ kN}$$

Verification

$$V_{Sd} / V_{Rd} \leq 1.0$$

$$16.83 / 160.4 = 0.11 \leq 1 \quad \text{OK}$$

PROJECT : Toolkit validation
 SUBJECT : Stiffened plate DNV C201
 Calc by: GJS Date : 20-Feb-2014 Checked :

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 Job No : 0000
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Test compression in plate

Stiffened deck plate design to DNV-RP-C201, 2010

Design loads

M1.Sd (kNm) = -14.02 M2.Sd (kNm) = 7.01
 N.Sd (kN) = 16.83 V.Sd (kN) = 31.08

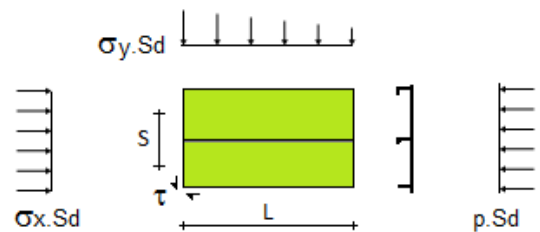
Stiffener is continuous

Stresses (MPa)

$\sigma_x.Sd = 4$ $\tau.Sd = 30$
 $\sigma_{y1}.Sd = 4$ $\sigma_{y2}.Sd = 2$
 $p.Sd = 0.004$

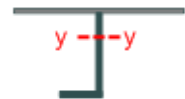
Lengths (mm)

Unbraced segment $L_t = 2300$
 Column buckling $L_k = 2300$
 Stiffener c/c = 700
 Stiffener span = 5000
 Girder span = 7000



Section

150x75 x10 RSA plus effective plate: 303 x 8
 Plate $S_e = 303.4$ $t = 8$
 F_y of plate (MPa) = 420
 F_y of stiffener (MPa) = 355



Section data

Area = 4577
 $I_s (I_{yy}) = 20655982$ $I_e (I_{yy}) = 16490852$
 $W_{ep} (W_{el.y} \text{ at plate}) = -323035$ $W_{es} (W_{el.y} \text{ at flange}) = 154192$
 rat hole web depth loss (shear only) mm = 50

7.0 Verification

Plate side loading

7.7 Interaction formulae

(7.50) = 0.42 (7.51) = 0.16
 (7.52) = 0.20 (7.53) = 0.15

7.4 Panel shear

(7.18) = 0.14 (7.19) = 0.09

7.8 Check shear

(7.76) = 0.10

Section O.K. use 150x75 x10 RSA plus effective plate: 303 x 8

27.0 Vortex induced vibration to DNV-RP-C205, 2010

Consider a tubular member 10m long, 400mm diam, $t_w = 10\text{mm}$

There is a coating of thickness 10mm and density of 1000kg/m^3

The site design wind speed = 40m/s (1 year, 1 minute)

Density of air = 1.25 kg/m^3

Density of steel = 7850kg/m^3

Strouhal number = 0.2

Kinematic viscosity of air (ν) = $1.45\text{E-}5\text{ m}^2/\text{s}$

Damping ratio (ζ) = 0.15% (0.0015)

9.5 Wind induced vortex shedding

9.4.5.6

$$U^*w = 0.8.D.Fn/St$$

Frequency

$$Fn = K / (2 \pi) * \sqrt{(E. I / (m. L^4))}$$

beam end support			K
simple	pin	pin	9.9
prop. cant.	fix	pin	15.4
encastre	fix	fix	22.4

Assume fixity is 80% of fully fixed (9.5.4.4)

$$K = 0.8 * 22.4 = 17.9$$

m = total mass/m of member

$$m (\text{tubular}) = 7850 * \pi/4 * (400^2 - (400-20)^2) = 96\text{ kg/m}$$

$$m (\text{coating}) = 1000 * \pi/4 * (420^2 - 400^2) = 12.9\text{ kg/m}$$

$$m \text{ total} = 109\text{kg/m}$$

$$I = \pi/64 * (400^4 - (400-20)^4) = 233.1\text{E-}6\text{ m}^4$$

$$E = 210,000\text{ MPa} = 210\text{E}12\text{ N/m}^2$$

$$Fn = 18.86\text{ Hz}$$

9.5.4.7

$$U^*w = 0.8 * (0.400 + 2 * 0.010) * 18.86 / 0.2 = 31.68\text{ m/s}$$

This is less than the design speed of 40m/s so check for response

9.5.4.8

Reynolds number $Re^* = U \cdot w \cdot D / \nu$

$$Re^* = 31.68 \cdot 0.420 / 1.45E-5 = 917,649 = 9.17E5$$

$$K_s = 4\pi^2 \zeta \rho_s / \rho [t/D - (t/D)^2]$$

$$K_s = 4\pi^2 \cdot 0.0015 \cdot 7850 / 1.25 [10/400 - (10/400)^2]$$

$$K_s = 9.06$$

As Re^* is greater than $5 \cdot 10^5$ check that $K_s \geq 15$

$K_s < 15$ therefore member FAILS

27.0 Vortex induced vibration to DNV-RP-C205, 2010

Consider a tubular member 10m long, 400mm diam, $t_w = 10\text{mm}$

There is a coating of thickness 10mm and density of 1000kg/m^3

The site design wind speed = 40m/s (1 year, 1 minute)

Density of air = 1.25 kg/m^3

Density of steel = 7850kg/m^3

Strouhal number = 0.2

Kinematic viscosity of air (ν) = $1.45\text{E-}5\text{ m}^2/\text{s}$

Damping ratio (ζ) = 0.15% (0.0015)

9.5 Wind induced vortex shedding

9.4.5.6

$$U^*w = 0.8.D.Fn/St$$

Frequency

$$Fn = K / (2 \pi) * \sqrt{(E. I / (m. L^4))}$$

beam end support			K
simple	pin	pin	9.9
prop. cant.	fix	pin	15.4
encastre	fix	fix	22.4

Assume fixity is 80% of fully fixed (9.5.4.4)

$$K = 0.8 * 22.4 = 17.9$$

m = total mass/m of member

$$m (\text{tubular}) = 7850 * \pi/4 * (400^2 - (400-20)^2) = 96\text{ kg/m}$$

$$m (\text{coating}) = 1000 * \pi/4 * (420^2 - 400^2) = 12.9\text{ kg/m}$$

$$m \text{ total} = 109\text{kg/m}$$

$$I = \pi/64 * (400^4 - (400-20)^4) = 233.1\text{E-}6\text{ m}^4$$

$$E = 210,000\text{ MPa} = 210\text{E}12\text{ N/m}^2$$

$$Fn = 18.86\text{ Hz}$$

9.5.4.7

$$U^*w = 0.8 * (0.400 + 2 * 0.010) * 18.86 / 0.2 = 31.68\text{ m/s}$$

This is less than the design speed of 40m/s so check for response

9.5.4.8

Reynolds number $Re^* = U \cdot w \cdot D / \nu$

$$Re^* = 31.68 \cdot 0.420 / 1.45E-5 = 917,649 = 9.17E5$$

$$K_s = 4\pi^2 \zeta \rho_s / \rho [t/D - (t/D)^2]$$

$$K_s = 4\pi^2 \cdot 0.0015 \cdot 7850 / 1.25 [10/400 - (10/400)^2]$$

$$K_s = 9.06$$

As Re^* is greater than $5 \cdot 10^5$ check that $K_s \geq 15$

$K_s < 15$ therefore member FAILS

SilverFernSolutions

PROJECT : Toolkit validation
SUBJECT : Vortex induced vibration DNV C205
Calc by: GJS Date : 21-Feb-2014 Checked :

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Date :

DNV-RP-C205. Section 9.5 Vortex shedding in air.

Wind U = 40 (m/s) Air density = 1.25 (kg/m³) Kinematic viscosity = 1.45E-05 (m²/s)

Strouhal number = 0.2 Steel density = 7850 (kg/m³) Damping ξ = 0.15 (%)

If 9.5.4.8 = 'F, but $U < U^*$ ' then that check fails, but U^* is greater than U so VIV will never occur.

Memb	Len. (mm)	Ø (mm)	tw (mm)	tcoat (mm)	γcoat (kg/m ³)	K	mass (kg/m)	Freq (Hz)	U* (m/s)	U/U* >1	Re*	Ks	9.5.4.8
	10000	400	10	10	1000	17.9	109.1	18.9	31.7	1.26 **	917,649	9.1	FAIL