Structural Calculations:

Turnlok Access System

Component Safe Working Loads

Client: VR Access Solutions Ltd.

Reference: #1462-C2

Date: April 2016

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Project Ref : #1462

Engineer : IH

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INTRODUCTION

The following calculations derive the safe maximum working loads of selected components of the Turnlok façade scaffold system.

Safe working loads should be compared with unfactored applied loads. The values quoted are figures in isolation, relative to the stated component only – supporting components must be validated as being suitable to carry the forces applied to them.

Where a degree of end fixity is available due to a components connection method, this has been utilised in calculating the maximum applied loading unless noted otherwise.

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STANDARDS

Capacity of Standards for given tie patterns:

Capacities taken from frame buckling assessments in calculation package reference #1462-C1

	TG20 Tie Pattern	L_e (mm)	N (kN)
TUBE SYSTEM	A	3595	9.78
	B	3364	11.06
	D	3595	9.78
	E	3424	10.70
OMEGA SYSTEM	A	3166	12.36
	B	2938	14.17
	D	3166	12.36
	E	2967	13.92

Capacity of Standards for given effective lengths:

Refer to spreadsheet output for analysis

L_e (mm)	1000	1500	2000	2500
N (kN)	72.5	44.0	27.9	18.9

Capacity of connection of Ledger/Transom to Standard:

Capacities marked (*) taken from Oxford Brookes Report reference 407.

	Tube System	Omega System
Section Moment Capacity (kN.m)	1.78[a]	1.70 [b]
Section Shear Capacity (kN)	45.5[a]	32.02 [b]
Joint Moment Capacity (kN.m)		
(*) Ledger/Transom moving up	2.18	1.02
(*) Ledger/Transom moving down	2.05	1.39
Joint Rotational Stiffness (kN.m/rad)		
(*) Ledger/Transom moving up	74.26	86.97
(*) Ledger/Transom moving down	69.62	97.60

(a) – Section is as Standards, refer to relevant design output for derivation

(b) – Refer to analysis of Omega Transom section. Figures refer to 4.0mm section.

SPIGOT

Refer to analysis sheet:

Section	Moment Capacity (kN.m)	Tensile Capacity (kN)
Spigot	0.46	21.6

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SWIVEL BRACE

Refer to spreadsheet output for analysis

Note: Capacity of swivel brace is limited to the known capacity of the connection, based on Oxford Brookes Report reference 407 in all cases except 2.0 x 2.5m bays where the capacity is limited by buckling at 9.2 kN.

Capacity of Swivel Brace for given effective lengths:

L_e (mm)	1000	1500	2000	2500
N (kN)	38.5	28.1	19.6	14.0
Known Connection Capacity (kN)	9.42	9.42	9.42	9.42

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Capacity of Swivel Brace for given bay arrangements lengths:

Bay Geometry (m)	Strut Length (mm)	N (kN)	Connection Capacity (kN)
1.0 x 1.8	2059	18.8	9.42
1.0 x 2.5	2693	12.4	9.42
1.5 x 1.8	2343	15.5	9.42
1.5 x 2.5	2916	10.8	9.42
2.0 x 1.8	2691	12.4	9.42
2.0 x 2.5	3202	9.22	9.42

TUBE LEDGERS

From testing, ledger connections have a 2.05 kN.m moment capacity for downwards rotation with a rotational stiffness of 69.92 kN.m/rad. This stiffness is used in the analysis model, with the loads increased until either the support moment (2.05 kN.m) or the section moment (1.78 kN.m, from analysis of standards – see spreadsheet output) is reached.

2500mm Tube Ledger

From analysis:

Load Condition	Load	Total Load (kN)	Deflection (mm)
UDL	3.2 kN/m	8.0	25.4
CPL	4.4 kN	4.4	24.7
PL's at third points	2.8 kN	5.6	25.1

Max allowable deflection = L/100 = 25mm.

1800mm Tube Ledger

From analysis:

Load Condition	Load	Total Load (kN)	Deflection (mm)
UDL	7.5 kN/m	13.5	18.1
CPL	6.2 kN	4.7	14.4
PL's at third points	4.8 kN	9.6	18.1

Max allowable deflection = L/100 = 18mm, or 25mm absolute limit.

1300mm Tube Ledger

From analysis:

Load Condition	Load	Total Load (kN)	Deflection (mm)
UDL	14.9 kN/m	19.4	11.1
CPL	8.1 kN	8.1	7.9
PL's at third points	-	-	-

Max allowable deflection = L/100 = 13mm, or 25mm absolute limit.

INTERMEDIATE TUBE TRANSOM

Tube is 48.3 3.2 S460, therefore from design sheets (same section as Standard) safe moment capacity = 1.78 kN.m.

Tube I_{yy} = 115856mm^4. Members are simply supported therefore:

1300 Inter Transom

$$UDL_{\max} = \frac{8 \times M_{safe}}{L^2}$$

$$\frac{8\ x\ 1.78}{1.3^2} = 8.4\ kN/m$$

I_{req} = 2.29 x 8.40 x 1.300^3 = 422614mm^4 for l/360, 3.6mm.

1300/100 = 13mm therefore L/100 is critical, not absolute 25mm limit.

Pro rata for l/100 = 422614 x 100/360 = 117393mm^4

Section I_{yy} = 115856.

Therefore accept deflection check.

Actual deflection = 3.6mm x 422614/115856 = 13.1mm – allow.

1800 Inter Transom

$$UDL_{\max} = \frac{8 \times M_{safe}}{L^2}$$

$$\frac{8\ x\ 1.78}{1.8^2} = 4.4\ kN/m$$

I_{req} = 2.29 x 4.4 x 1.800^3 = 587632mm^4 for l/360, 5mm.

1800/100 = 18mm therefore L/100 is critical, not absolute 25mm limit.

Section I_{yy} = 115856.

Actual deflection = 5.0mm x 587632/115856 = 25.36mm

Therefore allowable load = 4.4 x 18/25.36 = 3.12 kN/m

Span (mm)	Load	Total Load (kN)	Deflection (mm)
1300	8.4 kN/m	10.9	13.1
1800	3.1 kN/m	5.6	18.0

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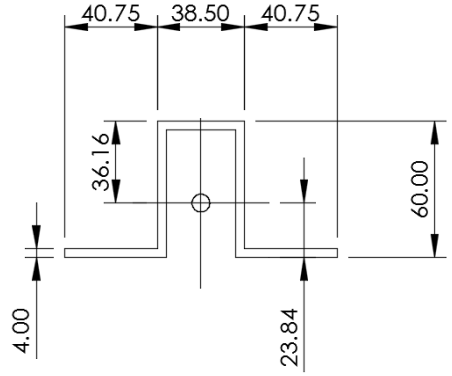
OMEGA TRANSOMS

Section Properties – 4.0mm Section



From analysis output:
A: 928 mm^2
I_{yy}: 460670 mm^4
I_{zz}: 709905 mm^4
$Z_{yy\ top}$: 12739 mm^3
$Z_{yy\ btm}$: 19323 mm^3
r_{yy}: $(I_{yy}/A)^{0.5}$ = 22.28 mm

Section Classification

Top section:	c/t: (38.5 – 4.0 – 4.0) / 4.0 =	7.62	(Internal element)
Web:	d/t: (60 – 4.0 – 4.0) / 4.0 =	13.0	(Internal element)
Flange:	c/t: 40.75/ 4.0 =	10.2	(Outstand element)

$\varepsilon = \sqrt{235}/_{220} = 1.03$

7.62 < 33 ε : Class 1 Top section

13.0 < 72 ε : Class 1 Web

10.2 < 14 ε : Class 3 Flange (hogging moments only)

End fixity creates hogging at connection, but this capacity has been derived by physical testing. Therefore derive normal sag moment capacity as Class 3 Section.

Moment Capacity

$$M_{c,Rd} = \frac{W_{el,\min} \times f_y}{\gamma_{M0}}$$ (12739 x 220/1.0) x 10^{-6} = 2.80 kN.m

Safe moment capacity: 2.80 / (1.1 x 1.5) = 1.70 kN.m

Shear Capacity

$$V_{pl,Rd} = \frac{A_v \times \left(\frac{f_y}{\sqrt{3}}\right)}{\gamma_{M0}} \qquad A_v = 2th$$

= 2 x 52 x 4.0 = 416mm^2

= 416 x (220/√3) / 1.0 = 52.84 kN

Safe shear capacity = 52.84 / (1.1 x 1.5) = 32.02 kN

Omega Transom 4.0mm

Design method is as noted previously for the tube ledgers, using section moment capacity of 1.70 kN.m, a maximum support moment of 1.39 kN.m and a connection rotational stiffness of 97.60 kN.m/rad based on testing.

From analysis:

Span	Load	Total Load (kN)	Deflection (mm)
800	26.4 kN/m	21.1	1.1
1300	11.0 kN/m	14.3	2.9

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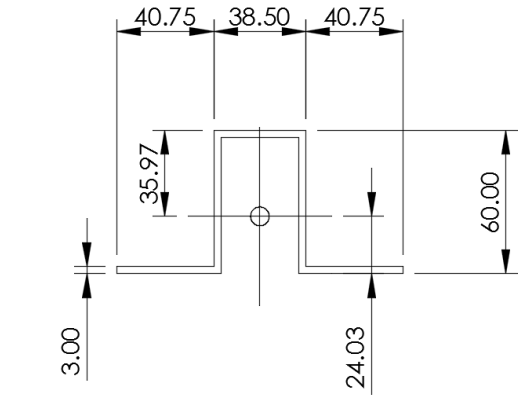
Section Properties – 3.0mm Section



From analysis output:
A: 702 mm^2
I_{yy}: 361043 mm^4
I_{zz}: 540007 mm^4
$Z_{yy\ top}$: 10037 mm^3
$Z_{yy\ btm}$: 15024 mm^3
r_{yy}: $(I_{yy}/A)^{0.5}$ = 22.67 mm

Section Classification

Top section:	c/t: (38.5 – 3.0 – 3.0) / 3.0 =	10.8	(Internal element)
Web:	d/t: (60 – 3.0 – 3.0) / 3.0 =	18.0	(Internal element)
Flange:	c/t: 40.75/ 3.0 =	13.6	(Outstand element)

$\varepsilon = \sqrt{235}/_{220} = 1.03$

10.8 < 33 ε : Class 1 Top section

18.2 < 72 ε : Class 1 Web

13.6 < 14 ε : Class 3 Flange (hogging moments only)

End fixity creates hogging at connection, but this capacity has been derived by physical testing. Therefore derive normal sag moment capacity as Class 3 Section.

Moment Capacity

$$M_{c,Rd} = \frac{W_{el,\min} \times f_y}{\gamma_{M0}}$$ (10037 x 220/1.0) x 10^{-6} = 2.21 kN.m

Safe moment capacity: 2.21 / (1.1 x 1.5) = 1.34 kN.m

Shear Capacity

$$V_{pl,Rd} = \frac{A_v \times \left(\frac{f_y}{\sqrt{3}}\right)}{\gamma_{M0}} \qquad A_v = 2th$$

= 2 x 54 x 3.0 = 324mm^2

= 324 x (220/√3) / 1.0 = 41.15 kN

Safe shear capacity = 41.15 / (1.1 x 1.5) = 24.94 kN

Omega Transom 3.0mm

Design method is as noted previous, using section moment capacity of 1.34 kN.m, a maximum support moment of 1.39 kN.m and a connection rotational stiffness of 97.60 kN.m/rad based on testing.

From analysis:

Span	Load	Total Load (kN)	Deflection (mm)
800	21.8 kN/m	17.4	1.1
1300	9.1 kN/m	11.8	2.9

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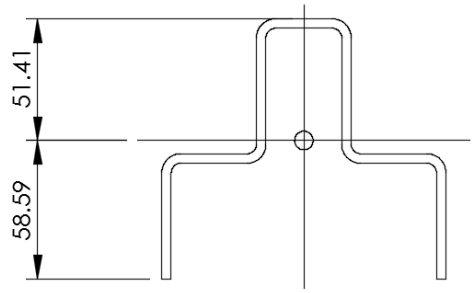
Section Properties – HD Omega Section



From analysis output:
A: 1266 mm^2
I_{yy}: 1174983 mm^4
I_{zz}: 1957919 mm^4
$Z_{yy\ top}$: 22855 mm^3
$Z_{yy\ btm}$: 20054 mm^3
r_{yy}: $(I_{yy}/A)^{0.5}$ = 30.46 mm

Section Classification

Top section:	c/t: (40 – 4.0 – 4.0) / 4.0 =	8.0	(Internal element)
Web:	d/t: (57 – 4.0 – 4.0) / 4.0 =	12.3	(Internal element)
Flange:	c/t: 40/ 4.0 =	10.0	(Internal element)
Downstand:	c/t: (53-4.0)/ 4.0 =	12.3	(Outstand element)

$\varepsilon = \sqrt{235}/_{220} = 1.03$

8.0 < 33 ε : Class 1 Top section

12.3 < 72 ε : Class 1 Web

10.0 < 14 ε : Class 3 Flange (hogging moments only)

End fixity creates hogging at connection, but this capacity has been derived by physical testing. Therefore derive normal sag moment capacity as Class 3 Section.

Moment Capacity

$$M_{c,Rd} = \frac{W_{el,\min} \times f_y}{\gamma_{M0}}$$ (20054 x 220/1.0) x 10 $^{-6}$ = 4.42 kN.m

Safe moment capacity: 4.42 / (1.1 x 1.5) = 2.67 kN.m

Shear Capacity

$$V_{pl,Rd} = \frac{A_v \times \left(\frac{f_y}{\sqrt{3}}\right)}{\gamma_{M0}} \qquad A_v = 2th$$

= 2 x 57 x 4.0 = 456mm^2

= 456 x (220/√3) / 1.0 = 57.92 kN

Safe shear capacity = 57.92 / (1.1 x 1.5) = 35.1 kN

Omega Transom HD Section

Design method is as noted previous, using section moment capacity of 2.67 kN.m, a maximum support moment of 1.39 kN.m and a connection rotational stiffness of 97.60 kN.m/rad based on testing.

From analysis:

Span	Load	Total Load (kN)	Deflection (mm)
2500	4.2 kN/m	10.6	6.6

HOP UP BRACKETS

One Board Hop Up

One board bracket is single cantilevering member only.

Support moment capacity = 2.05 kN.m (Tube) 1.39 kN.m (Omega)

Two and Three Board Hop Ups

Strut Tube

Use L_e= 800mm to cover all cases – see analysis output.

Moment capacity = 1.1 kN.m

Axial Capacity = 57.4 kN

Top Member

Tube Section

Tension capacity = 94.8 kN (same section as standards – refer to relevant design section)

Moment capacity = 1.36 kN.m

Support moment capacity = 2.05 kN.m

Omega Section

A: 928mm^2

F_y: 220N/mm^2 = 928 x 220 / (1.1 x 1.5) = 123.7 kN

Tension capacity = 124 kN

Moment capacity = 1.70 (sag) kN.m (refer to analysis of Omega Transom)

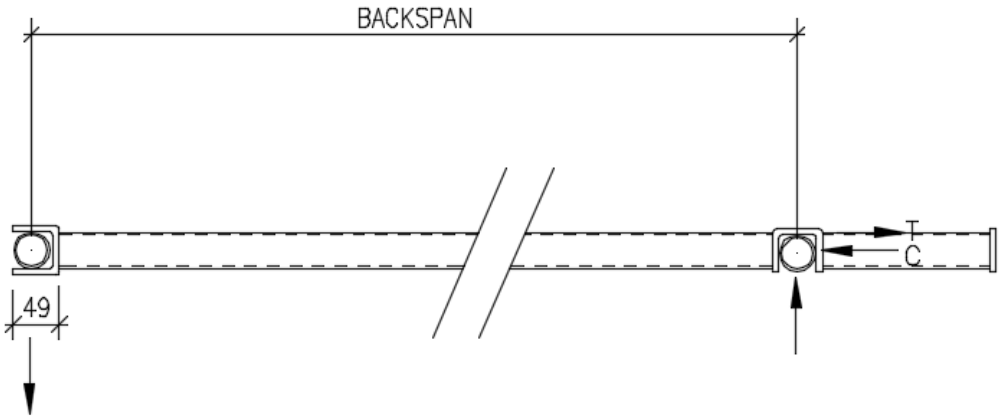
Support moment capacity = 1.39 kN.m (from test results)

Refer to analysis output for assessments of one, two and three board hop ups.

Summary of Analysis

Hop Up	Load	Control
1 Board Omega	40 kN/m	Arbitrary Limit
2 Board Omega	17.0 kN/m	Top tube support
3 Board Omega	8.7 kN/m	Top tube support
1 Board Tube	40 kN/m	Arbitrary Limit
2 Board Tube	32.8 kN/m	Top tube support
3 Board Tube	16.6 kN/m	Top tube support

INSIDE BOARD TRANSOM



One Board - Cantilever End

Moment capacity at cantilever end will be limited by:

i. Tube moment capacity

ii. Plate tension (at top of tube into bracket)

iii. Weld tension (at top of tube)

i. Tube moment capacity = 1.78 kN.m (same section as standards – refer to relevant design section).

ii. Saddle plate tension capacity = 235 N/mm^2 x 8t x 125L x 10^{-3} = 180 kN.

iii. Weld modulus as 48.3 x 1.0 = 1722mm^3 x 1mm weld throat = 1722mm^2.

For 3mm weld P_t = 0.47 kN/m. (S275, ref SCI P363 2013 edition pp. C-393)

Moment capacity = 1722 x 470 = 809340 N.mm = 0.81 kN.m

Safe moment capacity = 0.81/ (1.1 x 1.5) = 0.49 kN.m (to prevent cantilever tube tearing off plate)

Tension/Compression couple force = 0.49/(0.048/2 + 0.012/2) (lever arm) = 16.3 kN therefore plate ok (180 kN capacity)

Therefore 0.49 kN.m moment capacity is available for the cantilever.

Backspan Connection

Bending of bottom plate at end of backspan

Max backspan connection force (i.e reaction from analysis) = 4.2 kN in backspan loaded only condition.

Induced moment = 4.2 x 0.049/2 = 0.01 kN.m

Plate elastic modulus = 75 x 8^2/6 = 800mm^3

Moment capacity = 800 x 180 x 10^{-6} = 0.144 kN.m

Safe moment capacity = 0.144/ (1.1 x 1.5) = 0.088

Safe moment capacity greater than maximum induced moment therefore connection ok.

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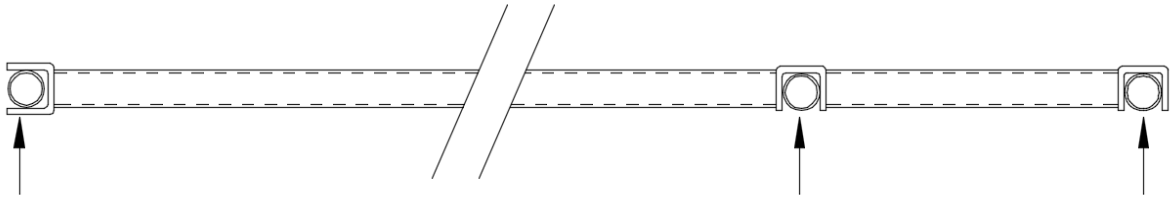
Two and Three Board – Simply Supported Inside Board Section



Maximum UDL for each bay is based on a simply supported tube, $M_{c,Rd}$ = 1.78 kN.m.

Therefore $UDL_{\max} = \frac{8 \times M_{safe}}{L^2}$

$\frac{8\ x\ 1.78}{1.3^2} = 8.4\ kN/m$

I_{req} = 2.29 x 8.4 x 1.300^3 = 422614mm^4 for l/360, 3.6mm.

1300/100 = 13mm therefore L/100 is critical, not absolute 25mm limit.

Pro rata for l/100 = 422614 x 100/360 = 117393mm^4

Section I_{yy} = 115856.

Therefore accept deflection check.

Actual deflection = 3.6mm x 422614/115856 = 13.1mm - allow

For +2 Inside span of 565mm, UDL = 44.6 kN/m (25.2 kN)

For +3 Inside span of 795mm, UDL = 22.5 kN/m (17.9 kN)

Summary of Analysis

Section	Backspan Load (kN/m)	Tip Load (kN/m)	Deflection both spans loaded (mm)	Critical Moment
+1 Inside Board Transom	6.4	12.5	7.9 Backspan. 4.0 tip uplift.	Cantilever connection for full UDL.
+2 Inside Board Transom	8.4	44.6	13.1 Main Deck.	Span sag.
+3 Inside Board Transom	8.4	22.5	13.1 Main Deck. 3.8 Inside Span	Span sag.

APPENDIX A – ANALYSIS OUTPUT – AXIAL CAPACITY OF STANDARDS

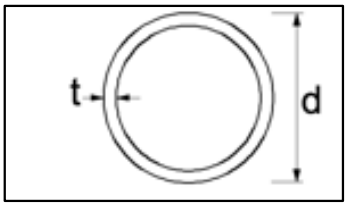
S-Mech Ltd.		Project#: 1462
Consulting Engineering		Section: CHS
Suite 9, Railway House,		Material: Steel
Railway Road, Chorley, PR6 0HW		Code: BS EN 1993-1

1.0 Global Partial Factors

Cross Section Partial Factor (γ_{M0})	1
Material Partial Factor (γ_{m}) =	1.1
Load Partial Factor (γ_{f}) =	1.5

2.0 Section Properties

Section : 48.3 x 3.2 CHS



Outside Dia.	48.3	mm
Inside Dia.	41.9	mm
Thickness	3.2	mm
Py	450	N/mm^2
Area	453.4	mm^2
Tube I_{yy}	115856.5	mm^4
R_{yy}	15.99	mm
R_{zz}	15.99	mm
Z_{yy}	4797	mm^3
S_{xx}	6520	mm^3
Weight	0.035	kN/m

3.0 Section Classification

Modification Factor ε = $\sqrt{(235/f_y)}$

ε = 0.722649

ε^2 = 0.522222

d/t = 15.09375

Section Classification =	Class 1

S-Mech Ltd.		Project#: 1462
Consulting Engineering		Section: CHS
Suite 9, Railway House,		Material: Steel
Railway Road, Chorley, PR6 0HW		Code: BS EN 1993-1

4.0 Axial Capacity

Axial Capacity Ignoring Buckling

Max Capacity $N_{c,Rd}$ = $\frac{A f_y}{\gamma_{M0}}$ (For Class 1,2,3 Sections)

Max Capacity $N_{c,Rd}$ = 204.03 kN

Permissible Axial Force = 123.65 kN (Ignoring Buckling)

Buckling Capacity

Buckling Capacity ($N_{b,Rd}$) = $\frac{\chi A f_y}{\gamma_{M1}}$ (For Class 1,2,3 Sections)

Buckling Mode Reduction Factor (χ) = $\frac{1}{\varphi + \sqrt{(\varphi^2 - \underline{\lambda}^2)}}$
(NB. $\chi \leq 1$)

φ = $0.5 [1 + \alpha (\underline{\lambda}-0.2) + \underline{\lambda}^2]$

$\underline{\lambda}$ = $\frac{1 L_{cr}}{i \lambda_1}$

λ_1 = 93.9ε

ε = $\sqrt{(235/f_y)}$

α = 0.49 For cold rolled hollow sects

i = Rad of gyration on relevant axis

Axial Buckling Capacities							
Effective Length (mm)	1000	1500	2000	2500	0	0	0
$\underline{\lambda}$	0.922	1.383	1.844	2.305	0.000	0.000	0.000
φ	1.102	1.746	2.603	3.672	0.451	0.451	0.451
χ	0.586	0.356	0.225	0.153	1.109	1.109	1.109
$N_{b,Rd}$ (kN)	119.65	72.56	45.96	31.25	226.19	226.19	226.19
Permissible Axial Force (kN)	72.51	43.98	27.85	18.94	137.09	137.09	137.09

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Project#: 1462
Section: CHS
Material: Steel
Code: BS EN 1993-1

5.0 Tensile Capacity

Tensile Design Plastic Resistance $N_{pl,Rd}$ = $\frac{A\ f_y}{\gamma_{M0}}$

Tensile Design Plastic Resistance $N_{pl,Rd}$ = 204.03 kN

Permissible Tensile Force =	123.65	kN

6.0 Section Bending Capacity

Section is not susceptible to lateral torsional buckling therefore:

Section Bending Resistance ($M_{c,Rd}$) = $\frac{W_{pl}\ f_y}{\gamma_{M0}}$ Class 1/2 Sections

$\frac{W_{el,min}\ f_y}{\gamma_{M0}}$ Class 3 Sections

Section Bending Resistance ($M_{c,Rd}$) = 2.93 kN.m Class 1/2

Section Bending Resistance ($M_{c,Rd}$) = 2.16 kN.m Class 3

Permissible Moment =	1.778	kN.m	Class 1

7.0 Section Shear Capacity

Section Shear Resistance ($V_{pl,Rd}$) = $\frac{A_v(f_y/\sqrt{3})}{\gamma_{M0}}$

For CHS Section Shear Area (A_v) = $2A/\pi$

Shear Area (A_v) = 289 mm^2

Section Shear Resistance ($V_{pl,Rd}$) = 74.99 kN

Permissible Shear Resistance =	45.45	kN

APPENDIX B – ANALYSIS OUTPUT – AXIAL CAPACITY OF SWIVEL BRACE

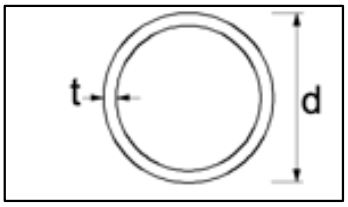
S-Mech Ltd.		Project#: 1462
Consulting Engineering		Section: CHS
Suite 9, Railway House,		Material: Steel
Railway Road, Chorley, PR6 0HW		Code: BS EN 1993-1

1.0 Global Partial Factors

Cross Section Partial Factor (γ_{M0})	1
Material Partial Factor (γ_{m}) =	1.1
Load Partial Factor (γ_{f}) =	1.5

2.0 Section Properties

Section : 48.3 x 2.5 CHS



Outside Dia.	48.3	mm
Inside Dia.	43.3	mm
Thickness	2.5	mm
Py	235	N/mm^2
Area	359.7	mm^2
Tube I_{yy}	94599.4	mm^4
R_{yy}	16.22	mm
R_{zz}	16.22	mm
Z_{yy}	3917	mm^3
S_{xx}	5249	mm^3
Weight	0.028	kN/m

3.0 Section Classification

Modification Factor ε = $\sqrt{(235/f_y)}$

ε = 1

ε^2 = 1

d/t = 19.32

Section Classification =	Class 1

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Consulting Engineering		Section: CHS
Suite 9, Railway House,		Material: Steel
Railway Road, Chorley, PR6 0HW		Code: BS EN 1993-1

4.0 Axial Capacity

Axial Capacity Ignoring Buckling

Max Capacity $N_{c,Rd}$ = $\frac{A f_y}{\gamma_{M0}}$ (For Class 1,2,3 Sections)

Max Capacity $N_{c,Rd}$ = 84.53 kN

Permissible Axial Force =	51.23 kN	(Ignoring Buckling)

Buckling Capacity

Buckling Capacity ($N_{b,Rd}$) = $\frac{\chi A f_y}{\gamma_{M1}}$ (For Class 1,2,3 Sections)

Buckling Mode Reduction Factor (χ) = $\frac{1}{\varphi + \sqrt{(\varphi^2 - \underline{\lambda}^2)}}$
(NB. $\chi \leq 1$)

φ = $0.5\,[1 + \alpha\,(\underline{\lambda}-0.2) + \underline{\lambda}^2]$

$\underline{\lambda}$ = $\frac{1\ L_{cr}}{i\ \lambda_1}$

λ_1 = $93.9\,\varepsilon$

ε = $\sqrt{(235/f_y)}$

α = 0.49 For cold rolled hollow sects

i = Rad of gyration on relevant axis

Axial Buckling Capacities							
Effective Length (mm)	2059	2693	2343	2916	2691	3202	2500
$\underline{\lambda}$	1.352	1.768	1.539	1.915	1.767	2.103	1.642
φ	1.696	2.448	2.012	2.754	2.445	3.177	2.201
χ	0.368	0.241	0.302	0.211	0.242	0.180	0.273
$N_{b,Rd}$ (kN)	31.07	20.41	25.56	17.86	20.44	15.21	23.05
Permissible Axial Force (kN)	18.83	12.37	15.49	10.83	12.39	9.22	13.97

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5.0 Tensile Capacity

Tensile Design Plastic Resistance $N_{pl,Rd}$ = $\frac{A\ f_y}{\gamma_{M0}}$

Tensile Design Plastic Resistance $N_{pl,Rd}$ = 84.53 kN

Permissible Tensile Force =	51.23	kN

6.0 Section Bending Capacity

Section is not susceptible to lateral torsional buckling therefore:

Section Bending Resistance ($M_{c,Rd}$) = $\frac{W_{pl}\ f_y}{\gamma_{M0}}$ Class 1/2 Sections

$\frac{W_{el,min}\ f_y}{\gamma_{M0}}$ Class 3 Sections

Section Bending Resistance ($M_{c,Rd}$) = 1.23 kN.m Class 1/2

Section Bending Resistance ($M_{c,Rd}$) = 0.92 kN.m Class 3

Permissible Moment =	0.748	kN.m	Class 1

7.0 Section Shear Capacity

Section Shear Resistance ($V_{pl,Rd}$) = $\frac{A_v(f_y/\sqrt{3})}{\gamma_{M0}}$

For CHS Section Shear Area (A_v) = $2A/\pi$

Shear Area (A_v) = 229 mm^2

Section Shear Resistance ($V_{pl,Rd}$) = 31.07 kN

Permissible Shear Resistance =	18.83	kN

APPENDIX C – ANALYSIS OUTPUT – TUBE LEDGERS

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Job Ref : 1462
Sheet : 1300 Tube Ledger /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
Approved :

MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group H1	Live Load
Load Group H3	Live Load

Load Case 001 : Live udl

Load Combination + 1.00 UT + 1.00 H3

Load Case 002 : Central Point Load

Load Combination + 1.00 UT + 1.00 H1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	1.300	0.000	0.000

Member Properties

Member 1

```
M  ...  ...          48.3x3.2 CHS 3.56 [S 355]
 A 4.53E-4            Ix 11.59E-8          Iy 11.59E-8          J 23.17E-8
 E 205.0E6            G 78.85E6
```

Member Loading

Member Self Weight Density Load Included in Load Group D1, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1

```
   H3 UDLY -014.900              ( kN/m )
   H1 PY   -008.100 0.650        ( kN,m )
```

Nodal Loading and Support Conditions

NODES 1-2

```
      UT Rs 1 1 1 0 0 0 (Pinned)
```

NODES 1-2

```
      UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0069.620
```

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Nodal Deflections Serviceability (001 : Live udl)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-1.13	0.00	2	0.00	0.00	1.13	0.00

Nodal Deflections Serviceability (002 : Central Point Load)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.71	0.00	2	0.00	0.00	0.71	0.00

Member Forces (001 : Live udl)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	9.685	-1.376	1.772	11.084
	2	0.000C	-9.685	-1.376	@ 0.650	@ 0.650

Member Forces (002 : Central Point Load)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	4.050	-0.863	1.769	7.928
	2	0.000C	-4.050	-0.863	@ 0.650	@ 0.650

Support Reactions Serviceability (001 : Live udl)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	9.685	1.376	2	0.000	9.685	-1.376
Total	0.000	19.370	0.000				

Support Reactions Serviceability (002 : Central Point Load)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	4.050	0.863	2	0.000	4.050	-0.863
Total	0.000	8.100	0.000				

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group H1	Live Load
Load Group H2	Live Load
Load Group H3	Live Load

Load Case 001 : Live udl
Load Combination + 1.00 UT + 1.00 H3

Load Case 002 : Central Point Load
Load Combination + 1.00 UT + 1.00 H1

Load Case 003 : Third Point Loads
Load Combination + 1.00 UT + 1.00 H2

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	1.800	0.000	0.000

Member Properties

Member 1
```
M  ...  ...        48.3x3.2 CHS 3.56 [S 355]
 A 4.53E-4          Ix 11.59E-8        Iy 11.59E-8        J 23.17E-8
 E 205.0E6          G 78.85E6
```

Member Loading

Member Self Weight Density Load Included in Load Group D1, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
```
   H3 UDLY -007.500             ( kN/m )
   H1 PY   -006.200 0.900       ( kN,m )
   H2 PY   -004.800 1.200       ( kN,m )
   H2 PY   -004.800 0.600       ( kN,m )
```

Nodal Loading and Support Conditions

NODES 1-2
```
   UT Rs 1 1 1 0 0 0 (Pinned)
```
NODES 1-2
```
   UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0069.920
```

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Nodal Deflections Serviceability (001 : Live udl)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-1.20	0.00	2	0.00	0.00	1.20	0.00

Nodal Deflections Serviceability (002 : Central Point Load)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.83	0.00	2	0.00	0.00	0.83	0.00

Nodal Deflections Serviceability (003 : Third Point Loads)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-1.14	0.00	2	0.00	0.00	1.14	0.00

Member Forces (001 : Live udl)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	6.750	-1.470	1.568	18.083
	2	0.000C	-6.750	-1.470	@ 0.900	@ 0.900

Member Forces (002 : Central Point Load)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	3.100	-1.013	1.777	14.440
	2	0.000C	-3.100	-1.013	@ 0.900	@ 0.900

Member Forces (003 : Third Point Loads)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	4.800	-1.394	1.486	18.058
	2	0.000C	-4.800	-1.394	@ 0.600	@ 0.900

Support Reactions Serviceability (001 : Live udl)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	6.750	1.470	2	0.000	6.750	-1.470
Total	0.000	13.500	0.000				

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Support Reactions Serviceability (002 : Central Point Load)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	3.100	1.013	2	0.000	3.100	-1.013
Total	0.000	6.200	0.000				

Support Reactions Serviceability (003 : Third Point Loads)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	4.800	1.394	2	0.000	4.800	-1.394
Total	0.000	9.600	0.000				

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group H1	Live Load
Load Group H2	Live Load
Load Group H3	Live Load

Load Case 001 : Live udl
Load Combination + 1.00 UT + 1.00 H3

Load Case 002 : Central Point Load
Load Combination + 1.00 UT + 1.00 H1

Load Case 003 : Third Point Loads
Load Combination + 1.00 UT + 1.00 H2

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	2.500	0.000	0.000

Member Properties

Member 1
M ... ... 48.3x3.2 CHS 3.56 [S 355]
A 4.53E-4 Ix 11.59E-8 Iy 11.59E-8 J 23.17E-8
E 205.0E6 G 78.85E6

Member Loading

Member Self Weight Density Load Included in Load Group D1, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
H3 UDLY -003.200 (kN/m)
H1 PY -004.400 1.250 (kN,m)
H2 PY -002.800 1.666 (kN,m)
H2 PY -002.800 0.833 (kN,m)

Nodal Loading and Support Conditions

NODES 1-2
UT Rs 1 1 1 0 0 0 (Pinned)
NODES 1-2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0069.920

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Nodal Deflections Serviceability (001 : Live udl)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-1.07	0.00	2	0.00	0.00	1.07	0.00

Nodal Deflections Serviceability (002 : Central Point Load)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.89	0.00	2	0.00	0.00	0.89	0.00

Nodal Deflections Serviceability (003 : Third Point Loads)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-1.00	0.00	2	0.00	0.00	1.00	0.00

Member Forces (001 : Live udl)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	4.000	-1.310	1.190	25.403
	2	0.000C	-4.000	-1.310	@ 1.250	@ 1.250

Member Forces (002 : Central Point Load)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	2.200	-1.081	1.669	24.728
	2	0.000C	-2.200	-1.081	@ 1.250	@ 1.250

Member Forces (003 : Third Point Loads)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	2.801	-1.223	1.111	25.140
	2	0.000C	-2.799	-1.223	@ 1.406	@ 1.250

Support Reactions Serviceability (001 : Live udl)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	4.000	1.310	2	0.000	4.000	-1.310
Total	0.000	8.000	0.000				

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Support Reactions Serviceability (002 : Central Point Load)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	2.200	1.081	2	0.000	2.200	-1.081
Total	0.000	4.400	0.000				

Support Reactions Serviceability (003 : Third Point Loads)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	2.801	1.223	2	0.000	2.799	-1.223
Total	0.000	5.600	0.001				

APPENDIX D – ANALYSIS OUTPUT – OMEGA TRANSOM

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Sheet : 800 OT 3mm /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group L1	Live Load

Load Case 001 : Max UDL

Load Combination + 1.00 UT + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	0.800	0.000	0.000

Member Properties

Member 1
M ... ... 3.0 OT [] E 205E6 G 80E6
A 7.02E-4 Ix 36.1E-8 Iy 54.0E-8 J 72.2E-8

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
L1 UDLY -021.780 (kN/m)

Nodal Loading and Support Conditions

NODES 1-2
UT Rs 1 1 1 0 0 0 (Pinned)
NODES 1-2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600

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Job Ref : 1462
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Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
Approved :

Nodal Deflections Serviceability (001 : Max UDL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.24	0.00	2	0.00	0.00	0.24	0.00

Member Forces (001 : Max UDL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	8.712	-0.401	1.341	1.136
	2	0.000C	-8.712	-0.401	@ 0.400	@ 0.400

Support Reactions Serviceability (001 : Max UDL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	8.712	0.401	2	0.000	8.712	-0.401
Total	0.000	17.424	0.000				

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group L1	Live Load

Load Case 001 : Max UDL

Load Combination + 1.00 UT + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	1.300	0.000	0.000

Member Properties

Member 1
M ... ... 3.0 OT [] E 205E6 G 80E6
A 7.02E-4 Ix 36.1E-8 Iy 54.0E-8 J 72.2E-8

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
L1 UDLY -009.100 (kN/m)

Nodal Loading and Support Conditions

NODES 1-2
UT Rs 1 1 1 0 0 0 (Pinned)
NODES 1-2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600

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Job Ref : 1462
Sheet : 1300 OT 3mm /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
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Approved :

Nodal Deflections Serviceability (001 : Max UDL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.35	0.00	2	0.00	0.00	0.35	0.00

Member Forces (001 : Max UDL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	5.915	-0.592	1.331	2.884
	2	0.000C	-5.915	-0.592	@ 0.650	@ 0.650

Support Reactions Serviceability (001 : Max UDL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	5.915	0.592	2	0.000	5.915	-0.592
Total	0.000	11.830	0.000				

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group L1	Live Load

Load Case 001 : Max UDL

Load Combination + 1.00 UT + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	0.800	0.000	0.000

Member Properties

Member 1
M ... ... 4.0 OT [] E 205E6 G 80E6
A 9.28E-4 Ix 46.07E-8 Iy 70.99E-8 J 92.14E-8

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
L1 UDLY -026.400 (kN/m)

Nodal Loading and Support Conditions

NODES 1-2
UT Rs 1 1 1 0 0 0 (Pinned)
NODES 1-2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600

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Date : 19 May 2016 / Ver. 2015.14
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Nodal Deflections Serviceability (001 : Max UDL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.24	0.00	2	0.00	0.00	0.24	0.00

Member Forces (001 : Max UDL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	10.560	-0.412	1.700	1.142
	2	0.000C	-10.560	-0.412	@ 0.400	@ 0.400

Support Reactions Serviceability (001 : Max UDL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	10.560	0.412	2	0.000	10.560	-0.412
Total	0.000	21.120	0.000				

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group L1	Live Load

Load Case 001 : Max UDL

Load Combination + 1.00 UT + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	1.300	0.000	0.000

Member Properties

Member 1
M ... ... 4.0 OT [] E 205E6 G 80E6
A 9.28E-4 Ix 46.07E-8 Iy 70.99E-8 J 92.14E-8

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
L1 UDLY -011.000 (kN/m)

Nodal Loading and Support Conditions

NODES 1-2
UT Rs 1 1 1 0 0 0 (Pinned)
NODES 1-2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600

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Nodal Deflections Serviceability (001 : Max UDL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.37	0.00	2	0.00	0.00	0.37	0.00

Member Forces (001 : Max UDL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	7.150	-0.622	1.701	2.938
	2	0.000C	-7.150	-0.622	@ 0.650	@ 0.650

Support Reactions Serviceability (001 : Max UDL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	7.150	0.622	2	0.000	7.150	-0.622
Total	0.000	14.300	0.000				

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Sheet : 2500 HD OT /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max UDL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	2.500	0.000	0.000

Member Properties

Member 1
```
M  ...  ...        TL HDOT []    E 205E6    G 80E6
 A 12.66E-4         Ix 117.5E-8        Iy 195.8E-8        J 235.0E-8
```

Member Loading

Member Self Weight Density Load Included in Load Group D1, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	77.01
>= 20.00	24.00
>= 2.00	10.00

Member 1
```
L1 UDLY -004.200            ( kN/m )
```

Nodal Loading and Support Conditions

NODES 1-2
```
UT Rs 1 1 1 0 0 0 (Pinned)
```
NODES 1-2
```
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600
```

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Sheet : 2500 HD OT /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
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Nodal Deflections Serviceability (001 : Max UDL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	0.00	-0.44	0.00	2	0.00	0.00	0.44	0.00

Member Forces (001 : Max UDL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	0.000C	5.372	-0.753	2.605	6.632
	2	0.000C	-5.372	-0.753	@ 1.250	@ 1.250

Support Reactions Serviceability (001 : Max UDL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	0.000	5.372	0.753	2	0.000	5.372	-0.753
Total	0.000	10.744	0.000				

APPENDIX E – ANALYSIS OUTPUT – HOP UP BRACKETS

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Job Ref : **1462**
Sheet : **THU 1 Bd SWL /**
Made by : **IH**
Date : **19 May 2016 / Ver. 2015.14**
Checked : **IH**
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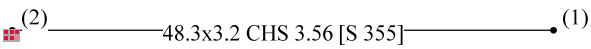

Frame Geometry - (Full Frame) - Front View

Not to Scale

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Job Ref : 1462
Sheet : THU 1 Bd SWL /
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Checked : IH
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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max SWL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.280	0.000	0.000	2	0.000	0.000	0.000

Member Properties

Member 1
M ... ... 48.3x3.2 CHS 3.56 [S 355]
A 4.53E-4 Ix 11.59E-8 Iy 11.59E-8 J 23.17E-8
E 205.0E6 G 78.85E6

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
L1 UDLY -040.000 (kN/m)

Nodal Loading and Support Conditions

NODE 2
UT Ls +0000.000 -0000.000 +0000.000 +0000.000 +0000.000 +0000.000
NODE 2
UT Rs 1 1 1 1 1 1 (Fixed)
NODE 2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0069.620

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Sheet : THU 1 Bd SWL /
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Date : 19 May 2016 / Ver. 2015.14
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Nodal Deflections Serviceability (001 : Max SWL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	-1.29	-0.35	1.29	2	0.00	0.00	0.00	0.00

Member Forces (001 : Max SWL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1 2	0.000C 0.000C	0.000 11.200	0.000 1.568		1.293 @ 0.000

Support Reactions Serviceability (001 : Max SWL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
2	0.000	11.200	1.568	Total	0.000	11.200	1.568

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Job Ref : **1462**
Sheet : **THU 2 Bd SWL /**
Made by : **IH**
Date : **19 May 2016 / Ver. 2015.14**
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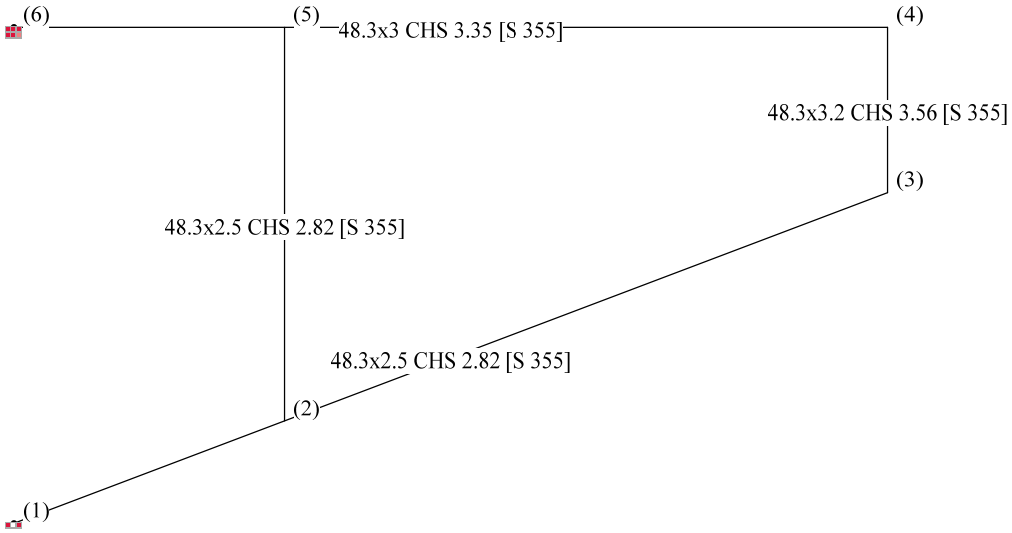

Frame Geometry - (Full Frame) - Front View

Not to Scale

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Job Ref : 1462
Sheet : THU 2 Bd SWL /
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Approved :

MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max SWL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	0.175	0.062	0.000
3	0.565	0.200	0.000	4	0.565	0.300	0.000
5	0.175	0.300	0.000	6	0.000	0.300	0.000

Member Properties

Members 1-2 and 6

```
M  ...  ...        48.3x2.5 CHS 2.82 [S 355]
 A 3.6E-4          Ix 9.46E-8         Iy 9.46E-8         J 18.92E-8
 E 205.0E6         G 78.85E6
```

Members 3-4

```
M  ...  ...        48.3x3 CHS 3.35 [S 355]
 A 4.27E-4         Ix 11.0E-8         Iy 11.0E-8         J 22.0E-8
 E 205.0E6         G 78.85E6
```

Member 5

```
M  ...  ...        48.3x3.2 CHS 3.56 [S 355]
 A 4.53E-4         Ix 11.59E-8        Iy 11.59E-8        J 23.17E-8
 E 205.0E6         G 78.85E6
```

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm²	Density kN/m³
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Members 3-4

```
L1 UDLY -032.800          ( kN/m )
```

Nodal Loading and Support Conditions

NODE 6

```
UT Ls +0000.000 -0000.000 +0000.000 +0000.000 +0000.000 +0000.000
```

NODE 6

```
UT Rs 1 1 1 1 1 1 (Fixed)
```

NODE 1

```
UT Rs 1 0 1 0 0 0 (Horizontally Restraint)
```

NODE 6

```
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0069.620
```

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Sheet : THU 2 Bd SWL /
Made by : IH
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Nodal Deflections Serviceability (001 : Max SWL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	-1.22	0.22	1.22	2	-0.20	-0.73	0.04	0.76
3	0.08	-1.64	-0.03	1.64	4	0.05	-1.65	0.04	1.65
5	0.02	-0.72	-0.27	0.72	6	0.00	0.00	0.00	0.00

Member Forces (001 : Max SWL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	10.006C	-3.545	0.000	-0.727	0.684
	2	10.006C	-3.545	-0.658	@ 0.186	@ 0.227
2	2	7.900C	3.225	-0.727	-0.727	0.684
	3	7.900C	3.225	0.607	@ 0.186	@ 0.227
3	4	6.372T	-5.676	-0.030	-0.690	0.450
	5	6.372T	7.116	0.251	@ 0.390	@ 0.211
4	5	10.615T	12.792	-0.690	-0.690	0.450
	6	10.615T	18.532	2.051	@ 0.390	@ 0.211
5	3	5.676C	-6.372	0.607		0.016
	4	5.676C	-6.372	-0.030		@ 0.042
6	2	5.676T	-4.243	0.069		0.165
	5	5.676T	-4.243	-0.941		@ 0.140

Support Reactions Serviceability (001 : Max SWL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	10.615	0.000	0.000	6	-10.615	18.532	2.051
Total	0.000	18.532	2.051				

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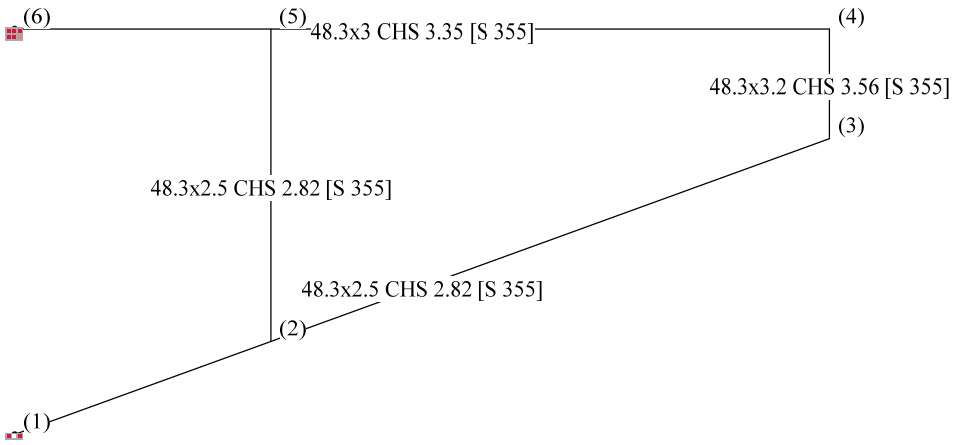
Job Ref : 1462
Sheet : THU 3 Bd SWL /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
Approved :



Frame Geometry - (Full Frame) - Front View

Not to Scale

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max SWL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	0.250	0.085	0.000
3	0.795	0.270	0.000	4	0.795	0.370	0.000
5	0.250	0.370	0.000	6	0.000	0.370	0.000

Member Properties

Members 1-2 and 6

```
M  ...  ...        48.3x2.5 CHS 2.82 [S 355]
 A 3.6E-4          Ix 9.46E-8         Iy 9.46E-8         J 18.92E-8
 E 205.0E6         G 78.85E6
```

Members 3-4

```
M  ...  ...        48.3x3 CHS 3.35 [S 355]
 A 4.27E-4         Ix 11.0E-8         Iy 11.0E-8         J 22.0E-8
 E 205.0E6         G 78.85E6
```

Member 5

```
M  ...  ...        48.3x3.2 CHS 3.56 [S 355]
 A 4.53E-4         Ix 11.59E-8        Iy 11.59E-8        J 23.17E-8
 E 205.0E6         G 78.85E6
```

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm²	Density kN/m³
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Members 3-4

```
L1 UDLY -016.600          ( kN/m )
```

Nodal Loading and Support Conditions

NODE 6

```
UT Ls +0000.000 -0000.000 +0000.000 +0000.000 +0000.000 +0000.000
```

NODE 6

```
UT Rs 1 1 1 1 1 1 (Fixed)
```

NODE 1

```
UT Rs 1 0 1 0 0 0 (Horizontally Restraint)
```

NODE 6

```
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0069.620
```

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Job Ref : 1462
Sheet : THU 3 Bd SWL /
Made by : IH
Date : 19 May 2016 / Ver. 2015.14
Checked : IH
Approved :

Nodal Deflections Serviceability (001 : Max SWL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	-2.52	0.35	2.52	2	-0.40	-1.43	0.06	1.49
3	0.09	-3.05	-0.03	3.05	4	0.06	-3.05	0.05	3.05
5	0.02	-1.42	-0.36	1.42	6	0.00	0.00	0.00	0.00

Member Forces (001 : Max SWL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	8.213C	-2.792	0.000	-0.730	1.361
	2	8.213C	-2.792	-0.737	@ 0.261	@ 0.316
2	2	6.583C	2.240	-0.696	-0.730	1.361
	3	6.583C	2.240	0.593	@ 0.261	@ 0.316
3	4	5.513T	-4.238	0.042	-0.744	0.888
	5	5.513T	4.809	0.198	@ 0.545	@ 0.305
4	5	8.675T	9.047	-0.744	-0.744	0.888
	6	8.675T	13.197	2.036	@ 0.545	@ 0.305
5	3	4.238C	-5.513	0.593		0.017
	4	4.238C	-5.513	0.042		@ 0.043
6	2	4.238T	-3.161	-0.041		0.263
	5	4.238T	-3.161	-0.942		@ 0.162

Support Reactions Serviceability (001 : Max SWL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	8.675	0.000	0.000	6	-8.675	13.197	2.036
Total	0.000	13.197	2.036				

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Job Ref : **1462**
Sheet : **OHU 1 Bd SWL /**
Made by : **IH**
Date : **19 May 2016 / Ver. 2015.14**
Checked : **IH**
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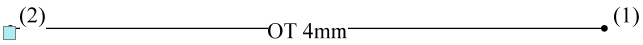

Frame Geometry - (Full Frame) - Front View

Not to Scale

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max SWL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.280	0.000	0.000	2	0.000	0.000	0.000

Member Properties

Member 1
M ... ... OT 4mm [] E 205E6 G 80E6
A 9.28E-4 Ix 46.07E-8 Iy 70.99E-8 J 92.14E-8

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Member 1
L1 UDLY -040.000 (kN/m)

Nodal Loading and Support Conditions

NODE 2
UT Ls +0000.000 -0000.000 +0000.000 +0000.000 +0000.000 +0000.000
NODE 2
UT Rs 1 1 1 1 1 1 (Fixed)
NODE 2
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0000.000

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Nodal Deflections Serviceability (001 : Max SWL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	-0.33	-0.09	0.33	2	0.00	0.00	0.00	0.00

Member Forces (001 : Max SWL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1 2	0.000C 0.000C	0.000 11.200	0.000 1.568		0.325 @ 0.000

Support Reactions Serviceability (001 : Max SWL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
2	0.000	11.200	1.568	Total	0.000	11.200	1.568

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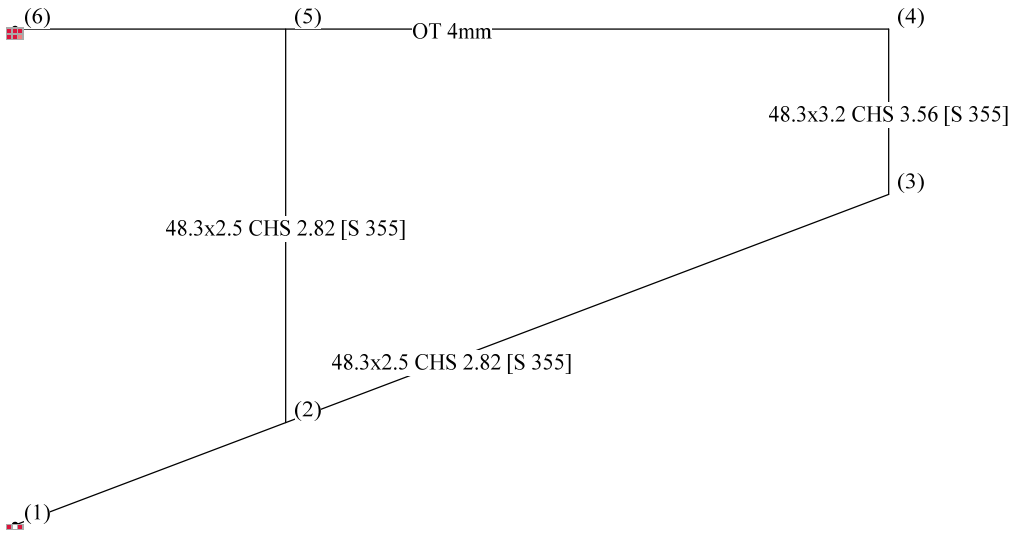

Frame Geometry - (Full Frame) - Front View

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max SWL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	0.175	0.062	0.000
3	0.565	0.200	0.000	4	0.565	0.300	0.000
5	0.175	0.300	0.000	6	0.000	0.300	0.000

Member Properties

Members 1-2 and 6

```
M  ...  ...        48.3x2.5 CHS 2.82 [S 355]
 A 3.6E-4          Ix 9.46E-8         Iy 9.46E-8         J 18.92E-8
 E 205.0E6         G 78.85E6
```

Members 3-4

```
M  ...  ...        OT 4mm []    E 205E6    G 80E6
 A 9.28E-4         Ix 46.07E-8        Iy 70.99E-8        J 92.14E-8
```

Member 5

```
M  ...  ...        48.3x3.2 CHS 3.56 [S 355]
 A 4.53E-4         Ix 11.59E-8        Iy 11.59E-8        J 23.17E-8
 E 205.0E6         G 78.85E6
```

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Members 3-4

```
L1 UDLY -017.000          ( kN/m )
```

Nodal Loading and Support Conditions

NODE 6

```
UT Ls +0000.000 -0000.000 +0000.000 +0000.000 +0000.000 +0000.000
```

NODE 6

```
UT Rs 1 1 1 1 1 1 (Fixed)
```

NODE 1

```
UT Rs 1 0 1 0 0 0 (Horizontally Restraint)
```

NODE 6

```
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600
```

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Nodal Deflections Serviceability (001 : Max SWL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	-0.33	0.09	0.33	2	-0.08	-0.15	0.01	0.17
3	0.00	-0.45	-0.01	0.45	4	0.01	-0.46	-0.01	0.46
5	0.00	-0.14	-0.07	0.14	6	0.00	0.00	0.00	0.00

Member Forces (001 : Max SWL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	4.165C	-1.476	0.000	-0.271	0.242
	2	4.165C	-1.476	-0.274	@ 0.184	@ 0.223
2	2	4.421C	1.028	-0.232	-0.271	0.242
	3	4.421C	1.028	0.193	@ 0.184	@ 0.223
3	4	3.825T	-2.443	-0.190	-0.365	0.059
	5	3.825T	4.187	0.150	@ 0.137	@ 0.179
4	5	4.419T	6.630	-0.033	-0.365	0.059
	6	4.419T	9.605	1.388	@ 0.137	@ 0.179
5	3	2.443C	-3.825	0.193		0.000
	4	2.443C	-3.825	-0.190		@ 0.000
6	2	2.443T	-0.594	-0.042		0.042
	5	2.443T	-0.594	-0.183		@ 0.131

Support Reactions Serviceability (001 : Max SWL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	4.419	0.000	0.000	6	-4.419	9.605	1.388
Total	0.000	9.605	1.388				

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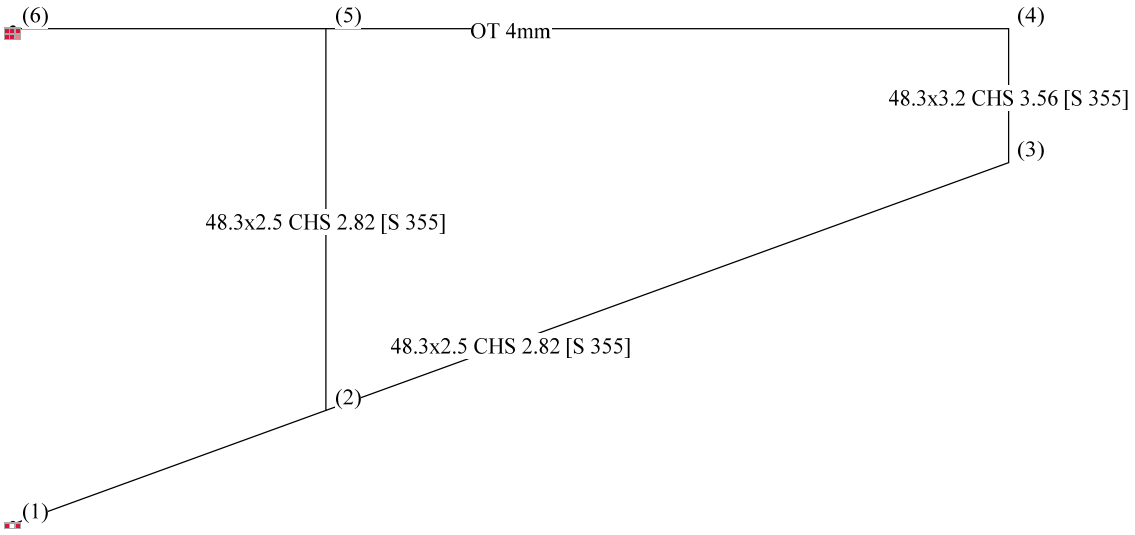

Frame Geometry - (Full Frame) - Front View

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MasterFrame Data File
Loading Cases and Load Combination

Load Group Labels

Load Group UT	Unity Load Factor (All Cases)
Load Group D1	Dead Load
Load Group L1	Live Load

Load Case 001 : Max SWL

Load Combination + 1.00 UT + 1.00 D1 + 1.00 L1

The Nodal Co-ordinates

Node	X (m)	Y (m)	Z (m)	Node	X (m)	Y (m)	Z (m)
1	0.000	0.000	0.000	2	0.250	0.085	0.000
3	0.795	0.270	0.000	4	0.795	0.370	0.000
5	0.250	0.370	0.000	6	0.000	0.370	0.000

Member Properties

Members 1-2 and 6

```
M  ...  ...        48.3x2.5 CHS 2.82 [S 355]
 A 3.6E-4          Ix 9.46E-8          Iy 9.46E-8          J 18.92E-8
 E 205.0E6         G 78.85E6
```

Members 3-4

```
M  ...  ...        OT 4mm []    E 205E6    G 80E6
 A 9.28E-4         Ix 46.07E-8         Iy 70.99E-8         J 92.14E-8
```

Member 5

```
M  ...  ...        48.3x3.2 CHS 3.56 [S 355]
 A 4.53E-4         Ix 11.59E-8         Iy 11.59E-8         J 23.17E-8
 E 205.0E6         G 78.85E6
```

Member Loading

Member Self Weight Density Load Included in Load Group D0, defined by Modulus of Elasticity

E kN/mm^2	Density kN/m^3
>= 200.00	78.00
>= 20.00	24.00
>= 2.00	10.00

Members 3-4

```
L1 UDLY -008.700          ( kN/m )
```

Nodal Loading and Support Conditions

NODE 6

```
UT Ls +0000.000 -0000.000 +0000.000 +0000.000 +0000.000 +0000.000
```

NODE 6

```
UT Rs 1 1 1 1 1 1 (Fixed)
```

NODE 1

```
UT Rs 1 0 1 0 0 0 (Horizontally Restraint)
```

NODE 6

```
UT Springs 0000.000 0000.000 0000.000 0000.000 0000.000 0097.600
```

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Nodal Deflections Serviceability (001 : Max SWL)

Node	Nodal Def. (mm and Degrees)				Node	Nodal Def. (mm and Degrees)			
	δ X →	δ Y ↑	ΦZ ↗	δ XY		δ X →	δ Y ↑	ΦZ ↗	δ XY
1	0.00	-0.71	0.14	0.71	2	-0.16	-0.29	0.02	0.33
3	0.00	-0.85	-0.02	0.85	4	0.01	-0.85	-0.01	0.85
5	0.00	-0.28	-0.09	0.28	6	0.00	0.00	0.00	0.00

Member Forces (001 : Max SWL)

Member No.	Node End1 End2	Axial Force (kN)	Shear Force (kN)	Bending Moment (kN.m)	Maximum Moment (kN.m @ m)	Maximum Deflection (mm @ m)
1	1	3.487C	-1.186	0.000	-0.310	0.501
	2	3.487C	-1.186	-0.313	@ 0.261	@ 0.304
2	2	3.830C	0.710	-0.224	-0.310	0.501
	3	3.830C	0.710	0.185	@ 0.261	@ 0.304
3	4	3.399T	-1.904	-0.155	-0.363	0.124
	5	3.399T	2.838	0.100	@ 0.218	@ 0.262
4	5	3.683T	4.742	-0.071	-0.363	0.124
	6	3.683T	6.917	1.387	@ 0.218	@ 0.262
5	3	1.904C	-3.399	0.185		0.000
	4	1.904C	-3.399	-0.155		@ 0.000
6	2	1.904T	-0.284	-0.089		0.068
	5	1.904T	-0.284	-0.170		@ 0.151

Support Reactions Serviceability (001 : Max SWL)

Node	Support Reactions (kN and kN.m)			Node	Support Reactions (kN and kN.m)		
	Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)		Rx→ (kN)	Ry↑ (kN)	Mz↗ (kN.m)
1	3.683	0.000	0.000	6	-3.683	6.917	1.387
Total	0.000	6.917	1.387				

APPENDIX F – ANALYSIS OUTPUT – SPIGOT

Spigot Capacities

Section : 32.8 x 32.8 x 3.0 SHS, Q235 Steel

$d_o := 32.8\ mm$ $t := 3.0\ mm$ $d_i := d_o - 2 \cdot t = 26.8\ mm$

$f_y := 235\ \frac{N}{mm^2}$ $f_u := 360\ \frac{N}{mm^2}$

Bolt Hole Diameter $a := 11\ mm$

Bolt Diameter $b := 10\ mm$

$\gamma_{M0} := 1.0$

$\gamma_{M2} := 1.1$ Revised from standard value of 1.25 down to 1.1 to suit requirements of BS EN 12811 with respect to steel design

Moment Capacity

$$W_{el} := \frac{\left(d_o^{\,4} - d_i^{\,4}\right)}{6 \cdot d_o} = 3260\ mm^3$$

$$M_{crd} := W_{el} \cdot f_y = 0.766\ kN \cdot m$$

$$M_{safe} := \frac{M_{crd}}{1.1 \cdot 1.5} = 0.464\ kN \cdot m$$

Tension Capacity

Net Area: $A_{net} := d_o^{\,2} - d_i^{\,2} - 2 \cdot a \cdot t = 291.6\ mm^2$

Gross Area: $A_{gross} := d_o^{\,2} - d_i^{\,2} = 357.6\ mm^2$

$$N_{plRd} := \frac{A_{gross} \cdot f_y}{\gamma_{M0}} = 84.036\ kN$$

$$N_{uRd} := \frac{0.9 \cdot A_{net} \cdot f_u}{\gamma_{M2}} = 85.889\ kN$$

$$T_{safe} := \frac{N_{uRd}}{1.5} = 57.26\ kN$$

N_{uRd} already allows for material safety factor

Bolt Bearing

$K_1 := 1.5$ To IstructE EC3 Manual

$\alpha_b := 1.0$

$$F_{bRd} := \frac{K_1 \cdot \alpha_b \cdot a \cdot t \cdot f_u}{\gamma_{M2}} = 16.2\ kN$$

per bearing surface

$$F_{bsafe} := \frac{F_{bRd}}{1.5} = 10.8\ kN$$

per bearing surface
F_{bRd} already allows for material safety factor