TEMPORARY WORKS DESIGN

DESIGN COVER SHEET

Design Ref	43648	Status	FOR APPROVAL	Category	2C
Area / Rep	SE1 / MP	Martin Smyrl / Joe Waller		CRM Project Ref	138226

Customer	HM---R087, ROCHFORD CONSTRUCTION LTD		
Contact	Keith Sheehan	<ksheehan@rochfordltd.co.uk>	075 8463 1722

Site	192 Haverstock Hill
Scheme	Havestock Hill, Temporary Basement Propping
Title	Capping Beam Propping Design Calculations

Issue	Rev	Date	Designer (TWD) Checker (TWDC)	Comments
1	T1	05.09.2016	Joe Waller Stephen Barker	Internal Tender Issue
2	A1	26/09/2016	Joe Waller Stephen Barker	Scheme design issued for Approval. Connection designs to follow upon confirmation of scheme layout and capping beam levels.
3	A2	28/09/2016	Joe Waller Stephen Barker	Scheme updated to suit revised pile design.

TEMPORARY WORKS DESIGN

DESIGN SUMMARY

EXCAVATION DETAILS

EXCAVATION TYPE	Multiple Sided Basement Excavation
PLAN DIMENSIONS (m)	Approx 35 x 7.5m
CLEARANCE (m)	n/a

FRAME LOAD SUMMARY

FRAME LOAD REF			Central Piling Report Ref: 36678A1 – *See Appendix A*	
FRAME(S)	1	Capping Beam Level	92	kN/m – SLS (Assumed @ Capping Beam Level as per report

DESIGN SOLUTION SUMMARY

GROUND SUPPORT SYSTEM			Frame(s) & Propping
FRAME(S)	1	Capping Beam Level	MGF 600 – 200 & 300 Series Struts
MAX. FRAME DEFLECTION (mm)			n/a
FRAME SUPPORT			Post fixed chemical anchors to RC capping beam – details TBC

TEMPORARY WORKS DESIGN

DESIGN NOTES

1. This design has only considered the design of the temporary frames / props.

2. Customer to provide suitable edge protection and provision for safe access and egress, as defined by Work at Height Regulation 2005 (+AMD 2007)

3. This design is offered based on information within the TWs Design Brief (Design Request Form). Prior to construction it is the Customer's responsibility to check that the Design Request Form is complete and accurate and that the installation proposed can be safely constructed. If the proposed works deviate from this design and / or site conditions vary, please seek a re-design. If in doubt, please contact MGF DSL (01942 420704).

4. Refer to the MGF Technical File and MGF Installation Guidelines for more detailed technical information.

5. References:-

   a. CIRIA Special Publication 95: - The Design and Construction of Sheet Piled Cofferdams

   b. BS EN 14653 (2005) Parts 1 & 2 Manually Operated Hydraulic Shoring Systems for Groundwork Support

   c. BS 5975 (2008) Code of Practice for Temporary Works Procedures and the Permissible Stress Design of Falsework

TEMPORARY WORKS DESIGN

SAFETY PRODUCTS

A number of safety products to ensure safe access and egress into the excavation are available to complement the equipment in this design:

MGF Edgesafe


MGF Laddersafe


MGF LW Davitsafe (A)


MGF Davitsafe (S)


MGF Ringsafe

We also have a comprehensive range of emergency escape breathing apparatus, gas detectors, fall arrest and rescue equipment and harnesses available. Please contact your local depot for more details.

For more information on our safety products, download our ancillaries booklet.

ADDITIONAL PRODUCTS


MGF Pipelifter


Culvert Pullers


Manhole Shutters


Pipe Stoppers

Temporary Works Design

APPENDX A – Design Information

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01942 402 704

a) From CIRIA C580 (2003), Embedded Retaining Walls: Guidance to Economical Design, Table 5.6

b) From Stroud & Butler (1975) – The Standard Penetration Test and the Engineering Properties of Glacial Materials

c) From Peck (1974) – Foundation Engineering (2nd Ed.)

3.2 Ground Water Table

The ground investigation has found the two holes dry at completion, with small localized seepages at 7.3 and 6.3mbgl, due to local more permeable intercluded layers rather than to a real proper ground water table.

4 Design

4.1 Software

The Wallap software, Version 5 developed by Geosolve, has been used for the design of the wall. A bending moment and displacement analysis has been performed where the software follows stage by stage the development of forces and wall movements which are modelled as construction proceeds. The wall and soil are represented as a beam and springs, with a subgrade reaction analysis.

4.2 Pile Loads

The structural engineer has provided a full list of compression loads acting on each wall pile: they range between 100kN and 386kN.

There are no external tension or lateral loads on the wall piles.

4.3 Structural Dimensions

The retaining wall along the two long sides of the building's perimeter is designed as a contiguous piled wall formed of 450mm at 600mm with pile lengths of 11.0m.

4.4 Materials

The materials allowed for in the design are as follows:

- Concrete: C28/35 strength class and DC-2 ACEC concrete class according to the recommendations of the BRE Special Digest 1 and in accordance with the site investigation report conclusions
- Steel: yield resistance of 500N/mm^2.

4.5 Propping/Anchorage

A propping layout has been preliminarily agreed with elements at 5m spacing and capping beam level along the wall sides. Props are assumed at a level of 1m below the top of the wall.

4.6 Surcharges

For the calculations of the prop forces the worst situation in terms of surcharges has been considered: this one allows for a 240kPa surcharge at a depth of 1.5m, assuming that this very high value is due to the foundations of an adjacent building.

The surcharge width is assumed equal to 1.5m, an average dimension for a line foundation.

4.7 Overdig

An overdig of 200mm was allowed for in all the wall calculations.

4.8 Design Standards

The retaining wall piles have been designed in accordance with the Eurocodes. An ultimate limit state approach (ULS) has been utilised to assess the forces in the piled wall, and a serviceability limit state (SLS) has been utilised to assess the lateral displacements and the forces in the props. The ULS analysis involved the application of partial factors on the soil parameters, whilst the SLS analysis considered the unfactored, characteristic values of the soil parameters.

4.9 Retaining Wall Construction Sequence

For propped wall sections, the following construction sequence was considered in the design:

1. Execution of piling platform
2. Construction of the piles
3. Trimming of the piles down to the cut-off level
4. Construction of the capping beam
5. Excavation to 1.0m below the ground level
6. Prop installation at -0.5mbgl
7. Excavation to the formation level of -3.9m, including a 200mm overdig.

Excavation cannot go further than 1.5m deep if the capping beam has not been previously constructed and the prop level put in place.

Props shall be used to retain the wall at the level of the capping beam, until the basement slab and lining wall are cast and cured.

4.10 Retaining Wall Results

Envelopes of the maximum bending moments and shear forces were utilized for the structural design of the wall piles. Tables 4 and 5 give the summarised displacement, prop force, moment, and shear results of the retaining wall analyses for a wall height of 3.7m. The full retaining wall calculations are given in Appendix 1.

Table 4 – Summary of Results for SLS (3.7m Height)

Design Section	Serviceability Limit State (SLS)	
	Displacement	Strut Force
	(mm)	(kN/m)
3.7m height	9	92

Table 5 – Summary of Results for ULS (3.7m Height)

Design Section	Ultimate Limit State (ULS)			
	Bending moment		Shear Force	
	per metre (kN-m/m)	per pile (kN-m)	per metre (kN/m)	per pile (kN/m)
3.7m height	143	85.8	135	81

In the absence of a more sophisticated numerical model the deflection estimate is a complicated matter that deserves few comments.

This estimate is strongly influenced – in a case like this one - by the presence of the high surcharge: in fact, the Wallap code creates in a first initial stage the natural ground stress conditions (total or effective natural stresses according to the presence or not of the groundwater) necessary for the following calculations.

When the external surcharge is applied, and this happens before any excavation takes place, the software already computes a deflection due to the presence of the new (horizontal) stress state in the soil from the existing foundation. In this case this deflection is in the order of 15mm, a very high value.

If this surcharge is important, like in this specific case, the resulting deflection, that has nothing to do with the excavation process, can be relevant, even if in (design) practice has scarce physical meaning.

To overcome this a supplementary stage has been added in the design model, where the deflection due to the initial application of the surcharge is set back to zero before any excavation activity takes place: in fact if the surcharge application time is in the order of years this effect is fully terminated and has no more influence on the new construction.

The resulting calculated final value with this procedure is the real value due to the construction process and excavation for the wall.

The estimate presented is even more prudential due to the fact that having a surcharge at a certain depth, 1.5m in this case, means that the original vertical stress at that depth is decreased by the excavated material, by an amount equal to 1.5 * 18 = 27kPa, so that the real surcharge to be applied in the calculation model should be equal in this case to 240 – 27 = 213kPa, a value which would of course bring to a lower deflection estimate. In any case this has been neglected.

The maximum calculated lateral displacement is thus 9mm, a value generally considered to be within the allowable range.

To fully ascertain the acceptability of this value with respect to the presence of buildings near the wall the following information will have to be made available to the structural engineer:

- kind of superstructure of the adjacent building (i.e. reinforced concrete, steel frame, wood, etc.) to allow for a proper structural engineering judgement on the capacity of the existing structure

Temporary Works Design

APPENDX B – Design Calculations

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DESIGN ASSUMPTIONS & PARAMETERS

Design Code	BS 5950-1:2000	
Accidental Load	10	kN
Level of site control	High	!Residual Risk! - Walers and props to be clear of loose material
Load Factors	1.50	Prop Load
	1.40	Self-weight Dead Load
	1.60	Imposed Load
	1.05	Accidental Load
Number of sides	4	Walers to be supported vertically. See Waler Design for max. centres.
Number of props	5	Props to be supported vertically at each end.
Powerpack warnings	Off	!Residual Risk! - Detail scheme to avoid excessive loads in powerpacks
Joint warnings	Off	!Residual Risk! - Position joints to avoid capacity being exceeded
Lateral shear restraint	No	Axial loads in walers are cumulative

RESULTS SUMMARY

Waler Ref.	Length (m)	Size / Type	Ulitisation
W1	30.92	CAPPING BEAM	n/a
W2	7.13	CAPPING BEAM	n/a
W3	30.22	CAPPING BEAM	n/a
W4	4.17	CAPPING BEAM	n/a

Prop Ref.	Length (m)	Size / Type	Ulitisation
P1	6.75	MGF 300 Series	0.848
P2	6.75	MGF 200 Series	0.916
P3	6.75	MGF 200 Series	0.813
P4	6.75	MGF 200 Series	0.925
P5	6.75	MGF 200 Series	0.928

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		Scheme Title Havestock Hill	Date 28/09/2016
Prepared By JCW	Checked By SB	Calculation Title Propping - Waler Analysis	Sheet of 1 1

WALER ANALYSIS

(Effects are unfactored)

Waler	***L (m)***	***Spans***		***End A***	***Intermediate Supports***												***End B***
W1	30.92	6	***X (m)***	0.00	6.03	11.03	16.03	21.03	26.03								30.92
			Prop	W8	P1	P2	P3	P4	P5								W2
			R (kN)	288	508	446	464	460	456								223
			Angle (°)	0	3	3	7	7	7								0
			F (kN)	288	509	446	467	464	459								223
W2	7.13	1	***X (m)***	0.00													7.13
			Prop	W1													W3
			R (kN)	328													328
			Angle (°)	0													0
			F (kN)	328													328
W3	30.22	6	***X (m)***	0.00	5.05	10.05	15.05	20.05	25.05								30.22
			Prop	W2	P5	P4	P3	P2	P1								W4
			R (kN)	233	462	459	461	458	467								240
			Angle (°)	0	7	7	7	3	3								0
			F (kN)	233	466	463	464	459	468								240
W4	4.17	1	***X (m)***	0.00													4.17
			Prop	W3													W1
			R (kN)	192													192
			Angle (°)	0													0
			F (kN)	192													192

Customer	Rochford Construction Ltd	Date:	42641
Scheme Title	Havestock Hill	Prepared By	JCW
Calculation Title	Waler W1 Analysis	Checked By	SB
Job No.	43648	Page No.	W1

(cyan)	Data from Waler Analysis sheet
(grey)	Input data
(yellow)	Results

Input Variables:														
Total Length of Beam (m)	30.92													
Type of end supports	Fixed at both ends													
No. of intermediate Supports	5	Right end free?	No											
Location of intermediate Supports (m)	6.03	11.03	16.03	21.03	26.03									
Load Information:			Value of UDL (kN/m)	92.0										
No. of Uniform Distributed Loads	1		Start of UDL (m)	0.00										
No. of Point Loads	0		End of UDL (m)	30.92										
Load (kN) (+ve downwards)														
Location of Load (m)														
No. of Moments	0													
Moment (kNm) (+ve anti-clockwise)														
Location of Moment (m)														
Reaction forces (kN) (+ve upwards)	288.0	508.0	445.8	463.5	460.2	455.7	223.5							
Location of Support (m)	0.00	6.03	11.03	16.03	21.03	26.03	30.92							
Reaction Moments (kNm)	300.1	-180.9												
Location of Support (m)	0.00	30.92												

Load Diagram

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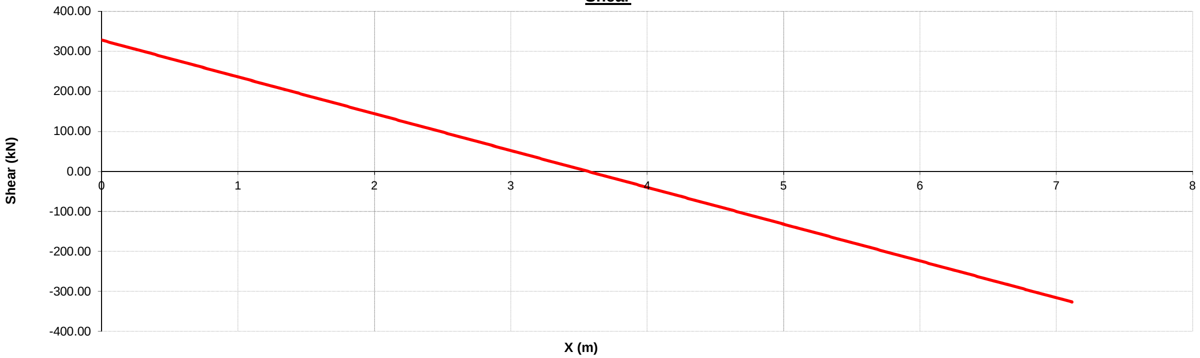
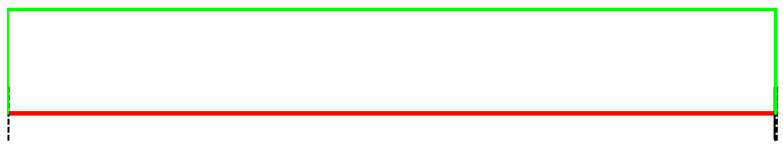
	Calculation Title	Waler W2 Analysis	Checked By	SB	Input data
	Job No.	43648	Page No.	W2	Results

Input Variables:							
Total Length of Beam (m)	7.13						
Type of end supports	Fixed at both ends						
No. of intermediate Supports	0	Right end free?	No				
Location of intermediate Supports (m)							
Load Information:		Value of UDL (kN/m)		92.0			
No. of Uniform Distributed Loads	1	Start of UDL (m)		0.00			
No. of Point Loads	0	End of UDL (m)		7.13			
Load (kN) (+ve downwards)							
Location of Load (m)							
No. of Moments	0						
Moment (kNm) (+ve anti-clockwise)							
Location of Moment (m)							
Reaction forces (kN) (+ve upwards)	328.1	327.8	467.1	537.3	417.9	386.0	109.3
Location of Support (m)	0.00	7.13	11.00	18.00	26.00	34.00	40.00
Reaction Moments (kNm)	390.1	-390.1					
Location of Support (m)	0.00	7.13					

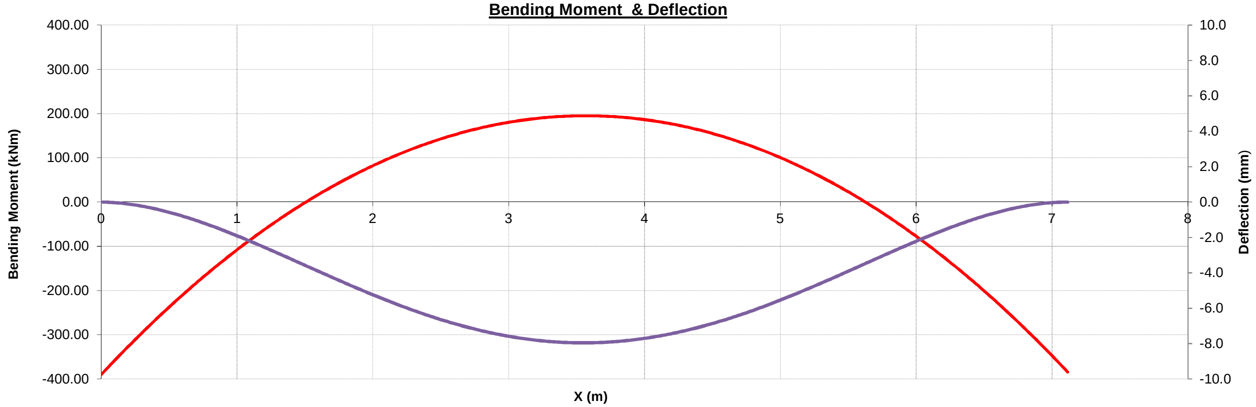
Shear



Load Diagram



Bending Moment & Deflection



BEAM DEFLECTIONS ARE INDICATIVE OF MGF 406UC BRACE - CAPPING BEAM DEFLECTIONS TO BE CALCULATED BY CAPPING BEAM DESIGNER

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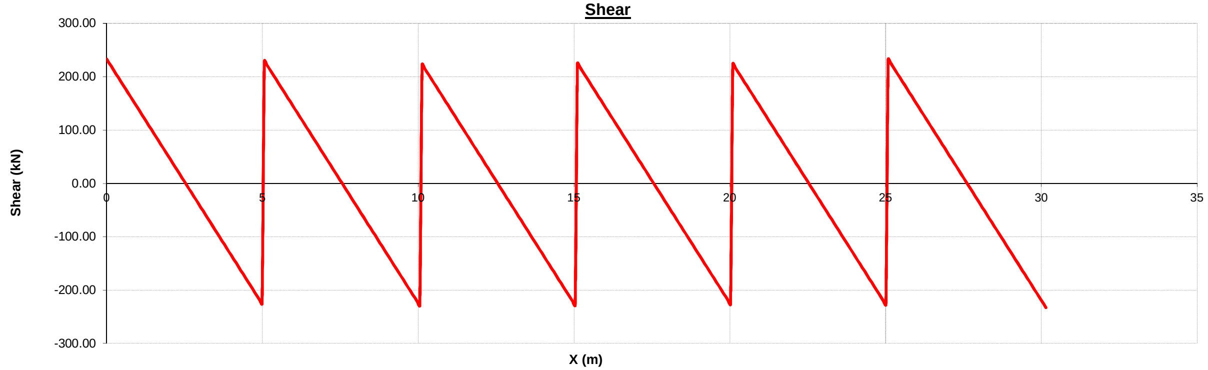
Customer	Rochford Construction Ltd	Date:	42641
Scheme Title	Havestock Hill	Prepared By	JCW
Calculation Title	Waler W3 Analysis	Checked By	SB
Job No.	43648	Page No.	W3

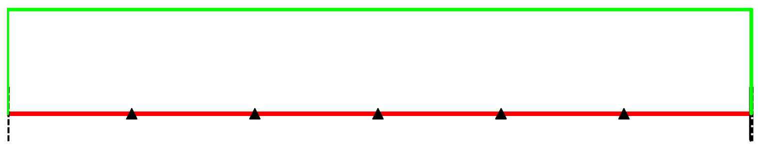
	Data from Waler Analysis sheet
	Input data
	Results

Input Variables:							
Total Length of Beam (m)	30.22						
Type of end supports	Fixed at both ends						
No. of intermediate Supports	5	Right end free?	No				
Location of intermediate Supports (m)	5.05	10.05	15.05	20.05	25.05		
Load Information:			Value of UDL (kN/m)	92.0			
No. of Uniform Distributed Loads	1		Start of UDL (m)	0.00			
No. of Point Loads	0		End of UDL (m)	30.22			
Load (kN) (+ve downwards)							
Location of Load (m)							
No. of Moments	0						
Moment (kNm) (+ve anti-clockwise)							
Location of Moment (m)							
Reaction forces (kN) (+ve upwards)	233.0	462.2	459.3	460.7	458.0	467.3	239.8
Location of Support (m)	0.00	5.05	10.05	15.05	20.05	25.05	30.22
Reaction Moments (kNm)	196.6	-208.3					
Location of Support (m)	0.00	30.22					

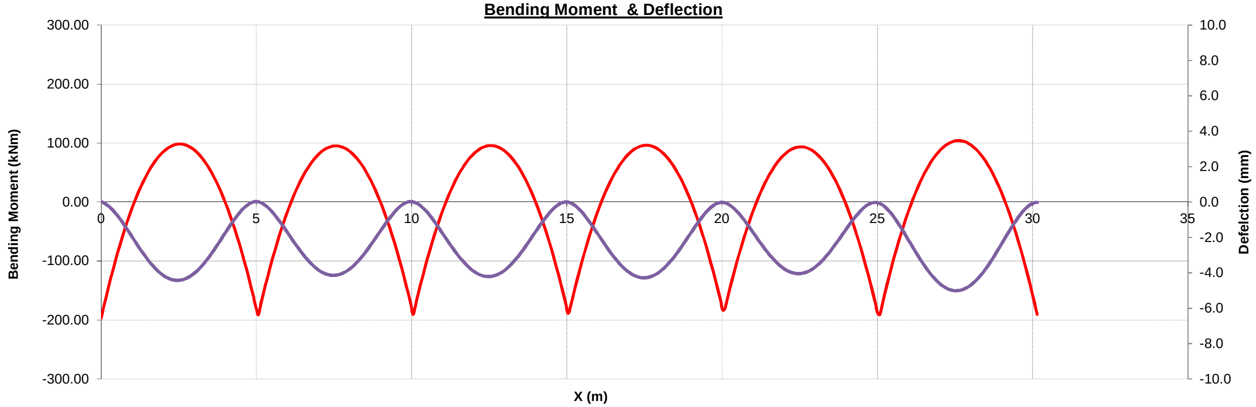
Shear



Load Diagram



Bending Moment & Deflection



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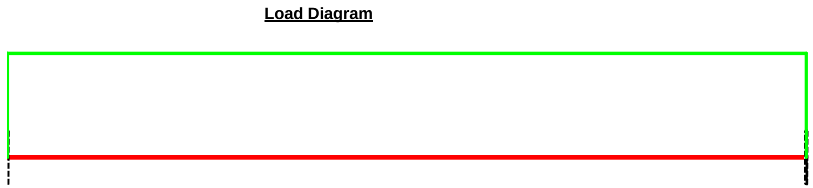
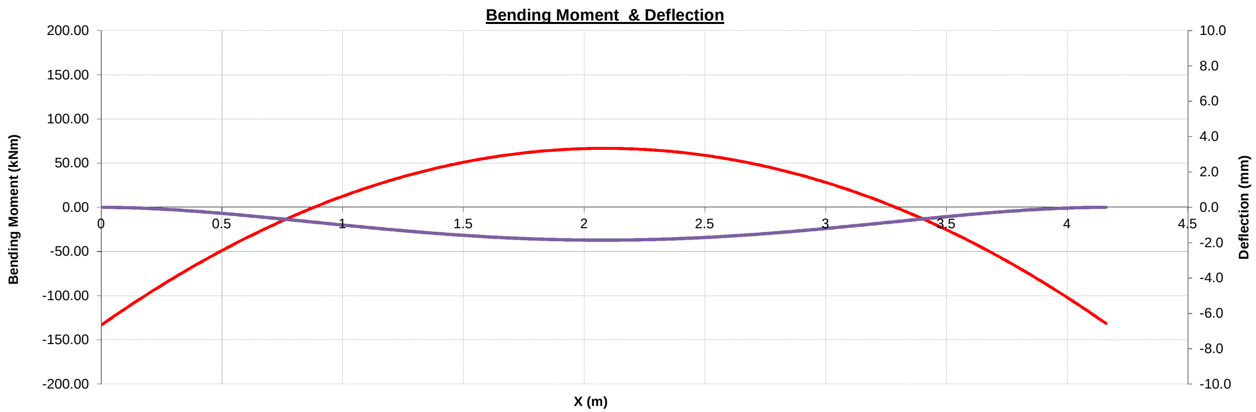
Customer	Rochford Construction Ltd	Date:	42641
Scheme Title	Havestock Hill	Prepared By	JCW
Calculation Title	Waler W4 Analysis	Checked By	SB
Job No.	43648	Page No.	W4

	Data from Waler Analysis sheet
	Input data
	Results

Input Variables:					
Total Length of Beam (m)	4.17				
Type of end supports	Fixed at both ends				
No. of intermediate Supports	0	Right end free?	No		
Location of intermediate Supports (m)					
Load Information:			Value of UDL (kN/m)	92.0	
No. of Uniform Distributed Loads	1		Start of UDL (m)	0.00	
No. of Point Loads	0		End of UDL (m)	4.17	
Load (kN) (+ve downwards)					
Location of Load (m)					
No. of Moments	0				
Moment (kNm) (+ve anti-clockwise)					
Location of Moment (m)					
Reaction forces (kN) (+ve upwards)	191.9	191.8	-66.2	278.2	-17.3
Location of Support (m)	0.00	4.17	6.50	9.00	10.00
Reaction Moments (kNm)	133.4	-133.4			
Location of Support (m)	0.00	4.17			





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Customer	Job No
Rochford Construction Ltd	43648
Scheme Title	Date
Havestock Hill	42641

Prepared By	Checked By	Calculation Title	Sheet	of
JCW	SB	Propping - Prop Loads	1	1

PROP ANALYSIS *(Effects are unfactored)*

Prop	Length (m)	Axial (kN)	Prop Size / Type	Adjustable Unit	Utilisation		Prop Weight (kg)
P1	6.750	509	**MGF 300 Series**	**600kN Hydraulic**	**0.848**	**OK**	**964**
P2	6.750	459	**MGF 200 Series**	**600kN Hydraulic**	**0.916**	**OK**	**593**
P3	6.750	467	**MGF 200 Series**	**600kN Hydraulic**	**0.813**	**OK**	**593**
P4	6.750	464	**MGF 200 Series**	**600kN Hydraulic**	**0.925**	**OK**	**593**
P5	6.750	466	**MGF 200 Series**	**600kN Hydraulic**	**0.928**	**OK**	**593**

PROP DESIGN P1

Maximum Effects (factored)

Axial	F_c	=	763	kN
Moment (x-x)	M_x	=	34	kNm
Moment (y-y)	M_y	=	0	kNm
Shear (x-x)	F_{vx}	=	18	kN
Deflection	δ_{Tot}	=	7.7	mm (unfactored)

M_x = (0 + 10 + 6 + 18) = ($M_{x,imp}$ + $M_{x,swt}$ + $M_{x,P\delta}$ + $M_{x,Acc}$)

Member Selection

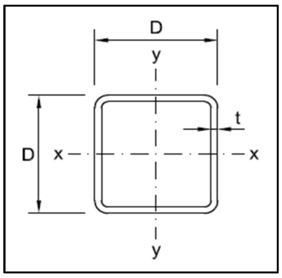
MGF proprietary equipment?	Yes	
Type	SHS	
Rolling Process	Cold	
Section Size	300 x 300 x 12.5	SHS
Steel Grade	S355	
Self-weight	130	kg/m
Adjustable Unit	600kN Hydraulic	
CHECK (Adjustable Capacity)	0.848	OK

MGF Tank Brace	*Section Size*		*Steel Grade*	*Rolling Process*	*S/Wt (kg/m)*
200 Series	200 x 200 x 8	SHS	S355	Cold	60
300 Series	300 x 300 x 12.5	SHS	S355	Cold	130
400 Series	400 x 400 x 16	SHS	S355	Hot	215
600 Series	610 x 12.5	CHS	S355	Cold	240
660 Series	660 x 20.6	CHS	S355	Cold	360
1000 Series	1067 x 14.3	CHS	X65	Cold	370
1000 Series +	1067 x 19.1	CHS	S355	Hot	520

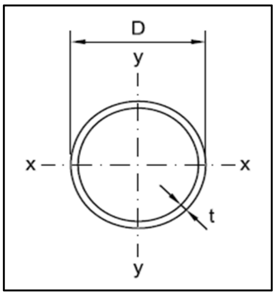
Section Properties

From Blue Book

Depth/Breath	D	=	300	mm	
Wall Thickness	t	=	12.5	mm	
Area	A	=	137	cm^2	
Effective Area	A_{eff}	=	N/A	cm^2	cl 3.6.2-3.6.6
Second moment of area	I	=	18300	cm^4	
Elastic Modulus	Z	=	1220	cm^3	
Effective Elastic Modulus	Z_{eff}	=	N/A	cm^3	cl 3.6.2-3.6.6
Plastic Modulus	S	=	1450	cm^3	
Effective Plastic Modulus	S_{eff}	=	N/A	cm^3	cl 3.5.6.3-3.5.6.4
Radius of gyration	r	=	11.6	cm	
Ratio for local buckling	d/t	=	19.0		



SHS Section



CHS Section

Steel Properties

cl 3.1

Design Strength	p_y	=	355	N/mm^2	cl 3.1.1
Modulus of elasticity	E	=	205000	N/mm^2	cl 3.1.3

Classification of cross-section

Flange	Class	1	Plastic	cl 3.5.2
Web	Class	1	Plastic	cl 3.5.2

Local Capacity Check — cl 4.2.3

Shear area	A_v	=	6850	mm^2		
Shear capacity	P_v	=	1459	kN		
CHECK	F_{vx}/P_{vx}	=	0.012	OK		
Shear condition			Low Shear			
Moment Capacity	M_c	=	515	kNm		cl 4.2.5.2-4.2.5.3
CHECK	M_x/M_c	=	0.066	OK		cl 4.3.6.2
Moment Capacity (y-y)	M_{cy}	=	515	kNm		cl 4.2.5.1
CHECK	M_y/M_c	=	0.00	OK		cl 4.2.5.2

Resistance to Lateral Torsional Buckling — cl 4.3.6

Buckling resistance moment	M_b	=	515	kNm		cl 4.3.6.4
Equivalent uniform moment factor	m_{LT}	=	0.925		Specific case	cl 4.3.6.6

Members with combined moment and axial force — cl 4.8

Effective length	L_E	=	6750	mm	cl 4.7.3
Slenderness	λ	=	58		cl 4.7.2
Strut curve		=	c		4.7.5, Table 23
Compression resistance	P_c	=	3450	kN	cl 4.7.4

Cross section capacity

Simplified method — cl 4.8.3.2

$$\frac{F_c}{Ap_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$ 0.223 OK

Note: For Class 1, Class 2 and Class 3 sections, $A = A_g$. For Class 4 sections, $A = A_{eff}$.

More exact method (for Class 1 and Class 2 sections) — cl 4.8.2.3

Method appropriate?			Yes		
Axial force ratio	n	=	0.16		*SCI P202*
Reduced plastic modulus	S_r	=	1404	cm^3	*SCI P202*
Reduced moment capacity	M_r	=	498	kNm	*Annex I.2.1*

$$\left(\frac{M_x}{M_{rx}}\right)^{z_1} + \left(\frac{M_y}{M_{ry}}\right)^{z_2} \leq 1$$ 0.005 OK

Member buckling resistance — cl 4.8.3.3

Simplified method — cl 4.8.3.3.1

Equivalent uniform moment factor (x-x)	m_x	=	0.95	Specific case	cl 4.8.3.3.4
Equivalent uniform moment factor (x-x)	m_y	=	0.90	Specific case	cl 4.8.3.3.4

$$\frac{F_c}{P_c} + \frac{m_x M_x}{p_y Z_x} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.296 OK — cl 4.8.3.3.1

Max. moment in segment governing M_b M_{LT} = 34 kNm — cl 4.8.3.3.1

$$\frac{F_c}{P_{cy}} + \frac{m_{LT} M_{LT}}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.283 OK — cl 4.8.3.3.1

More exact method (for CHS, RHS or box sections with equal flanges) — cl 4.8.3.3.3

Equivalent uniform moment factor (yx) m_{yx} = 0.90 Specific case — cl 4.8.3.3.4

- for major axis buckling:

$$\frac{F_c}{P_{cx}} + \frac{m_x M_x}{M_{cx}}\left(1 + 0.5\frac{F_c}{P_{cx}}\right) \leq 1$$ 0.291 OK

- for minor axis buckling (no lateral torsional buckling check needed):

$$\frac{F_c}{P_{cy}} + 0.5\frac{m_{LT} M_{LT}}{M_{cx}} \leq 1$$ 0.252 OK

Alternative method (for Stocky Class 1 & 2 Sections) — Annex I.1, SCI AD 301

Limit for stocky sections 85.8ε = 75.5

Annex I.1 appropriate? Yes

- for major axis buckling

$$\frac{m_x M_x}{M_{ax}} \leq 1$$ 0.081 OK

- for lateral torsional buckling:

$$\frac{m_{LT} M_{LT}}{M_{ab}} \leq 1$$ 0.073 OK

OVERALL *Maximum utilisation* = 0.848 OK

PROP DESIGN **P2**

Maximum Effects (factored)

Axial	F_c =	688	kN	
Moment (x-x)	M_x =	31	kNm	(0 + 5 + 9 + 18) = $M_{x,imp}$ + $M_{x,swt}$ + $M_{x,P\delta}$ + $M_{x,Acc}$
Moment (y-y)	M_y =	0	kNm	
Shear (x-x)	F_{vx} =	14	kN	
Deflection	δ_{Tot} =	8.9	mm	(unfactored)

Member Selection

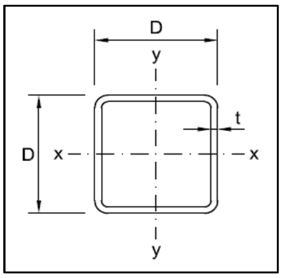
MGF proprietary equipment?	Yes	
Type	SHS	
Rolling Process	Cold	
Section Size	200 x 200 x 8	SHS
Steel Grade	S355	
Self-weight	60	kg/m
Adjustable Unit	600kN Hydraulic	
CHECK (Adjustable Capacity)	0.764	OK

MGF Tank Brace	*Section Size*		*Steel Grade*	*Rolling Process*	*S/Wt (kg/m)*
200 Series	200 x 200 x 8	SHS	S355	Cold	60
300 Series	300 x 300 x 12.5	SHS	S355	Cold	130
400 Series	400 x 400 x 16	SHS	S355	Hot	215
600 Series	610 x 12.5	CHS	S355	Cold	240
660 Series	660 x 20.6	CHS	S355	Cold	360
1000 Series	1067 x 14.3	CHS	X65	Cold	370
1000 Series +	1067 x 19.1	CHS	S355	Hot	520

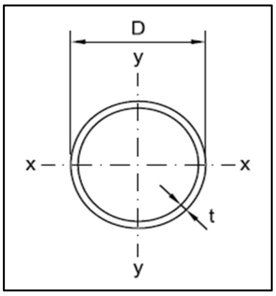
Section Properties

From Blue Book

Depth/Breath	D =	200	mm	
Wall Thickness	t =	8.0	mm	
Area	A =	59.2	cm^2	
Effective Area	A_{eff} =	N/A	cm^2	cl 3.6.2-3.6.6
Second moment of area	I =	3570	cm^4	
Elastic Modulus	Z =	357	cm^3	
Effective Elastic Modulus	Z_{eff} =	N/A	cm^3	cl 3.6.2-3.6.6
Plastic Modulus	S =	421	cm^3	
Effective Plastic Modulus	S_{eff} =	N/A	cm^3	cl 3.5.6.3-3.5.6.4
Radius of gyration	r =	7.8	cm	
Ratio for local buckling	d/t =	20.0		



SHS Section



CHS Section

Steel Properties

cl 3.1

Design Strength	p_y =	355	N/mm^2	cl 3.1.1
Modulus of elasticity	E =	205000	N/mm^2	cl 3.1.3

Classification of cross-section

Flange	Class	1	Plastic	cl 3.5.2
Web	Class	1	Plastic	cl 3.5.2

Local Capacity Check						cl 4.2.3
Shear area	A_v	=	2960	mm^2		
Shear capacity	P_v	=	630	kN		
CHECK	F_{vx}/P_{vx}	=	0.022	OK		
Shear condition			Low Shear			
Moment Capacity	M_c	=	149	kNm		cl 4.2.5.2-4.2.5.3
CHECK	M_x/M_c	=	0.208	OK		cl 4.3.6.2
Moment Capacity (y-y)	M_{cy}	=	149	kNm		cl 4.2.5.1
CHECK	M_y/M_c	=	0.00	OK		cl 4.2.5.2
Resistance to Lateral Torsional Buckling						cl 4.3.6
Buckling resistance moment	M_b	=	149	kNm		cl 4.3.6.4
Equivalent uniform moment factor	m_{LT}	=	0.925		Specific case	cl 4.3.6.6
Members with combined moment and axial force						cl 4.8
Effective length	L_E	=	6750	mm		cl 4.7.3
Slenderness	λ	=	87			cl 4.7.2
Strut curve		=	c			4.7.5, Table 23
Compression resistance	P_c	=	1007	kN		cl 4.7.4

Cross section capacity

Simplified method — cl 4.8.3.2

$$\frac{F_c}{Ap_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$ 0.535 OK

Note: For Class 1, Class 2 and Class 3 sections, A = A_g. For Class 4 sections, A = A_{eff}.

More exact method (for Class 1 and Class 2 sections)					cl 4.8.2.3
Method appropriate?			Yes		
Axial force ratio	n	=	0.33		*SCI P202*
Reduced plastic modulus	S_r	=	362	cm^3	*SCI P202*
Reduced moment capacity	M_r	=	129	kNm	*Annex I.2.1*

$$\left(\frac{M_x}{M_{rx}}\right)^{z_1} + \left(\frac{M_y}{M_{ry}}\right)^{z_2} \leq 1$$ 0.058 OK

Member buckling resistance						cl 4.8.3.3
Simplified method						cl 4.8.3.3.1
Equivalent uniform moment factor (x-x)	m_x	=	0.95		Specific case	cl 4.8.3.3.4
Equivalent uniform moment factor (x-x)	m_y	=	0.90		Specific case	cl 4.8.3.3.4

$$\frac{F_c}{P_c} + \frac{m_x M_x}{p_y Z_x} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.916 OK — cl 4.8.3.3.1

Max. moment in segment governing M_b — M_{LT} = 31 kNm — cl 4.8.3.3.1

$$\frac{F_c}{P_{cy}} + \frac{m_{LT} M_{LT}}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.875 OK — cl 4.8.3.3.1

<u>More exact method (for CHS, RHS or box sections with equal flanges)</u> — cl 4.8.3.3.3

Equivalent uniform moment factor (yx) m_{yx} = 0.90 — Specific case — cl 4.8.3.3.4

- for major axis buckling:

$$\frac{F_c}{P_{cx}} + \frac{m_x M_x}{M_{cx}}\left(1 + 0.5\frac{F_c}{P_{cx}}\right) \leq 1$$

0.948 OK

- for minor axis buckling (no lateral torsional buckling check needed):

$$\frac{F_c}{P_{cy}} + 0.5\frac{m_{LT} M_{LT}}{M_{cx}} \leq 1$$

0.779 OK

<u>Alternative method (for Stocky Class 1 & 2 Sections)</u> — Annex I.1, SCI AD 301

Limit for stocky sections 85.8ε = 75.5

Annex I.1 appropriate? No

- for major axis buckling

$$\frac{m_x M_x}{M_{ax}} \leq 1$$

0.836 N/A

- for lateral torsional buckling:

$$\frac{m_{LT} M_{LT}}{M_{ab}} \leq 1$$

0.607 N/A

<u>OVERALL</u> *Maximum utilisation* = 0.916 OK

PROP DESIGN P3

Maximum Effects (factored)

Axial	F_c	=	700	kN
Moment (x-x)	M_x	=	31	kNm
Moment (y-y)	M_y	=	0	kNm
Shear (x-x)	F_{vx}	=	14	kN
Deflection	δ_{Tot}	=	8.9	mm (unfactored)

$M_x = (0 + 5 + 9 + 18) = (M_{x,imp} + M_{x,swt} + M_{x,P\delta} + M_{x,Acc})$

Member Selection

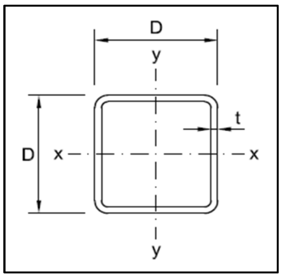
MGF proprietary equipment?	Yes	
Type	CHS	
Rolling Process	Cold	
Section Size	200 x 200 x 8	CHS
Steel Grade	X65	
Self-weight	60	kg/m
Adjustable Unit	600kN Hydraulic	
CHECK (Adjustable Capacity)	0.778	OK

MGF Tank Brace	*Section Size*		*Steel Grade*	*Rolling Process*	*S/Wt (kg/m)*
200 Series	200 x 200 x 8	SHS	S355	Cold	60
300 Series	300 x 300 x 12.5	SHS	S355	Cold	130
400 Series	400 x 400 x 16	SHS	S355	Hot	215
600 Series	610 x 12.5	CHS	S355	Cold	240
660 Series	660 x 25.4	CHS	S355	Cold	360
1000 Series	1067 x 14.3	CHS	X65	Cold	370
1000 Series +	1067 x 19.1	CHS	S355	Hot	520

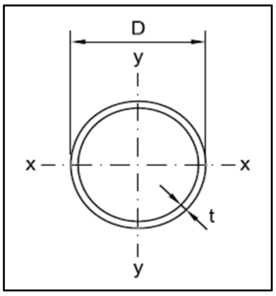
Section Properties

From Blue Book

Outer Diameter	D	=	200	mm	
Wall Thickness	t	=	8.0	mm	
Area	A	=	59.2	cm^2	
Effective Area	A_{eff}	=	N/A	cm^2	cl 3.6.2-3.6.6
Second moment of area	I	=	3570	cm^4	
Elastic Modulus	Z	=	357	cm^3	
Effective Elastic Modulus	Z_{eff}	=	N/A	cm^3	cl 3.6.2-3.6.6
Plastic Modulus	S	=	421	cm^3	
Effective Plastic Modulus	S_{eff}	=	N/A	cm^3	cl 3.5.6.3-3.5.6.4
Radius of gyration	r	=	7.8	cm	
Ratio for local buckling	d/t	=	20.0		



SHS Section



CHS Section

Steel Properties — cl 3.1

Design Strength	p_y	=	448	N/mm^2	cl 3.1.1
Modulus of elasticity	E	=	205000	N/mm^2	cl 3.1.3

Classification of cross-section

Compression due to bending	Class	1	Plastic	cl 3.5.2
Axial compression	Class	1	Plastic	cl 3.5.2

<u>Local Capacity Check</u> — cl 4.2.3

Shear area	A_v	=	3552	mm^2		
Shear capacity	P_v	=	955	kN		
CHECK	F_{vx}/P_{vx}	=	0.014	OK		
Shear condition			Low Shear			
Moment Capacity	M_c	=	189	kNm		cl 4.2.5.2-4.2.5.3
CHECK	M_x/M_c	=	0.166	OK		cl 4.3.6.2
Moment Capacity (y-y)	M_{cy}	=	189	kNm		cl 4.2.5.1
CHECK	M_y/M_c	=	0.00	OK		cl 4.2.5.2

<u>Resistance to Lateral Torsional Buckling</u> — cl 4.3.6

Buckling resistance moment	M_b	=	189	kNm		cl 4.3.6.4
Equivalent uniform moment factor	m_{LT}	=	0.925		Specific case	cl 4.3.6.6

<u>Members with combined moment and axial force</u> — cl 4.8

Effective length	L_E	=	6750	mm	cl 4.7.3
Slenderness	λ	=	87		cl 4.7.2
Strut curve		=	c		4.7.5, Table 23
Compression resistance	P_c	=	1117	kN	cl 4.7.4

<u>Cross section capacity</u>

<u>Simplified method</u> — cl 4.8.3.2

$$\frac{F_c}{Ap_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$ 0.430 OK

<u>Note:</u> For Class 1, Class 2 and Class 3 sections, $A = A_g$. For Class 4 sections, $A = A_{eff}$.

<u>More exact method (for Class 1 and Class 2 sections)</u> — cl 4.8.2.3

Method appropriate?			Yes		
Axial force ratio	n	=	0.26		*SCI P202*
Reduced plastic modulus	S_r	=	385	cm^3	*SCI P202*
Reduced moment capacity	M_r	=	173	kNm	*Annex I.2.1*

$$\left(\frac{M_x}{M_{rx}}\right)^{z_1} + \left(\frac{M_y}{M_{ry}}\right)^{z_2} \leq 1$$ 0.033 OK

<u>Member buckling resistance</u> — cl 4.8.3.3

<u>Simplified method</u> — cl 4.8.3.3.1

Equivalent uniform moment factor (x-x)	m_x	=	0.95		Specific case	cl 4.8.3.3.4
Equivalent uniform moment factor (x-x)	m_y	=	0.90		Specific case	cl 4.8.3.3.4

$$\frac{F_c}{P_c} + \frac{m_x M_x}{p_y Z_x} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.813 OK — cl 4.8.3.3.1

Max. moment in segment governing M_b M_{LT} = 31 kNm — cl 4.8.3.3.1

$$\frac{F_c}{P_{cy}} + \frac{m_{LT} M_{LT}}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.781 OK — cl 4.8.3.3.1

More exact method (for CHS, RHS or box sections with equal flanges) — cl 4.8.3.3.3

Equivalent uniform moment factor (yx) m_{yx} = 0.90 — Specific case — cl 4.8.3.3.4

- for major axis buckling:

$$\frac{F_c}{P_{cx}} + \frac{m_x M_x}{M_{cx}}\left(1 + 0.5\frac{F_c}{P_{cx}}\right) \leq 1$$

0.834 OK

- for minor axis buckling (no lateral torsional buckling check needed):

$$\frac{F_c}{P_{cy}} + 0.5\frac{m_{LT} M_{LT}}{M_{cx}} \leq 1$$

0.704 OK

Alternative method (for Stocky Class 1 & 2 Sections) — Annex I.1

Limit for stocky sections 85.8ε = 67.2 — SCI AD 301

Annex I.1 appropriate? No

- for major axis buckling

$$\frac{m_x M_x}{M_{ax}} \leq 1$$

0.555 N/A

- for lateral torsional buckling:

$$\frac{m_{LT} M_{LT}}{M_{ab}} \leq 1$$

0.412 N/A

OVERALL — *Maximum utilisation* = 0.813 OK

PROP DESIGN **P4**

Maximum Effects (factored)

Axial	F_c	=	695	kN
Moment (x-x)	M_x	=	31	kNm
Moment (y-y)	M_y	=	0	kNm
Shear (x-x)	F_{vx}	=	14	kN
Deflection	δ_{Tot}	=	8.9	mm (unfactored)

M_x = (0 + 5 + 9 + 18) = ($M_{x,imp}$ + $M_{x,swt}$ + $M_{x,P\delta}$ + $M_{x,Acc}$)

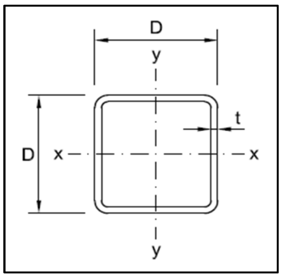
Member Selection

MGF proprietary equipment?	Yes	
Type	SHS	
Rolling Process	Cold	
Section Size	200 x 200 x 8	SHS
Steel Grade	S355	
Self-weight	60	kg/m
Adjustable Unit	600kN Hydraulic	
CHECK (Adjustable Capacity)	0.773	OK

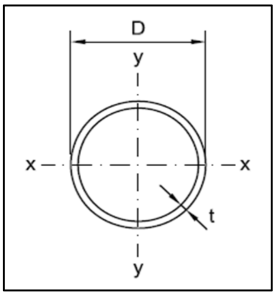
MGF Tank Brace	*Section Size*		*Steel Grade*	*Rolling Process*	*S/Wt (kg/m)*
200 Series	200 x 200 x 8	SHS	S355	Cold	60
300 Series	300 x 300 x 12.5	SHS	S355	Cold	130
400 Series	400 x 400 x 16	SHS	S355	Hot	215
600 Series	610 x 12.5	CHS	S355	Cold	240
660 Series	660 x 25.4	CHS	S355	Cold	360
1000 Series	1067 x 14.3	CHS	X65	Cold	370
1000 Series +	1067 x 19.1	CHS	S355	Hot	520

Section Properties — From Blue Book

Depth/Breath	D	=	200	mm	
Wall Thickness	t	=	8.0	mm	
Area	A	=	59.2	cm^2	
Effective Area	A_{eff}	=	N/A	cm^2	cl 3.6.2-3.6.6
Second moment of area	I	=	3570	cm^4	
Elastic Modulus	Z	=	357	cm^3	
Effective Elastic Modulus	Z_{eff}	=	N/A	cm^3	cl 3.6.2-3.6.6
Plastic Modulus	S	=	421	cm^3	
Effective Plastic Modulus	S_{eff}	=	N/A	cm^3	cl 3.5.6.3-3.5.6.4
Radius of gyration	r	=	7.8	cm	
Ratio for local buckling	d/t	=	20.0		



SHS Section



CHS Section

Steel Properties — cl 3.1

Design Strength	p_y	=	355	N/mm^2	cl 3.1.1
Modulus of elasticity	E	=	205000	N/mm^2	cl 3.1.3

Classification of cross-section

Flange	Class	1	Plastic	cl 3.5.2
Web	Class	1	Plastic	cl 3.5.2

Local Capacity Check

Shear area	A_v	=	2960	mm^2		cl 4.2.3
Shear capacity	P_v	=	630	kN		
CHECK	F_{vx}/P_{vx}	=	0.022	OK		
Shear condition			Low Shear			
Moment Capacity	M_c	=	149	kNm		cl 4.2.5.2-4.2.5.3
CHECK	M_x/M_c	=	0.209	OK		cl 4.3.6.2
Moment Capacity (y-y)	M_{cy}	=	149	kNm		cl 4.2.5.1
CHECK	M_y/M_c	=	0.00	OK		cl 4.2.5.2

Resistance to Lateral Torsional Buckling

						cl 4.3.6
Buckling resistance moment	M_b	=	149	kNm		cl 4.3.6.4
Equivalent uniform moment factor	m_{LT}	=	0.925		Specific case	cl 4.3.6.6

Members with combined moment and axial force

					cl 4.8
Effective length	L_E	=	6750	mm	cl 4.7.3
Slenderness	λ	=	87		cl 4.7.2
Strut curve		=	c		4.7.5, Table 23
Compression resistance	P_c	=	1007	kN	cl 4.7.4

Cross section capacity
Simplified method

cl 4.8.3.2

$$\frac{F_c}{Ap_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$ 0.540 OK

Note: For Class 1, Class 2 and Class 3 sections, $A = A_g$. For Class 4 sections, $A = A_{eff}$.

More exact method (for Class 1 and Class 2 sections)

					cl 4.8.2.3
Method appropriate?			Yes		
Axial force ratio	n	=	0.33		*SCI P202*
Reduced plastic modulus	S_r	=	361	cm^3	*SCI P202*
Reduced moment capacity	M_r	=	128	kNm	*Annex I.2.1*

$$\left(\frac{M_x}{M_{rx}}\right)^{z_1} + \left(\frac{M_y}{M_{ry}}\right)^{z_2} \leq 1$$ 0.059 OK

Member buckling resistance
Simplified method

cl 4.8.3.3
cl 4.8.3.3.1

Equivalent uniform moment factor (x-x)	m_x	=	0.95	Specific case	cl 4.8.3.3.4
Equivalent uniform moment factor (x-x)	m_y	=	0.90	Specific case	cl 4.8.3.3.4

$$\frac{F_c}{P_c} + \frac{m_x M_x}{p_y Z_x} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.925 OK — cl 4.8.3.3.1

Max. moment in segment governing M_b M_{LT} = 31 kNm — cl 4.8.3.3.1

$$\frac{F_c}{P_{cy}} + \frac{m_{LT} M_{LT}}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.884 OK — cl 4.8.3.3.1

<u>More exact method (for CHS, RHS or box sections with equal flanges)</u> — cl 4.8.3.3.3

Equivalent uniform moment factor (yx) m_{yx} = 0.90 — Specific case — cl 4.8.3.3.4

- for major axis buckling:

$$\frac{F_c}{P_{cx}} + \frac{m_x M_x}{M_{cx}}\left(1 + 0.5\frac{F_c}{P_{cx}}\right) \le 1$$

0.957 OK

- for minor axis buckling (no lateral torsional buckling check needed):

$$\frac{F_c}{P_{cy}} + 0.5\frac{m_{LT} M_{LT}}{M_{cx}} \le 1$$

0.787 OK

<u>Alternative method (for Stocky Class 1 & 2 Sections)</u> — Annex I.1, SCI AD 301

Limit for stocky sections 85.8ε = 75.5

Annex I.1 appropriate? No

- for major axis buckling

$$\frac{m_x M_x}{M_{ax}} \le 1$$

0.863 N/A

- for lateral torsional buckling:

$$\frac{m_{LT} M_{LT}}{M_{ab}} \le 1$$

0.624 N/A

<u>OVERALL</u> *Maximum utilisation* = 0.925 OK

PROP DESIGN **P5**

Maximum Effects (factored)

Axial	F_c	=	699	kN
Moment (x-x)	M_x	=	31	kNm
Moment (y-y)	M_y	=	0	kNm
Shear (x-x)	F_{vx}	=	14	kN
Deflection	δ_{Tot}	=	8.9	mm (unfactored)

$M_x = (0 + 5 + 9 + 18)$ = ($M_{x,imp}$ + $M_{x,swt}$ + $M_{x,P\delta}$ + $M_{x,Acc}$)

Member Selection

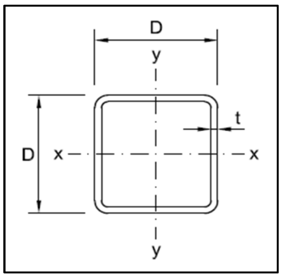
MGF proprietary equipment?	Yes	
Type	SHS	
Rolling Process	Cold	
Section Size	200 x 200 x 8	SHS
Steel Grade	S355	
Self-weight	60	kg/m
Adjustable Unit	600kN Hydraulic	
CHECK (Adjustable Capacity)	0.776	OK

MGF Tank Brace	*Section Size*		*Steel Grade*	*Rolling Process*	*S/Wt (kg/m)*
200 Series	200 x 200 x 8	SHS	S355	Cold	60
300 Series	300 x 300 x 12.5	SHS	S355	Cold	130
400 Series	400 x 400 x 16	SHS	S355	Hot	215
600 Series	610 x 12.5	CHS	S355	Cold	240
660 Series	660 x 25.4	CHS	S355	Cold	360
1000 Series	1067 x 14.3	CHS	X65	Cold	370
1000 Series +	1067 x 19.1	CHS	S355	Hot	520

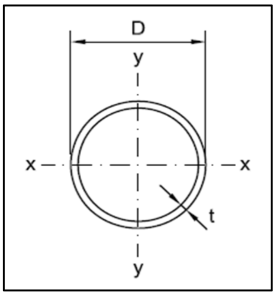
Section Properties

From Blue Book

Depth/Breath	D	=	200	mm	
Wall Thickness	t	=	8.0	mm	
Area	A	=	59.2	cm^2	
Effective Area	A_{eff}	=	N/A	cm^2	cl 3.6.2-3.6.6
Second moment of area	I	=	3570	cm^4	
Elastic Modulus	Z	=	357	cm^3	
Effective Elastic Modulus	Z_{eff}	=	N/A	cm^3	cl 3.6.2-3.6.6
Plastic Modulus	S	=	421	cm^3	
Effective Plastic Modulus	S_{eff}	=	N/A	cm^3	cl 3.5.6.3-3.5.6.4
Radius of gyration	r	=	7.8	cm	
Ratio for local buckling	d/t	=	20.0		



SHS Section



CHS Section

Steel Properties

cl 3.1

Design Strength	p_y	=	355	N/mm^2	cl 3.1.1
Modulus of elasticity	E	=	205000	N/mm^2	cl 3.1.3

Classification of cross-section

Flange	Class	1	Plastic	cl 3.5.2
Web	Class	1	Plastic	cl 3.5.2

Local Capacity Check						cl 4.2.3
Shear area	A_v	=	2960	mm^2		
Shear capacity	P_v	=	630	kN		
CHECK	F_{vx}/P_{vx}	=	0.022	OK		
Shear condition			Low Shear			
Moment Capacity	M_c	=	149	kNm		cl 4.2.5.2-4.2.5.3
CHECK	M_x/M_c	=	0.209	OK		cl 4.3.6.2
Moment Capacity (y-y)	M_{cy}	=	149	kNm		cl 4.2.5.1
CHECK	M_y/M_c	=	0.00	OK		cl 4.2.5.2
Resistance to Lateral Torsional Buckling						cl 4.3.6
Buckling resistance moment	M_b	=	149	kNm		cl 4.3.6.4
Equivalent uniform moment factor	m_{LT}	=	0.925		Specific case	cl 4.3.6.6
Members with combined moment and axial force						cl 4.8
Effective length	L_E	=	6750	mm		cl 4.7.3
Slenderness	λ	=	87			cl 4.7.2
Strut curve		=	c			4.7.5, Table 23
Compression resistance	P_c	=	1007	kN		cl 4.7.4

Cross section capacity

Simplified method — cl 4.8.3.2

$$\frac{F_c}{Ap_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$ 0.542 OK

Note: For Class 1, Class 2 and Class 3 sections, $A = A_g$. For Class 4 sections, $A = A_{eff}$.

More exact method (for Class 1 and Class 2 sections)					cl 4.8.2.3
Method appropriate?			Yes		
Axial force ratio	n	=	0.33		*SCI P202*
Reduced plastic modulus	S_r	=	360	cm^3	*SCI P202*
Reduced moment capacity	M_r	=	128	kNm	*Annex I.2.1*

$$\left(\frac{M_x}{M_{rx}}\right)^{z_1} + \left(\frac{M_y}{M_{ry}}\right)^{z_2} \leq 1$$ 0.060 OK

Member buckling resistance						cl 4.8.3.3
Simplified method						cl 4.8.3.3.1
Equivalent uniform moment factor (x-x)	m_x	=	0.95		Specific case	cl 4.8.3.3.4
Equivalent uniform moment factor (x-x)	m_y	=	0.90		Specific case	cl 4.8.3.3.4

$$\frac{F_c}{P_c} + \frac{m_x M_x}{p_y Z_x} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.928 OK — cl 4.8.3.3.1

Max. moment in segment governing M_b — M_{LT} = 31 kNm — cl 4.8.3.3.1

$$\frac{F_c}{P_{cy}} + \frac{m_{LT} M_{LT}}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$$ 0.887 OK — cl 4.8.3.3.1

More exact method (for CHS, RHS or box sections with equal flanges) — cl 4.8.3.3.3

Equivalent uniform moment factor (yx) m_{yx} = 0.90 — Specific case — cl 4.8.3.3.4

- for major axis buckling:

$$\frac{F_c}{P_{cx}} + \frac{m_x M_x}{M_{cx}}\left(1 + 0.5\frac{F_c}{P_{cx}}\right) \leq 1$$ 0.961 OK

- for minor axis buckling (no lateral torsional buckling check needed):

$$\frac{F_c}{P_{cy}} + 0.5\frac{m_{LT} M_{LT}}{M_{cx}} \leq 1$$ 0.790 OK

Alternative method (for Stocky Class 1 & 2 Sections) — Annex I.1, SCI AD 301

Limit for stocky sections 85.8ε = 75.5

Annex I.1 appropriate? No

- for major axis buckling

$$\frac{m_x M_x}{M_{ax}} \leq 1$$ 0.874 N/A

- for lateral torsional buckling:

$$\frac{m_{LT} M_{LT}}{M_{ab}} \leq 1$$ 0.632 N/A

OVERALL *Maximum utilisation* = 0.928 OK