GGP CONSULT

STRUCTURAL DESIGN CALCULATIONS

FOR

27937-51ft(15.67m)/5R(3.81m)/EXT/BG(0.5m)/NCS/1.20 FoS

FOR

hendic
embracing water

PROJECT REF:

Structural report/27937-51ft (15.67m)-5R (3.81m)-EXT-BG (0.5m)-1.20 FoS/ Issue 1

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REV.	Revision description	Date
01	First issue	19/03/2019
B	Wind loading modifications & size note added	26/07/2019

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CONTENTS

1 Introduction and Codes

1.1 General

GGP Consult has been employed by Hendic bv to carry out a structural design of 51 feet (15.67m) in diameter and 5 rings high (3.85m) water tank.

Please note: the sheet thicknesses calculated here are acceptable for a tank with a specification **48ft(14.630m)-5R(3.85m)-EXT-BG(0.5m)-NCS-1.20FoS.**

The tank location is outside, it's buried at 500 mm and has a non-concrete surround.

The calculations are the static stability design for a corrugated metal tank with circular cross section in plan. The tank walls consist of factory pre-bent corrugated metal sheets bolted together. The resultant tensile force due to the contents is acting horizontally on the rings exclusively.

1.2 Main Codes

BS EN 1990:2002	Basis of structural design
BS EN 1991-1-1:2002	Eurocode 1: Actions on structures - Part 1-1: General actions – Densities, self- weight, imposed loads for buildings
BS EN 1991-1-4:2005	Eurocode 1: Actions on structures - Part 1-4: General actions – Wind actions
BS EN 1991-4:2006	Eurocode 1: Actions on structures – Part 4: Silos and tanks
BS EN 1993-1-3:2006	Eurocode 3: Design of steel structures – Part 1-3: General – Cold formed thin gauge members and sheeting
BS EN 1993-1-8:2005	Eurocode 3: Design of steel structures – Part 1-8: Design of joints

1.3 Execution Class

The design is using BS EN 1993-4-2:2007.

According to table C.1 BS EN 1993-1-1:2005+A1:2014 NOTE 2 consequences class CC2 is chosen.

Loading type is determined as static, quasi-static or seismic DCL.

This product has been calculated to be within execution class EXC2.

1.4 Materials

Sheet 0.80mm are structural grade cold formed strip galvanised S280GD+Z as per below Table3.1b BS EN 1993-1-3

f_y = 280 N/mm^2
f_u = 360 N/mm^2

All sheets 1.00mm to 2.50mm and above are structural grade cold formed strip galvanised S350GD+Z as per below
Table3.1b BS EN 1993-1-3

f_y = 350 N/mm^2
f_u = 420 N/mm^2

Sheet bolts M10 and M12 are grade 8.8.

Blank sheet widths are:

- 885mm

All sheets formed to 757mm depth with 20mm deep corrugations and approximately 10 pitches at 75.7mm.
For sheet ultimate sheet tension capacity, design for the 885mm wide blanks.

1.5 Non-concrete surround to buried tanks

i. The backfilling around the tank is done in uniform layers not exceeding 250mm in thickness and to a width of at least 500mm and compacted prior to placing the next layer of fill material.

ii. The backfill material is uniform throughout.

iii. Dry density assumed 19 kN/m^2, **backfill must be dry when the tank is emptied**.

iv. Backfill should be well graded, predominantly granular with only nominal compaction.

v. External loading applied to the ground around the perimeter of the tank is no greater than 100 kg/m^2. Where greater ground loads are required these must be notified to the Engineer and may result in a site specific and more robust design.

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1.6 Design Assumptions

i. The density of water used in the calculation is 9.81 kN/m^3.

ii. **Partial factor of safety** used for water contents with constant density is **1.20.**

iii. Overflow at depth 0.15 m and the tank has not been designed for overflow failure.

iv. Tank base to be fully restrained from lateral displacement.

v. Wind loads determined on the basis of a basic velocity of 40 m/s for specific terrain categories:

Terrain Category 0 - *Sea, coastal area exposed to the open sea(EN 1991-1-4:2005)*

Terrain Category I - *Lakes or area with negligible vegetation and without obstacles*

Terrain Category II - *Area with low vegetation such as grass and isolated obstacles (tress, buildings) with separations of at least 20 obstacle heights.*

Terrain Category III - *Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain and permanent forest)*

Terrain Category IV - *Area in which at least 15% of the surface is covered with buildings and their average height exceeds 15m (Towns & Cities)*

Water tanks located within Terrain Categories II, III, IV only.

For use in Terrain Categories 0, I special design required.

vi. All bolts Grade 8.8. M12 bolts can be used instead of M10.

2 Sheeting Pressures

Density of water γ_1 = 1000 kg/m^3 = 9.81 kN/m^3

Horizontal pressure on wall = γ_1 H

Tensile force on sheets (SLS) = γ_1 H D/2

Tensile force on sheets (ULS) = $\gamma_{G,1}\ \gamma_1\ H\ D/2$

Partial factor of safety for water $\gamma_{G,1}$ = 1.20

No allowance for change of purpose – i.e. contents with greater density

Ultimate sheet loads

Ring No.	Depth(z) m	Horizontal Pressure kN/m²	Tension Ultimate kN/m
1	0.607	5.95	55.5
2	1.364	13.38	124.8
3	2.121	20.81	194.1
4	2.878	28.23	263.3
5	3.635	35.66	332.6

Note:
(1) Design load assumes ultimate ring tension at base of sheet, no account made for average load over sheet depth.
(2) Tank overflow limited to 150mm below top ring, overflow failure has not been considered in the design.
(3) Partial factor of safety for water contents with constant density 1000 kg/m^3 used is 1.20.

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2.1 Suggested Sheet Design to Sheeting Pressure

Ring No.	Ultimate Ring Tension kN/m	Suggested		
		Sheet thickness mm	Steel Grade	Grade 8.8 Bolt Type
1	55.5	0.80	S280GD + Z	M10 x 2
2	124.8	1.00	S350GD + Z	M10 x 2
3	194.1	1.00	S350GD + Z	M10 x 3
4	263.3	1.25	S350GD + Z	M10 x 3
5	332.6	1.25	S350GD + Z	M10 x 3

Note:
(1) For final sheet selection please see the deflection calculations.
(2) The overflow of 150 mm has been deducted from the top ring.

Hendic Tank Standard wall sheet Load Capacities to BS-EN 1993-1-3

14.1 mm Hole Allowable Sheet Loads kN/m					
Material	**Sheet t (mm)**	**2 Row M10**	**3 Row M10**	**2 Row M12**	**3 Row M12**
S280GD+Z	0.8	114.6 b	156.2 b	151.3 b	187.6 s
S350GD+Z	1.00	179.7 b	244.8 b	237.2 b	273.6 s
S350GD+Z	1.25	244.1 b	332.6 b	322.2 b	342.0 s
S350GD+Z	1.60	312.5 b	425.8 b	412.4 b	437.7 s
S350GD+Z	2.00	390.6 b	532.2 b	515.5 b	547.2 s
S350GD+Z	*2.50			644.4 b	683.9 s
S350GD+Z	*2.60				711.3 s
S350GD+Z	*2.85				779.7 s
S350GD+Z	*3.0				820.7 s
* b - bearing failure s - sheet failure v-shear failure					

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3 WIND LOADS: EN 1991-1-4:2005

Wind loading on sheets critical for empty tank condition:

Reference height	z_e	= 3.81m	
Basic wind speed	v_b	= 40 m/s	(Agreed by client)
	q_b	= $0.5\rho\, v_b^2$	
		= $0.613 \times 40^2 \times 10^{-3}$	= 0.98 kN/m^2

Terrain category: II z_e = *3.81m* Assumes Orography Insignificant

Assume minimum distance upwind to shoreline

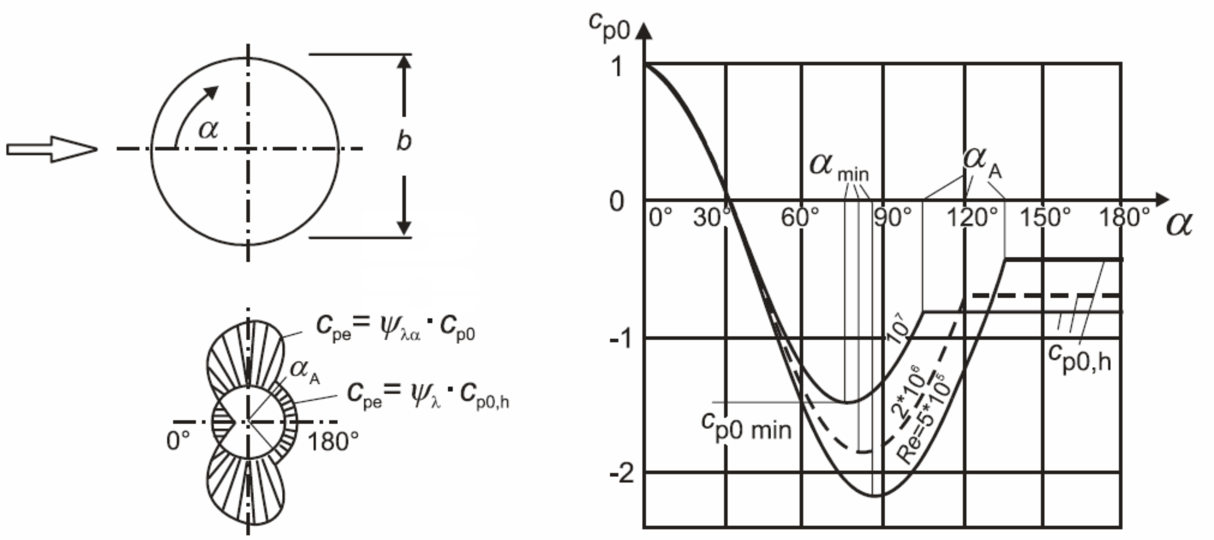
	$c_{e(z)}$	= 1.7	*Figure 4.2*
Design for terrain cat. II	q_p	= $c_{e(z)}\, q_b$	
Peak velocity pressure	q_p	= 1.7 x 0.98	= 1.67 kN/m^2

Pressure coefficients:

Open Top silo/Tank	C_{pi}	= -0.6	*7.2.9 (8)*	*BS EN 1991-1-4*
Reynold No.	R_e	= $b\, v_{(ze)} / v$		
Kinematic viscosity	v	= 15×10^{-6} m^2/s		

Peak wind velocity	$v_{(ze)}$	= v_b	= 40 m/s
Diameter	b	= 15.67 m	

Characteristic Values of C_{po} from *table 7.12* and interpolation from *figure 7.27*



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External pressure coefficient $C_{pe} = C_{po}\,\Psi_{\lambda\alpha}$

Where:

$\Psi_{\lambda\alpha} = 1$ for $0^\circ \leq \alpha \leq \alpha_{min}$

$\Psi_{\lambda\alpha} = \psi_\lambda + (1-\psi_\lambda)\cos\left(\frac{\pi}{2}\left(\frac{\alpha-\alpha_{min}}{\alpha_A-\alpha_{min}}\right)\right)$ for $\alpha_{min} \leq \alpha \leq \alpha_A$

$\Psi_{\lambda\alpha} = \Psi_\lambda$ for $\alpha_A \leq \alpha \leq 180^\circ$

Effective slenderness for circular cylinders λ from *table 7.16*

l < 15m λ = smaller of l/b or 70

End effect factor Ψ_λ from *figure 7.36*

Diameter (m)	Re	λ = l/b	Ψλ
15.67	5.4 x10^7	3.5	0.63

Analysis wind loading carried out by Robot Structural Analysis Software.

Tank modelled as circular panels of depth 0.757m per ring, in 10 degree increments. Wind load evaluated and applied per average 10˚ increment around tank.

Peak velocity external pressure: $W_e = q_p \times C_{pe}$

Sector	Angle ˚	Angle in sector ˚	$C_{p,0}$	Avg $C_{p,0}$	$\Psi_{\lambda\alpha}$	C_{pe}	W_e
	0		1		1		
1	10	0-10	0.8	0.9	1	0.8	1.34
2	20	10-20	0.68	0.74	1	0.68	1.14
3	30	20-30	0.24	0.46	1	0.24	0.40
4	40	30-40	-0.12	0.06	1	-0.12	-0.20
5	50	40-50	-0.64	-0.38	1	-0.64	-1.07
6	60	50-60	-1	-0.82	1	-1	-1.67
7	70	60-70	-1.32	-1.16	1	-1.32	-2.20
8	80	70-80	-1.5	-1.41	1	-1.5	-2.51
9	90	80-90	-1.32	-1.41	0.950	-1.255	-2.10
10	100	90-100	-1.16	-1.24	0.815	-0.945	-1.58
11	110	100-110	-0.8	-0.98	0.63	-0.504	-0.84
12	120	110-120	-0.8	-0.8	0.63	-0.504	-0.84
13	130	120-130	-0.8	-0.8	0.63	-0.504	-0.84
14	140	130-140	-0.8	-0.8	0.63	-0.504	-0.84
15	150	140-150	-0.8	-0.8	0.63	-0.504	-0.84
16	160	150-160	-0.8	-0.8	0.63	-0.504	-0.84
17	170	160-170	-0.8	-0.8	0.63	-0.504	-0.84
18	180	170-180	-0.8	-0.8	0.63	-0.504	-0.84

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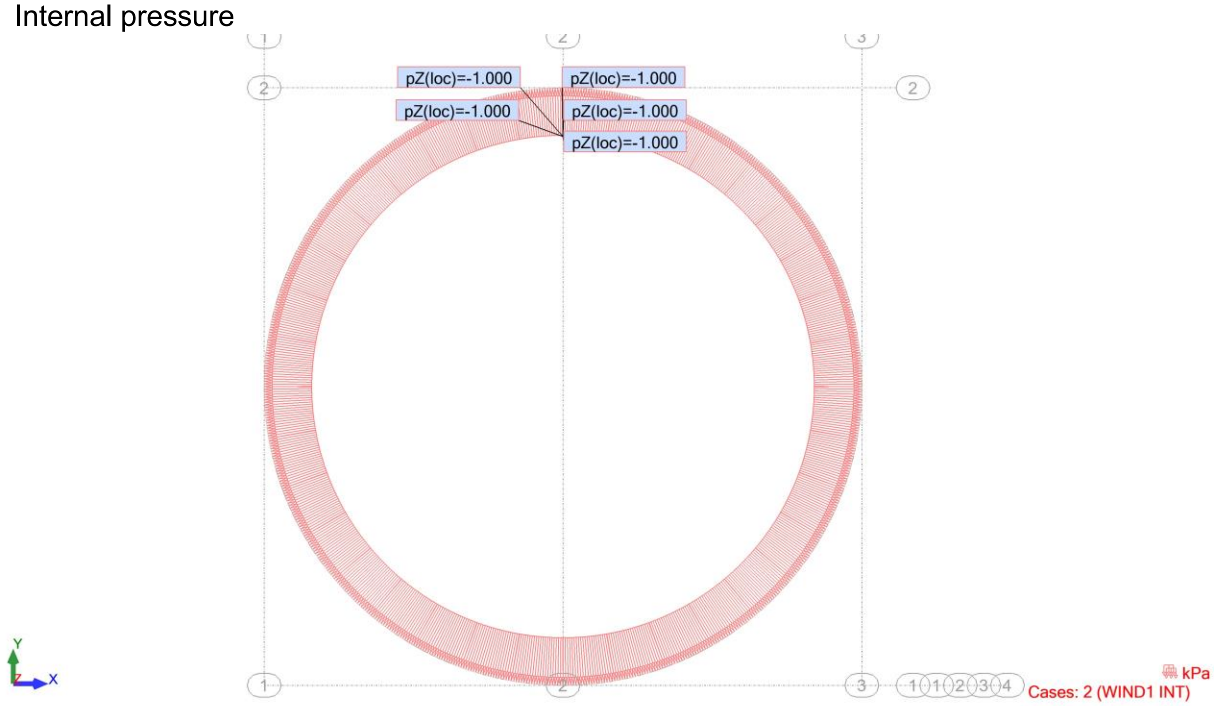
Internal pressure coefficient for open top tanks/silos C_{pi} = -0.6

Negative internal pressure W_i = C_{pi} x q_p= -0.6 x 1.67 = -1.00 kN/m^2

Visual representation of loads applied to the structure, for values see table above

External pressure

Internal pressure



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4 TANK DESIGN

DEFLECTION IN SERVICEABILITY LIMIT STATE

Maximum displacement of unrestrained free edge of sheets δ =3.00mm

Consider displacement limit of H/100=3810/100=38.1mm

3.00 mm < 38.1 mm OK

The displacement is considered to have no impact on the serviceability of the tank.

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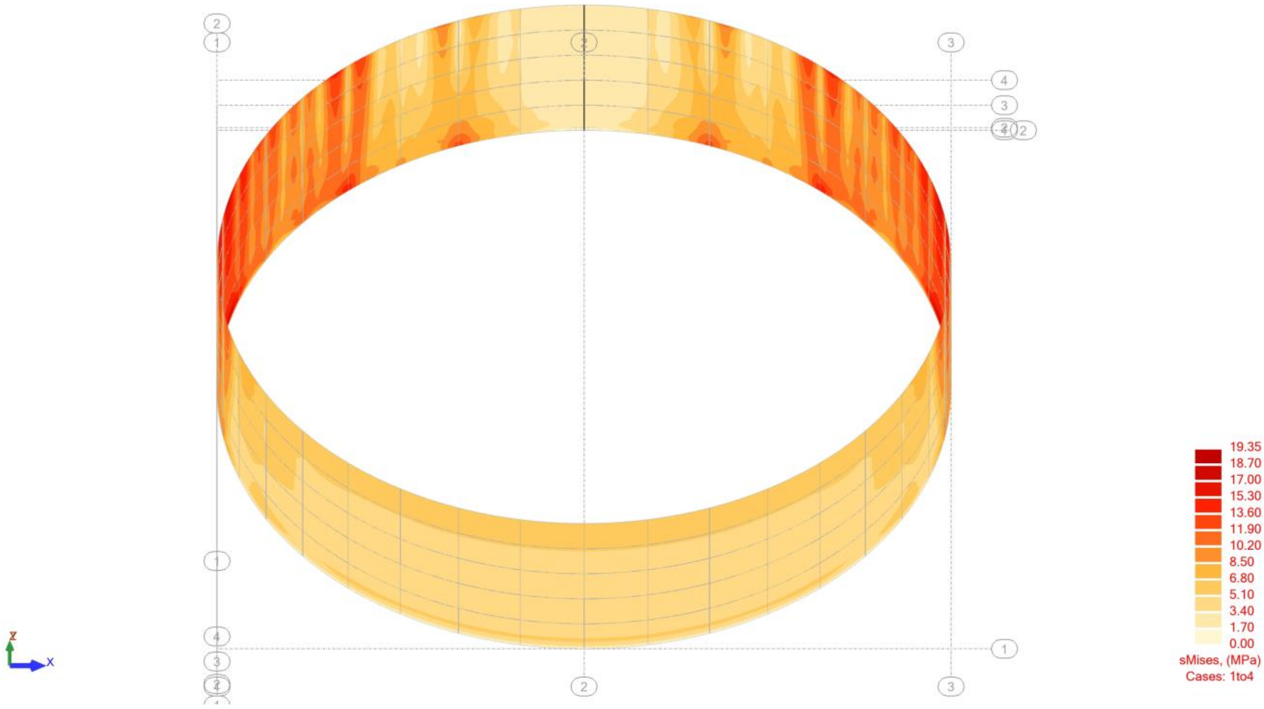
STRESS IN ULTIMATE LIMIT STATE



The maximum stress is 14.12 N/mm^2.

The stresses in the tank overall will be less than 280 N/mm^2, which is acceptable.

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5 SUMMARY

5.1 Required Sheet thicknesses

Ring 1: 0.80mm	Bolts: M10 x 2	S280GD+Z
Ring 2: 1.00mm	Bolts: M10 x 2	S350GD+Z
Ring 3: 1.00mm	Bolts: M10 x 3	S350GD+Z
Ring 4: 1.25mm	Bolts: M10 x 3	S350GD+Z
Ring 5: 1.25mm	Bolts: M10 x 3	S350GD+Z

Note:
(1) Partial factor of safety for water contents with constant density 1000kg/m^3 used is 1.20.
(2) All sheets have Z450 coating.
(3) ZM250 coating can be used instead of Z450.
(4) The sheet thicknesses will be acceptable for a 48/5 tank with the same design parameters.
(5) Please note: the sheet thicknesses calculated here are acceptable for a tank with a specification **48ft(14.630m)-5R(3.81m)-EXT-BG(0.5m)-NCS-1.20FoS.**

5.2 Non-concrete surround to buried tanks

vi. The backfilling around the tank is done in uniform layers not exceeding 250mm in thickness and to a width of at least 500mm and compacted prior to placing the next layer of fill material.

vii. The backfill material is uniform throughout.

viii. Dry density assumed 19 kN/m^2, **backfill must be dry when the tank is emptied**.

ix. Backfill should be well graded, predominantly granular with only nominal compaction.

x. External loading applied to the ground around the perimeter of the tank is no greater than 100 kg/m^2. Where greater ground loads are required these must be notified to the Engineer and may result in a site specific and more robust design.