Version: 01/11/2022

F.P. McCann
Bullhurst Lane
Weston Underwood
Derbyshire , DE6 4PH
1 of 38

Water Storage Tank

Notes:

Refer to FP McCann drawings: SKE-FPM-ZZ-XX-DR-X-0001
SKE-FPM-ZZ-XX-DR-X-0002
SKE-FPM-ZZ-XX-DR-X-0003

Contract Name: **Skelmanthorpe, Saville Road**

Contract Number: **05-BYL-xxxx**

Client: **Lovell Homes**

Reference: **Attenuation Tank**

By: **PM**

Date: **05/05/2023**

Checked By:

Date:

Design in line with the general principles of:

BS EN 1990:2002+A1	& UK NA to BS EN 1990:2002+A1	Basis of structural design
BS EN 1991-1-1:2002	& UK NA to BS EN 1991-1-1:2002	Actions on structures, General actions
BS EN 1991-2: 2003	& UK NA to BS EN 1991-2: 2003	Actions on structures, Traffic loads
BS EN 1991-4: 2006	& UK NA to BS EN 1991-4: 2006	Actions on structures, Silos and tanks
BS EN 1992-1-1: 2004+A1	& UK NA to BS EN 1992-1-1: 2004+A1	Design of concrete structures, General rules for buildings
BS EN 1992-3: 2006	& UK NA to BS EN 1992-3: 2006	Design of concrete structures, Liquid retaining structures
BS EN 1997-1: 2004	& UK NA to BS EN 1997-1: 2004	Geotechnical design, General rules
BS 8500-1:2015+A2 2019		Complimentary British Standard to BS EN 206
BS 8500-2:2015+A2 2019		Complimentary British Standard to BS EN 206
BS 8110-1:1997		Structural use of concrete
CIRIA C660		Early-age thermal crack control in concrete
PD 6694-1:2011		Recommendations for the design of structures subject to traffic loading

Rev	Description	By	Date
P-01	Preliminary Issue	PM	05/05/23

		Version: 01/11/2022	05-May-23	**F.P. McCann**
	Contract Name:	Skelmanthorpe, Saville Road		Bullhurst Lane
	Contract Number:	05-BYL-xxxx	Rev: P-01	Weston Underwood
	Client:	Lovell Homes		Derbyshire , DE6 4PH
	Reference:	Attenuation Tank	By: PM Chk: Sheet: **2 of 38**	

Contents:

1. INTRODUCTION

Tank Details:

Internal Length (L):	11,800	mm
Internal Width (B):	10,225	mm
Number of lanes (over width):	3	No.
Clear Span between walls:	3,225	mm
Internal Height (H):	2,000	mm
Ext. Wall Thickness (T_{we}):	250	mm
Int. Wall Thickness (T_{wi}):	275	mm
Base Thickness (T_b):	250	mm
Cover Slab Thickness (T_s):	240	mm
Overburden above slab ($h_{o,max}$):	1,300	mm Max.
Overburden above slab ($h_{o,min}$):	400	mm Min.
Intended working life at least:	50	Years

Water Tightness: (BS EN 1992-3)   Class 1

Leakage to be limited to a small amount. Some surface staining or damp patches acceptable.

Ground Details:

Soil Density (γ_s):	18	kN/m³
Water Density (γ_w):	10	kN/m³

Ø: 30 °   ka: 0.333

Modulus of subgrade reaction (k_s): 25,000 kN/m³

Live Loading:

As the tank is not subject to highway loading, the recommendations of PD6694 are not considered appropriate, as such the tank is designed to suit the most onerous of:

a) 10kN/m² as a Blanket UDL

b) 38 tonne, five axle articulated - designation 5A-H, in line with table NA.5 in the UK National Annex to BS EN 1991-2:2003 (Traffic loads on bridges)

c) Accidental vehicle in line with cl. 5.6.3 in BS EN 1991-2:2003 (Traffic loads on bridges)
    Refer to Appendix B: 40.8 kN/m²

or d) User specified surcharge: - kN/m²

Surcharge (w):   40.8 kN/m²

Exposure Conditions:

Precast: w/c: max 0.4, cement type: IIB-V (+SR), min 380kg/m³

XC Exposure:	XC3/4	20 + Δc
XD Exposure:	XD1	25 + Δc
XS Exposure:	N/A	
Precast: Grade:	C40/50	DC 4
f_{ck} (N/mm²):	40	
f_y (N/mm²):	500	
Unit Weight γ_c (kN/m²):	25	
Minimum Cover (mm):	25	Δc: 5
Nominal Cover (mm):	30	

Partial factors:

Dead γ_{f_g}:	1.35	QP Factor ψ:	0.30	
Live γ_{f_q}:	1.50	Internal Water γ_{f_w}:	1.20	

Exposure Conditions:

Insitu: w/c: max 0.45, cement type: CEM I, min 360kg/m³

XC Exposure:	XC3/4	30 + Δc
XD Exposure:	XD1	35 + Δc
XS Exposure:	N/A	
Insitu: Grade:	C30/37	DC 2
f_{ck} (N/mm²):	30	
f_y (N/mm²):	500	
Unit Weight γ_c (kN/m²):	25	
Minimum Cover (mm):	35	Δc: 10
Nominal Cover (mm):	45	
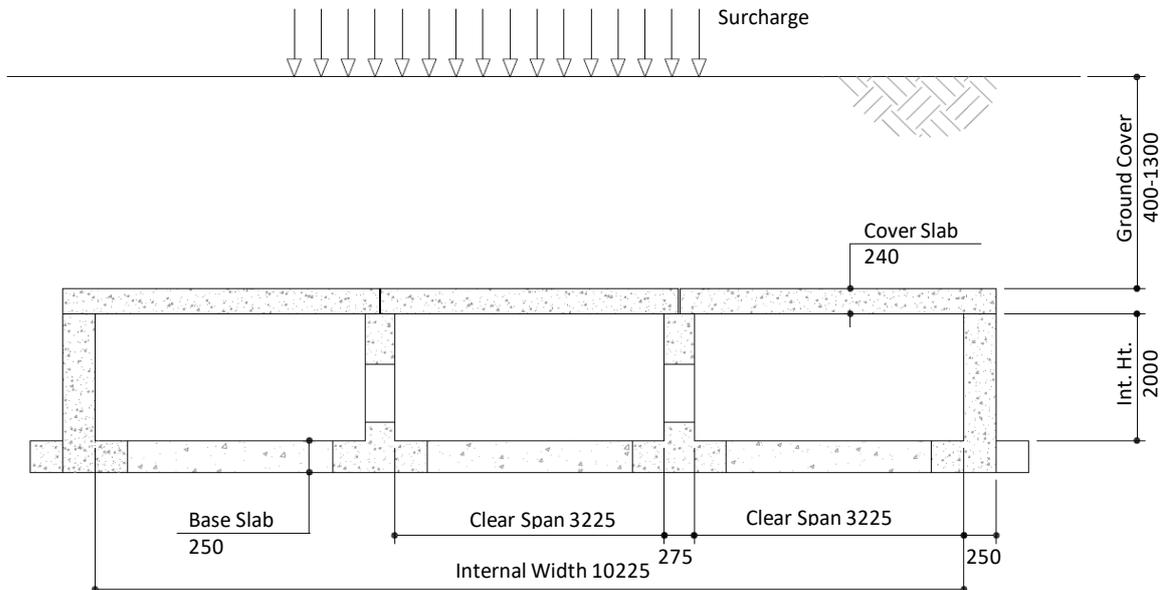
TYPICAL SECTION THROUGH TANK

F.P. McCann

Bullhurst Lane
Weston Underwood
Derbyshire , DE6 4PH

05-May-23

Rev: P-01

By: PM   Chk: Sheet: **4 of 38**

Contract Name: Skelmanthorpe, Saville Road
Contract Number: 05-BYL-xxxx
Client: Lovell Homes
Reference: Attenuation Tank

2. EXTERNAL WALLS

Load Case 1: **The tank is assumed to be empty, surrounded by saturated soil**
For the purposes of this calculation, assume the external ground water is at surface:

Consider   1.30 m Ground Cover
15.7 kN/m² Surcharge

240
2,000
250
1,540
2.125

q_t q_s

q_b
Soil   Surcharge

External Walls: (1m Width Considered)
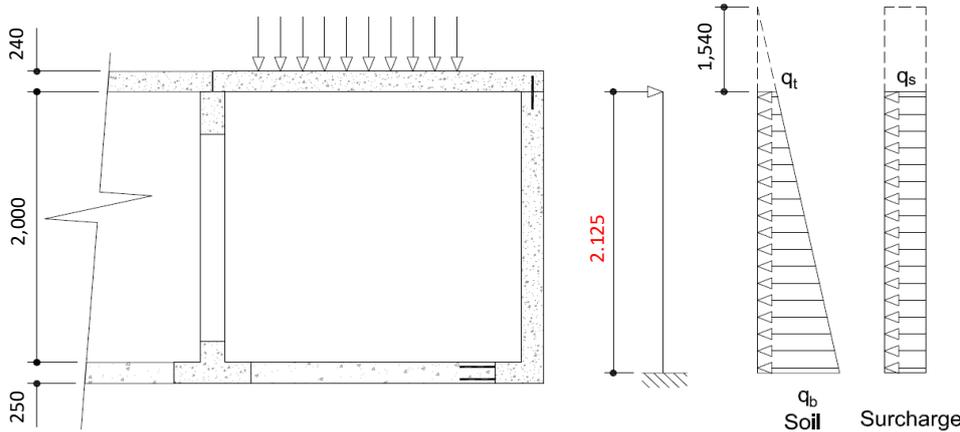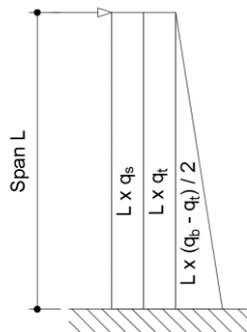Consider wall acts as a propped cantilever:

Span L
$L \times q_s$
$L \times q_t$
$L \times (q_b - q_t) / 2$

ψ: 0.3
γ_{f_g} 1.35
γ_{f_q} 1.5
Span L: 2.125 m

Load Case 1:	Dead	Live	SLS	QP	ULS	
Soil q_t (kN/m)	19.5	0.0	19.5	19.5	26.3	
Soil q_b (kN/m)	46.4	0.0	46.4	46.4	62.7	
Surcharge q_s (kN/m)	0.0	5.2	5.2	1.6	7.8	
UDL: (L x (q_s+q_t)) (kN)	41.4	11.1	52.6	44.8	72.6	
ΔDL: (L x (q_b-q_t)/2) (kN)	28.6	0.0	28.6	28.6	38.6	
Bending Moment M @ Base (kNm)	19.1	3.0	22.1	20.0	30.2	(Tension outer face)
Design Bending Moment M @ Invert (kNm)	13.4	2.1	15.5	14.0	21.2	
Design Bending Moment M @ ~Mid (kNm)	9.8	1.7	11.5	10.3	15.7	(Tension inner face)
Shear V @ Base (kN)	48.8	6.9	55.7	50.9	76.3	
Design Shear V @ d from Base (kN)					53.9	
Design Shear V @ 2d from Base (kN)					41.0	
Shear V @ Top (kN)	21.3	4.2	25.4	22.5	34.9	

34.9kN

15.7kNm

Contraflexure 0.513
from base c.l.

21.2kNm
@ invert

30.2kNm

41kN @ 2d
53.9kN @ d

76.3kN

MOMENT   SHEAR
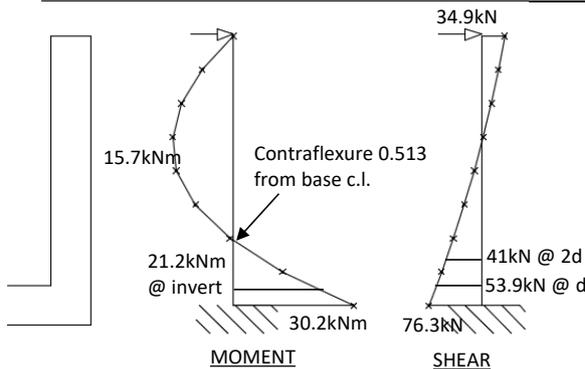
LOAD CASE 1 - SUMMARY

Load Case 2:   **The tank is full, without cover slab**

(This load case is a check for the water test prior to backfilling)

2,000

2,000

q_w
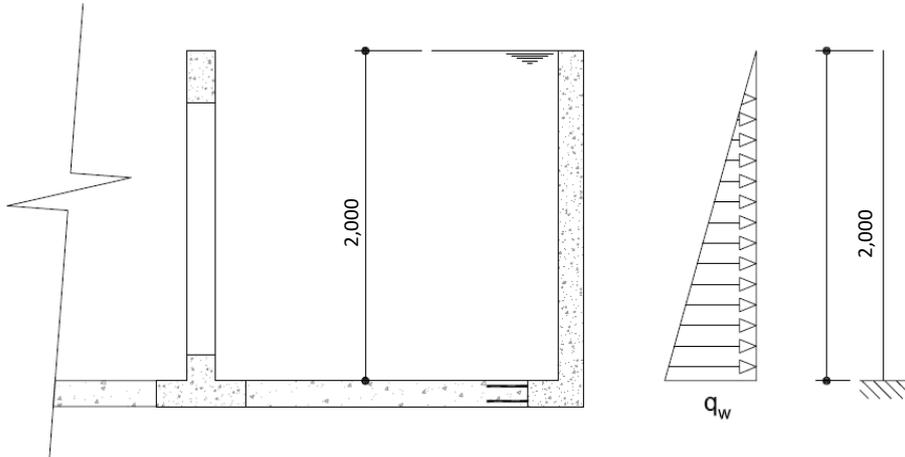
External Walls: (1m Width Considered)

Consider wall acts as a cantilever:

$H \times q_w / 2$

Span L
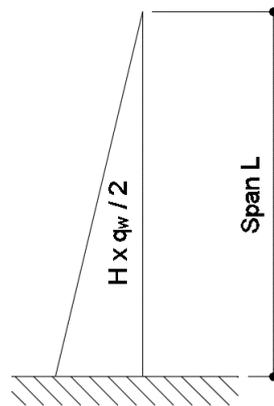
Load Case 2

ψ:	0.3
γ_{f_g}	1.35
γ_{f_w}	1.2
Span L:	2.000 m
Water Depth H:	2.000 m

Load Case 2:	Dead	Live	SLS	QP	ULS	
Water q_w (kN/m)	0.0	20.0	20.0	6.0	24.0	
ΔDL: (H x q_w/2) (kN)	0.0	20.0	20.0	6.0	24.0	
Bending Moment M @ Base (kNm)	0.0	13.3	13.3	4.0	16.0	(Tension inner face)
Shear V @ Base (kN)	0.0	20.0	20.0	6.0	24.0	
Design Shear V @ d from Base (kN)	0.0	16.1	16.1	4.8	19.3	

LOAD CASE 2 - SUMMARY

19.3kN

16kNm

MOMENT

24kN

SHEAR

			Version: 01/11/2022	05-May-23	**F.P. McCann**
					Bullhurst Lane
	Contract Name:	Skelmanthorpe, Saville Road			Weston Underwood
	Contract Number:	05-BYL-xxxx		Rev: P-01	Derbyshire , DE6 4PH
	Client:	Lovell Homes			
	Reference:	Attenuation Tank		By: PM	Chk:	Sheet: **6 of 38**
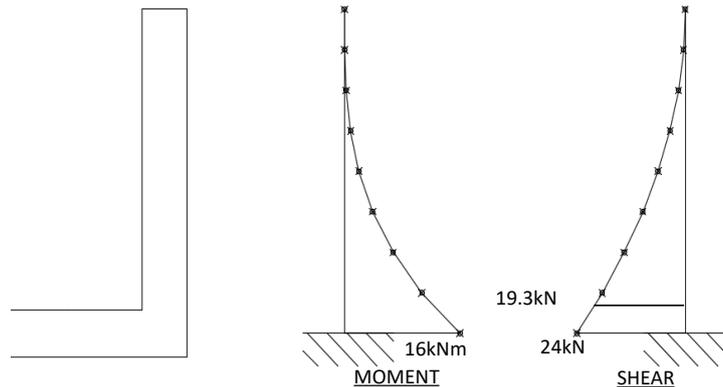
Reinforcement Design

2A) External Walls: Outer Face (At Base) Load Case 1

M_{ult}	21.2 kNm	f_{ck}	40 N/mm²	b	1000 mm	f_{ctm}	3.51 N/mm²
M_{qp}	14.0 kNm	f_y	500 N/mm²	d	205 mm	$A_{s,min}$	0.0018 b.d.

V @d 53.9 kN, allowing for reduction factor β of 0.5 (a_v/2d), V_{Ed} = 27.0 kN

V @2d 41.0 kN, Therefore adopt V_{Ed} of **41.0** kN

Moment:

$K = M / f_{ck} \bullet b \bullet d^2 =$ 0.013

$z/d = \frac{1}{2} \bullet [1 + (1 - 3.53 \bullet K)^{1/2}] =$ 0.95

$A_s = M / (0.87 \bullet f_y \bullet z) =$ 251 mm²

As,min = 0.0018•b•d = 369 mm²

Use B10 @ 150 ctrs

As prov = 524 mm²

Satisfactory

Shear:

$v = V / (0.9 \bullet b \bullet d) =$ 0.22 N/mm²

$v_{Rd,c} =$ 0.62 N/mm²

No Links req.
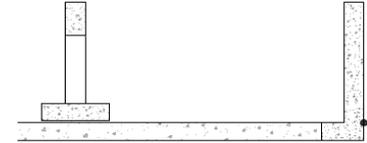
Crack width (See Appendix)

$w_k =$ **0.12 mm**

< 0.19 mm

Satisfactory

Limiting Crack Width: Tightness Class 1

Ht. water 2,000 mm *

Thickness 250 mm

wk1 0.19 mm

2B) External Walls: Inner Face (Mid Height) Load Case 1

M_{ult}	15.7 kNm	f_{ck}	40 N/mm²	b	1000 mm	f_{ctm}	3.51 N/mm²
M_{qp}	10.3 kNm	f_y	500 N/mm²	d	205 mm	$A_{s,min}$	0.0018 b.d.

Moment:

$K = M / f_{ck} \bullet b \bullet d^2 =$ 0.009

$z/d = \frac{1}{2} \bullet [1 + (1 - 3.53 \bullet K)^{1/2}] =$ 0.95

$A_s = M / (0.87 \bullet f_y \bullet z) =$ 186 mm²

As,min = 0.0018•b•d = 369 mm²

Use B10 @ 150 ctrs

As prov = 524 mm²

Satisfactory

Crack width:

$w_k =$ **0.09 mm**

< 0.20 mm

Satisfactory

Limiting Crack Width: Tightness Class 1

Ht. water 1,000 mm *

Thickness 250 mm

wk1 0.20 mm

2C) External Walls: Inner Face (At Base) Load Case 2

M_{ult}	16.0 kNm	f_{ck}	40 N/mm²	b	1000 mm	f_{ctm}	3.51 N/mm²
M_{qp}	4.0 kNm	f_y	500 N/mm²	d	205 mm	$A_{s,min}$	0.0018 b.d.
V_{Ed}	19.3 kN						

Moment:

$K = M / f_{ck} \bullet b \bullet d^2 =$ 0.010

$z/d = \frac{1}{2} \bullet [1 + (1 - 3.53 \bullet K)^{1/2}] =$ 0.95

$A_s = M / (0.87 \bullet f_y \bullet z) =$ 189 mm²

As,min = 0.0018•b•d = 369 mm²

Use B10 @ 150 ctrs

As prov = 524 mm²

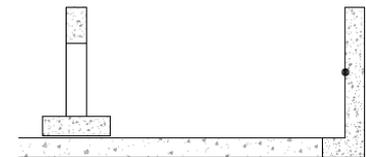**Satisfactory**

Shear:

$v = V / (0.9 \bullet b \bullet d) =$ 0.10 N/mm²

$v_{Rd,c} =$ 0.62 N/mm²

No Links req.
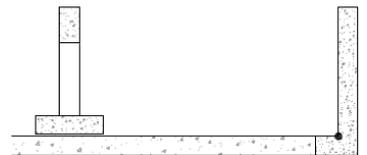
Crack width (See Appendix)

$w_k =$ **0.03 mm**

< 0.19 mm

Satisfactory

Limiting Crack Width: Tightness Class 1

Ht. water 2,000 mm *

Thickness 250 mm

wk1 0.19 mm

* For the water tightness check in the quasi permanent sate, the external ground water level is assumed
to be at the top of the tank.

Transverse Reinforcement
Provide Minimum Steel / 20% Main Steel

Walls:	250 mm thick, precast		**Use B10 @**	**200 ctrs**	
As,min = 0.0018•b•d =	369 mm²		As prov =	393 mm²	
20% Main Steel =	105 mm²		**Satisfactory**		

Dowel connection between walls and cover slab

Dowels to transfer reaction from wall into slab, to ensure propped cantilever action.

From Load Case 1

Maximum Reaction:	34.9	kN/m
Dowel Centres:	875	mm
Load per dowel = 34.9 x 875 / 1000:	30.5	kN

Assume **B20** **dowels**

Shear resistance of dowel $F_{Rd} = 0.87 f_y A / \sqrt{3}$

F_{Rd} = **78.9** kN > 30.5kN

Satisfactory

Check Shear in PCC Wall
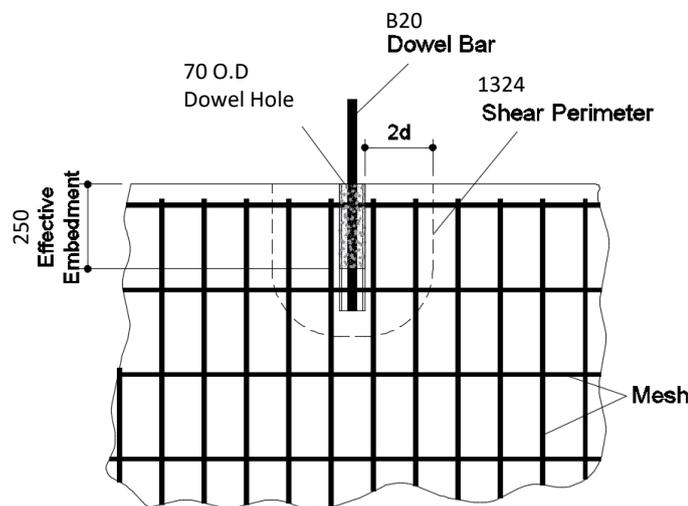
Dowel Embedment:	250	mm	V_{Ed}	30.5	kN	
Dowel Hole	70	mm	f_{ck}	40	N/mm²	
d = 250 - 90 - 30 - 10	120	mm	f_y	500	N/mm²	
Shear Perimeter:			Mesh:			
250 x 2 + 70 + π(2 x 120)	1324	mm	Horiz	**4 No. B10**	314	mm²
			Vert	**3 No. B10**	235	mm²
			Additional:			
			Horiz	**0 No. B10**	0	mm²
				As prov =	549	mm²

v = V / (0.9•b•d) = 0.21 N/mm²

$v_{Rd,c}$ = 0.63 N/mm²

No Links req.

Version: 01/11/2022

			05-May-23		**F.P. McCann**
	Contract Name:	Skelmanthorpe, Saville Road			Bullhurst Lane
	Contract Number:	05-BYL-xxxx	Rev: P-01		Weston Underwood
	Client:	Lovell Homes			Derbyshire , DE6 4PH
	Reference:	Attenuation Tank	By: PM	Chk:	Sheet: **8 of 38**

3. INTERNAL WALLS

	Serv. kN/m²		Ult kN/m²	Q.P.		ψ:	0.30
UDL @ Cover Slab Level (Dead):	7.2	x 1.35 =	9.7	7.2		γ_{f_g}	1.35
(Live):	40.8	x 1.50 =	61.2	12.2		γ_{f_q}	1.50
Self Weight Cover Slab:	6.0	x 1.35 =	8.1	6.0 *240mm Thick*			
w:	**54.0**		**79.0**	**25.4**			

Maximum span between wall centres L: 3.50 m
For 3 Lanes Continuity Factor k: 0.10

Max. reaction onto internal wall: wL(1+k)
           Therefore:
Line load applied to walls: w x 3.5 x 1.1:   207.9 kN/m (Serv)
          :   304.2 kN/m (Ult)
          :   97.9 kN/m (QP)

<u>Consider:</u>

Top Beam Height:	475 mm	Base Beam Height:	250 mm
Width:	275 mm	Width:	775 mm

Beam elements:

Consider horizontal elements of wall acts as a series of built in beams spanning between columns:
Beam Self Wt: 0.475 x 0.275 x 25   3.3 kN/m (Serv)
                                     4.4 kN/m (Ult)

Therefore design load: **211.2** kN/m (Serv)
                        308.6 kN/m (Ult)
                        101.2 kN/m (QP)

Line Load:
211.2kN/m (Serv.)
308.6kN/m (Ult.)
101.2kN/m (QP)

Check Bending Moments and Shear:

65.7kNm   65.7kNm   65.7kNm

A   **D**   **B**   **E**   **C**

32.8kNm   32.8kNm

Bending Moment Diagram (Ultimate Loads)

246.5KN   246.5KN   201.3KN

0   0

A   **B**   **C**

201.3KN   246.5KN   246.5KN

Shear Force Diagram (Ultimate Loads)
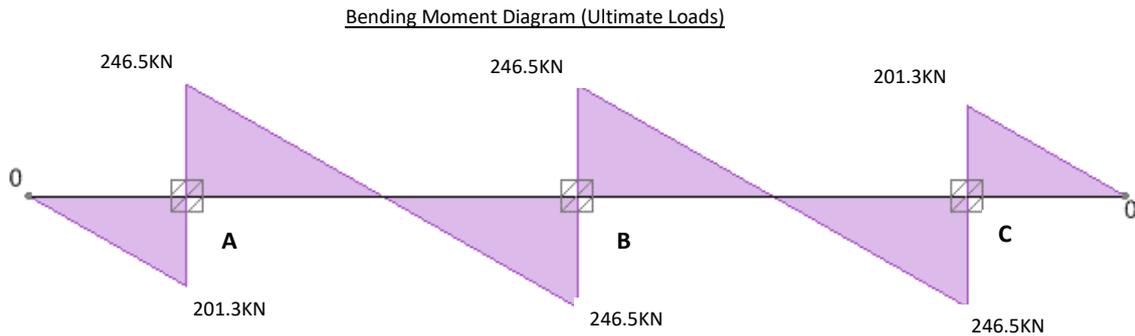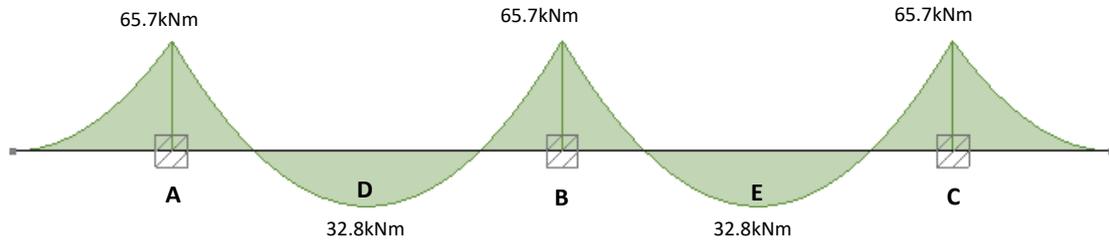
Reinforcement Design

3A) Internal Walls: Top Beam, Hogging

M_{ult}	65.7 kNm	f_{ck}	40 N/mm²	b	275 mm	f_{ctm}	3.51 N/mm²
M_{qp}	21.5 kNm	f_y	500 N/mm²	d	427 mm	$A_{s,min}$	0.0018 b.d.
V_{max}	246.5 kN	V_{Ed}	246.5 - (0.2+0.427) x 304.2				
			55.8 kN				
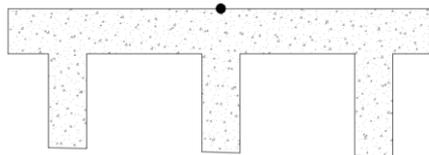
Moment:		Shear	
$K = M / f_{ck}\cdot b\cdot d^2 =$	0.033	$v = V / (0.9\cdot b\cdot d) =$	0.53 N/mm²
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53\cdot K)^{\wedge}\frac{1}{2}] =$	0.95	$v_{Rd,c} =$	0.56 N/mm²
$As = M / (0.87\cdot f_y\cdot z) =$	373 mm²	Cot(theta) =	2.5 Ok
As,min = 0.0018•b•d =	211 mm²	Asv/sv =	0.320
Use 2	**B20**	**Use 2 Legs**	**B8**	**@ 250 ctrs.**
As prov =	628 mm²	Actual Asv/sv =	0.402
Satisfactory		**Satisfactory**	

Crack width (See Appendix)		Limiting Crack Width: Tightness Class 0	
$w_k =$	**0.06 mm**	Ht. water	N/A
<	0.30 mm	Thickness	N/A
Satisfactory		wkmax	0.30 mm

3B) Internal Walls: Top Beam, Sagging

M_{ult}	32.8 kNm	f_{ck}	40 N/mm²	b	275 mm	f_{ctm}	3.51 N/mm²
M_{qp}	10.8 kNm	f_y	500 N/mm²	d	429 mm	$A_{s,min}$	0.0018 b.d.

Moment:	
$K = M / f_{ck}\cdot b\cdot d^2 =$	0.016
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53\cdot K)^{\wedge}\frac{1}{2}] =$	0.95
$As = M / (0.87\cdot f_y\cdot z) =$	185 mm²
As,min = 0.0018•b•d =	212 mm²
Use 2	**B16**
As prov =	402 mm²
Satisfactory	
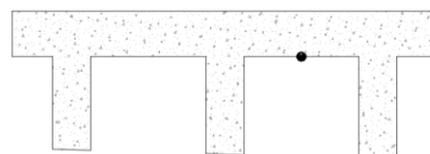
Crack width (See Appendix)		Limiting Crack Width: Tightness Class 0	
$w_k =$	**0.06 mm**	Ht. water	N/A
<	0.30 mm	Thickness	N/A
Satisfactory		wkmax	0.30 mm

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Reinforcement Design

3C) Internal Walls: Bottom Beam, Hogging

M_{ult}	65.7 kNm	f_{ck}	40 N/mm²	b	775 mm	f_{ctm}	3.51 N/mm²
M_{qp}	21.5 kNm	f_y	500 N/mm²	d	204 mm	$A_{s,min}$	0.0018 b.d.
V_{max}	246.5 kN	V_{Ed}	246.5 - (0.2+0.204) x 304.2				
			123.6 kN				

Moment:

$K = M / f_{ck} \cdot b \cdot d^2 = $ 0.051

$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{\frac{1}{2}}] = $ 0.95

$A_s = M / (0.87 \cdot f_y \cdot z) = $ 780 mm²

$A_{s,min} = 0.0018 \cdot b \cdot d = $ 285 mm²

Use 6   B16

As prov = 1206 mm²

Satisfactory

Shear

$v = V / (0.9 \cdot b \cdot d) = $ 0.87 N/mm²

$v_{Rd,c} = $ 0.75 N/mm²

Cot(theta) = 2.5 Ok

Asv/sv = 0.620

Use 4 Legs   B8   @ 250 ctrs.

Actual Asv/sv = 0.804

Satisfactory
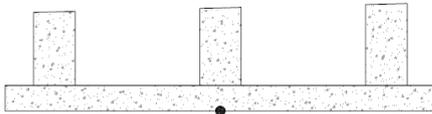
Crack width (See Appendix)

$w_k = $ **0.06 mm**

< 0.30 mm

Satisfactory

Limiting Crack Width: Tightness Class 0

Ht. water   N/A

Thickness   N/A

wkmax   0.30 mm

3D) Internal Walls: Bottom Beam, Sagging

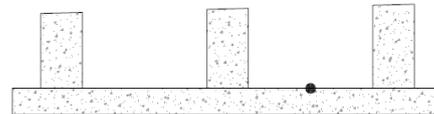|							
M_{ult}	32.8 kNm	f_{ck}	40 N/mm²	b	775 mm	f_{ctm}	3.51 N/mm²
M_{qp}	10.8 kNm	f_y	500 N/mm²	d	206 mm	$A_{s,min}$	0.0018 b.d.

Moment:

$K = M / f_{ck} \cdot b \cdot d^2 = $ 0.025

$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{\frac{1}{2}}] = $ 0.95

$A_s = M / (0.87 \cdot f_y \cdot z) = $ 386 mm²

$A_{s,min} = 0.0018 \cdot b \cdot d = $ 287 mm²

Use 6   B12

As prov = 679 mm²

Satisfactory

Crack width (See Appendix)

$w_k = $ **0.06 mm**

< 0.30 mm

Satisfactory

Limiting Crack Width: Tightness Class 0

Ht. water   N/A

Thickness   N/A

wkmax   0.30 mm

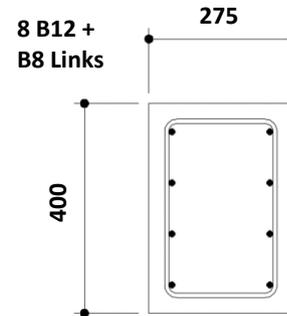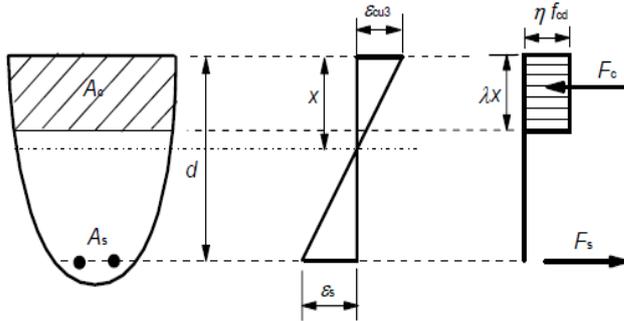**Consider typical vertical elements acting as column**   275 x 400 Column, reinforced as shown:

LC 1 - one side only loaded

Moment   66 kNm

Thrust   247 kN

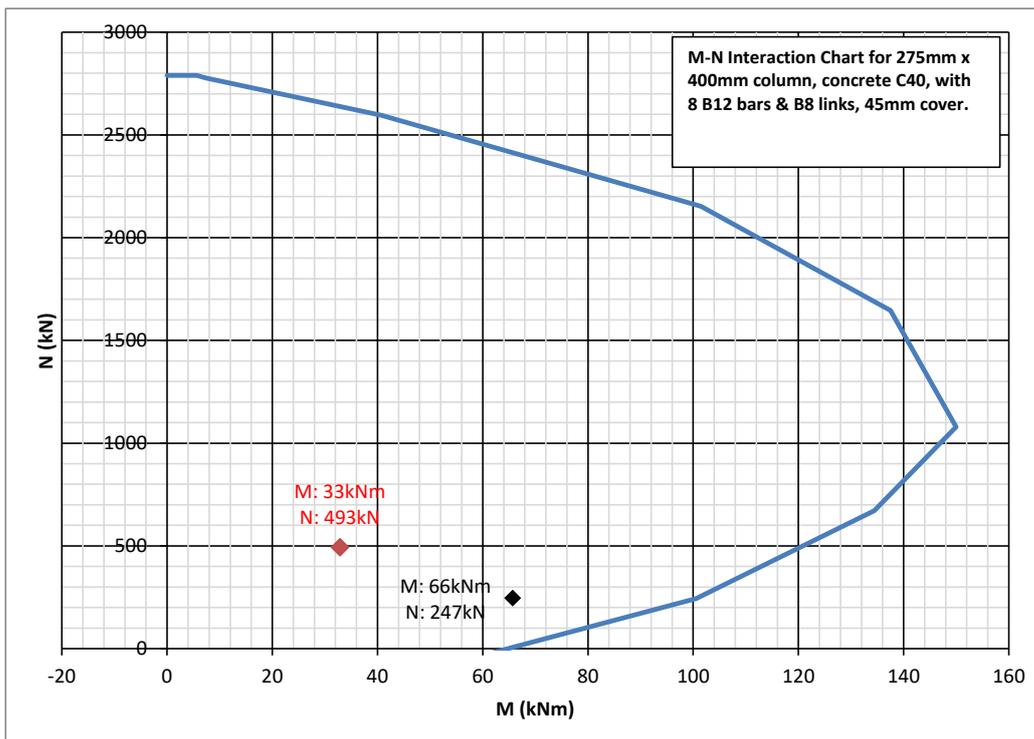**LC 2 - both sides loaded, assume eccentricity of load = h/6**

Moment   33 kNm

Thrust   493 kN

8 B12 + B8 Links

275

400

3 Layers Reinforcement

b	275 mm		
h	400 mm	Layer 1:	d	54 mm
f_{ck}	40 N/mm²		No.	2
γ_c	1.5		Dia.	12 mm
f_y	500 N/mm²		A_s	226 mm²
γ_s	1.15			
E_s	200,000 N/mm²	Layer 2:	d	200 mm
ε_{c3}	0.00175		No.	4
ε_{cu3}	0.00350		Dia.	12 mm
$(1-\varepsilon_{c3}/\varepsilon_{cu3})h$	200.0		A_s	452 mm²
η	1.00			
λ	0.80	Layer 3:	d	346 mm
ηf_{cd}	22.67 N/mm²		No.	2
f_y/γ_s	434.78 N/mm²		Dia.	12 mm
Net f_y/γ_m	412.12 N/mm²		A_s	226 mm²

M-N Interaction Chart for 275mm x 400mm column, concrete C40, with 8 B12 bars & B8 links, 45mm cover.

M: 33kNm
N: 493kN

M: 66kNm
N: 247kN

4. BASE SLAB   (Refer to Appendix C)

Consider Ultimate loads: Modulous of subgrade reaction taken as 25MPa

Shear Diagram

Moment Diagram

Bearing Pressure Diagram

Version: 01/11/2022

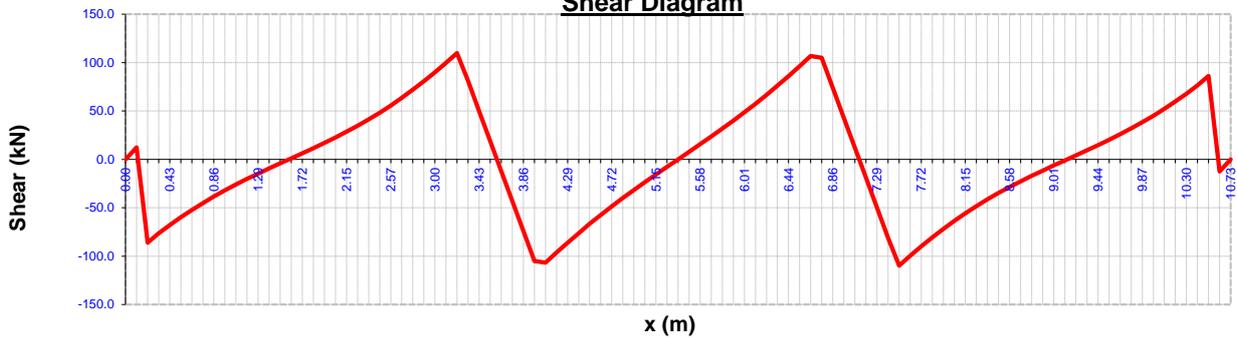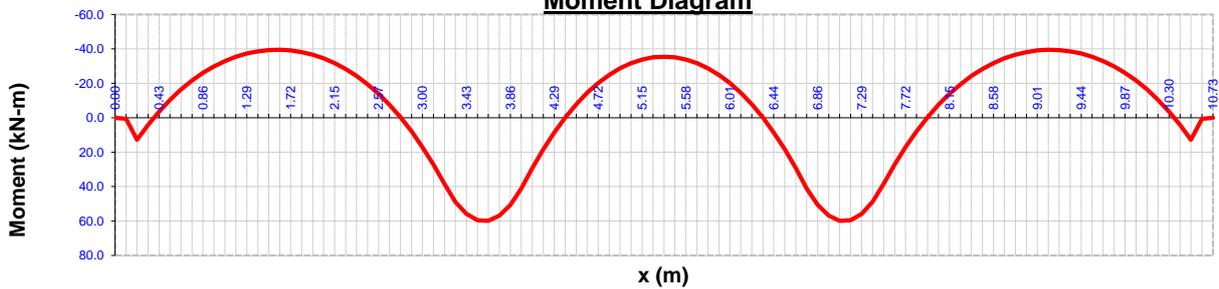|		
Contract Name:	Skelmanthorpe, Saville Road	05-May-23
Contract Number:	05-BYL-xxxx	Rev: P-01
Client:	Lovell Homes	
Reference:	Attenuation Tank	By: PM Chk: Sheet: 13 of 38

F.P. McCann
Bullhurst Lane
Weston Underwood
Derbyshire , DE6 4PH
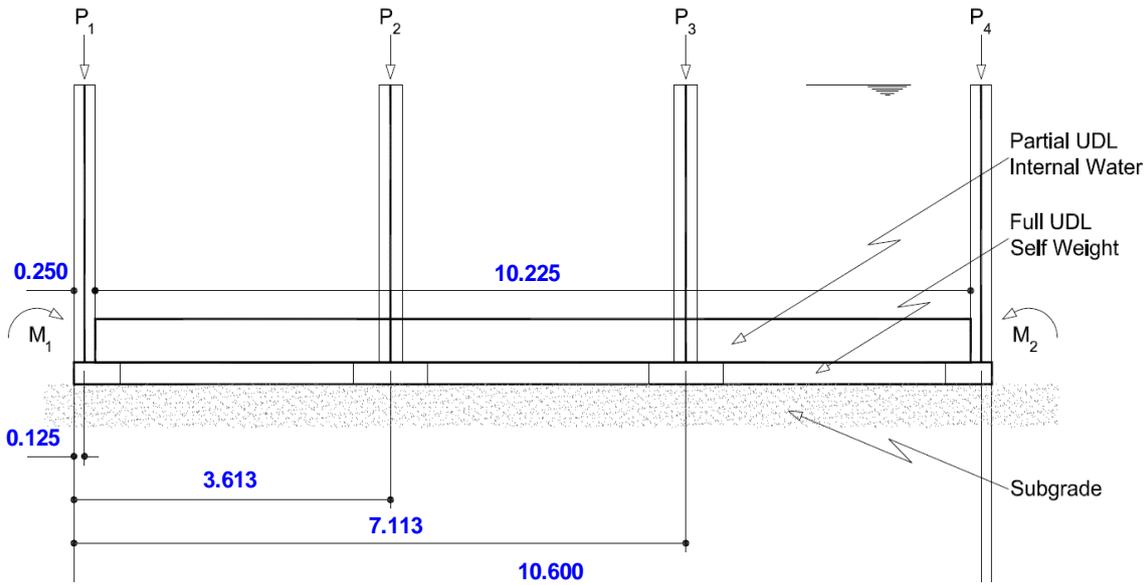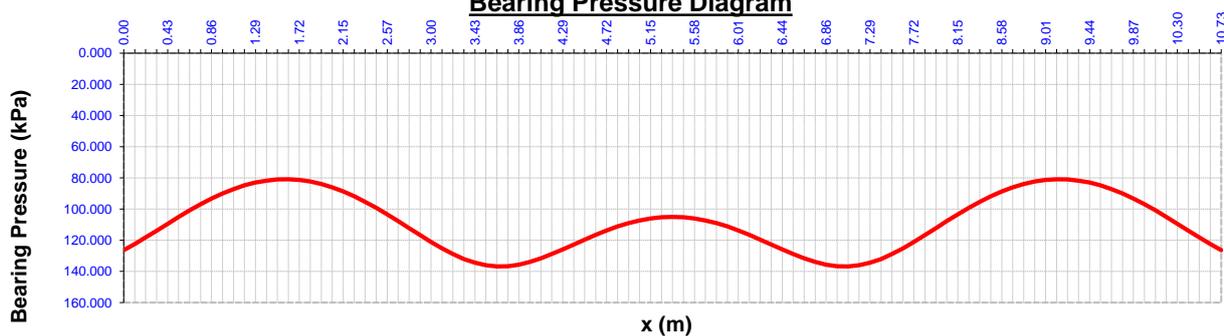
Similarly the following table has been developed for service and QP loads

Parameter	0.4m Fill + 40.8kN/m² surcharge			
	Ultimate	Alternate Ult/Serv	Service	Q.P.
Hog Mt. under int. wall (kNm)	60.1	51.5	40.9	19.1
Hog Mt. under int. wall edges (kNm)	39.3	34.6	26.5	12.5
Sag Mt. @ Ext Wall Proj. (kNm)	23.8	22.8	17.1	5.2
Sag Mt. (kNm)	39.5	37.4	28.1	11.8
Vmax (kN)	114.3	97.1	77.9	36.7
V @ d - Internal Walls (kN)	95.6	81.2	65.1	30.7
V @ d - External Walls (kN)	67.0	75.8	55.2	27.1
Δmax (mm)	5.5	5.2	3.1	1.6
Max Bearing (kN/m²)	136.8	130.6	77.4	40.1

Deflection:
Max. deflection (ULS): 5.5 mm
(SLS): 3.1 mm

Bearing:
Max. bearing pressure (ULS): 136.8 kN/m²
(SLS): 77.4 kN/m²

Allow for Bearing
150 kN/m²(Ultimate)
90 kN/m²(Service)

Reinforcement Design

4A) Base Slab: Hogging under internal wall midpoint:

M_{ult}	60.1 kNm	f_{ck}	30 N/mm²	b	1000 mm	f_{ctm}	2.90 N/mm²
M_{qp}	19.1 kNm	f_y	500 N/mm²	d	190 mm	$A_{s,min}$	0.0015 b.d.
V_{Ed}	95.6 kN						

Moment:
$K = M / f_{ck} \cdot b \cdot d^2 =$ 0.056
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{1/2}] =$ 0.95
$A_s = M / (0.87 \cdot f_y \cdot z) =$ 767 mm²
As,min = 0.0015•b•d = 285 mm²
Use B10 @ 100 ctrs
Plus additional B10 @ 200 ctrs x 2000 Lg
As prov = 1178 mm²
Satisfactory

Shear:
$v = V / (0.9 \cdot b \cdot d) =$ 0.56 N/mm²
$v_{Rd,c} =$ 0.64 N/mm²
No Links req.

Crack width (See Appendix)
$w_k =$ 0.07 mm
< 0.18 mm
Satisfactory
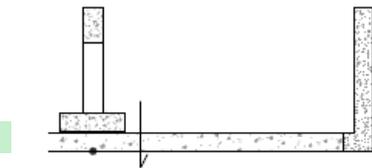
Limiting Crack Width: Tightness Class 1
Ht. water 2,250 mm
Thickness 250 mm
wk1 0.18 mm

4B) Base Slab: Hogging under internal wall edges:

M_{ult}	39.3 kNm	f_{ck}	30 N/mm²	b	1000 mm	f_{ctm}	2.90 N/mm²
M_{qp}	12.5 kNm	f_y	500 N/mm²	d	190 mm	$A_{s,min}$	0.0015 b.d.
V_{Ed}	95.6 kN						

Moment:
$K = M / f_{ck} \cdot b \cdot d^2 =$ 0.036
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{1/2}] =$ 0.95
$A_s = M / (0.87 \cdot f_y \cdot z) =$ 500 mm²
As,min = 0.0015•b•d = 285 mm²
Use B10 @ 100 ctrs
As prov = 785 mm²
Satisfactory

Shear:
$v = V / (0.9 \cdot b \cdot d) =$ 0.56 N/mm²
$v_{Rd,c} =$ 0.64 N/mm²
No Links req.

Crack width (See Appendix)
$w_k =$ 0.08 mm
< 0.18 mm
Satisfactory
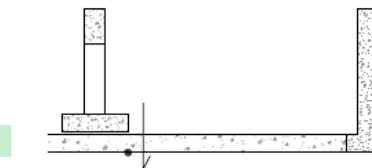
Limiting Crack Width: Tightness Class 1
Ht. water 2,250 mm
Thickness 250 mm
wk1 0.18 mm

4C) Base Slab: Sag Mt. @ Ext Wall Proj.

M_{ult}	23.8 kNm	f_{ck}	30 N/mm²	b	1000 mm	f_{ctm}	2.90 N/mm²
M_{qp}	5.2 kNm	f_y	500 N/mm²	d	190 mm	$A_{s,min}$	0.0015 b.d.
V_{Ed}	75.8 kN						

Moment:
$K = M / f_{ck} \cdot b \cdot d^2 =$ 0.022
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{1/2}] =$ 0.95
$A_s = M / (0.87 \cdot f_y \cdot z) =$ 303 mm²
As,min = 0.0015•b•d = 285 mm²
Use B10 @ 100 ctrs
As prov = 785 mm²
Satisfactory

Shear:
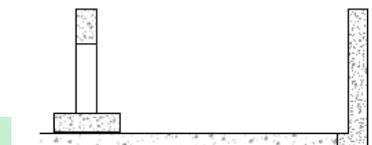$v = V / (0.9 \cdot b \cdot d) =$ 0.44 N/mm²
$v_{Rd,c} =$ 0.56 N/mm²
No Links req.

Crack width (See Appendix)
$w_k =$ 0.03 mm
< 0.18 mm
Satisfactory

Limiting Crack Width: Tightness Class 1
Ht. water 2,250 mm
Thickness 250 mm
wk1 0.18 mm

Version: 01/11/2022

F.P. McCann
Bullhurst Lane
Weston Underwood
Derbyshire , DE6 4PH

05-May-23			
Rev: P-01			
By: PM	Chk:	Sheet:	**14 of 38**

Contract Name: Skelmanthorpe, Saville Road
Contract Number: 05-BYL-xxxx
Client: Lovell Homes
Reference: Attenuation Tank

4D) Base Slab: Sagging in Insitu

M_{ult}	39.5 kNm	f_{ck}	30 N/mm²	b	1000 mm	f_{ctm}	2.90 N/mm²
M_{qp}	11.8 kNm	f_y	500 N/mm²	d	190 mm	$A_{s,min}$	0.0015 b.d.

Moment:

$K = M / f_{ck} \cdot b \cdot d^2 =$ 0.036

$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{1/2}] =$ 0.95
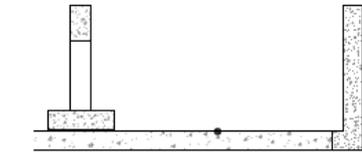
$A_s = M / (0.87 \cdot f_y \cdot z) =$ 503 mm²

$As,min = 0.0015 \cdot b \cdot d =$ 285 mm²

Use B10 @ 100 ctrs

As prov = 785 mm²

Satisfactory

Crack width (See Appendix)

$w_k =$ **0.07** mm

< 0.18 mm

Satisfactory

Limiting Crack Width: Tightness Class 1

Ht. water	2,250 mm
Thickness	250 mm
wk1	0.18 mm

4E) Base Slab: Sagging in Insitu - DWF

M_{ult}	39.5 kNm	f_{ck}	30 N/mm²	b	1000 mm	f_{ctm}	2.90 N/mm²
M_{qp}	11.8 kNm	f_y	500 N/mm²	d	149 mm	$A_{s,min}$	0.0015 b.d.

Moment:

$K = M / f_{ck} \cdot b \cdot d^2 =$ 0.059

$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{1/2}] =$ 0.94

$A_s = M / (0.87 \cdot f_y \cdot z) =$ 646 mm²

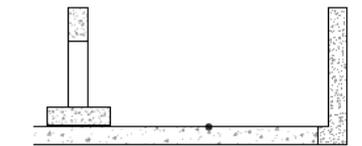$As,min = 0.0015 \cdot b \cdot d =$ 224 mm²

Use B12 @ 100 ctrs

As prov = 1131 mm²

Satisfactory

Crack width (See Appendix)

$w_k =$ **0.05** mm

< 0.18 mm

Satisfactory

Limiting Crack Width: Tightness Class 1

Ht. water	2,250 mm
Thickness	250 mm
wk1	0.18 mm

4F) Base Slab: Transverse Steel / Thermal Cracking

From C660 Spreadsheets:

As, min =	785 mm²	Early age crack width:	0.08 mm
Use B10 @ 100 ctrs		Long term crack width:	**0.13** mm
As prov =	785 mm²	<	0.18 mm
Satisfactory		**Satisfactory**	

Thermal Cracking to CIRIA C660:

Parameter	Value	Equations and assumptions	Source
Early Age			
Base Thickness h_0	**250mm**		FPM Drg.
Age at cracking	**3 days**		Default value used
Creep coefficient K_1	**1**		Default value used
Sustained load factor	**0.8**		Default value used
Coefficient of thermal expansion α_c	**12με/°C**		Default value used
Temperature drop T_1	**18°C**	Binder: 360 kg/m³ CEM I PFA: - % C30/37 Thickness: 250 mm F'Work 18mm plywood	See CIRIA Spreadsheet, input based on C660 Table 4.2
Restraint R_1	**0.50**		Default value used
Long Term			
Temperature Change T_2	**20°C**	T_2 and ε_{cd} only apply when causing differential contraction or when the sections acting integrally are subject to external restraint	See CIRIA Spreadsheet, input based on C660 Table 4.2
Drying Shrinkage ε_{cd}	**103με**		

Risk and control of cracking due to continuous edge restraint

Input parameters	Symbol	Unit	Value	
Section details and material properties				
Section thickness	h	mm	**250**	
Strength class	$f_{ck}/f_{ck,cube}$	MPa	**C30/37**	
Age at cracking	t_c	days	**3 days**	Assume 3 days unless more reliable information is available
Creep factor	K_1		**1.00**	K_1 = 0.65 if R is calculated; K_1 = 1 if R is assumed to be 0.5 (including creep to EN1992-1-1)
Sustained load factor	K_2		**0.80**	
Coefficient of thermal expansion of concrete	α_c	με/°C	**12.0**	If aggregate is unknown use 12 με / °C
Characteristic yield strength of reinforcement	f_{yk}	MPa	**500**	500 Mpa
Early age concrete properties				
Tensile strength at cracking	$f_{ctm}(t_c)$	MPa	1.73	Mean value of tensile strength $f_{ctm}(t_c)$
Elastic modulus	$E_{cm}(t_c)$	GPa	28.1	Mean value of elastic modulus $E_{cm}(t_c)$
Tensile strain capacity	$\varepsilon_{ctu(ea)}$	με	49	$\varepsilon_{ctu(ea)} = [f_{ctm}(t_c) / E_{cm}(t_c)] \times [K_2 / K_1]$
Long term concrete properties				
Tensile strength	f_{ctm}	MPa	2.90	Mean 28-day value
Elastic modulus	E_{cm}	GPa	32.8	Mean 28-day value
Tensile strain capacity (sustained loading)	$\varepsilon_{ctu(lt)}$	με	71	$\varepsilon_{ctu(lt)} = [f_{ctm} / E_{cm}] \times [K_2 / K_1]$
Early-age strain				
Temperature drop	T_1	°C	**18°C**	T_1 = Peak temperature - mean ambient temperature
Autogenous shrinkage	$\varepsilon_{ca(ea)}$	με	15	EN1992-1-1 $\varepsilon_{ca(ea)}$ = 2.5 (f_{ck} - 10) x (1-exp(- 0.2 $t_c^{0.5}$)
Free contraction	$\varepsilon_{free(ea)}$	με	231	$\varepsilon_{free(ea)} = T_1 \alpha_c + \varepsilon_{ca}$
Restrained early-age strain and risk of cracking				
Restraint	R		**0.50**	Use restraint calculator for walls or adjacent slabs; or historical data
Early-age restrained contraction	$\varepsilon_{r(ea)}$	με	115	$\varepsilon_{r(ea)} = R_1 K_1 (T_1 \alpha_c + \varepsilon_{ca})$
Risk of early age cracking	$\varepsilon_{r(ea)}/\varepsilon_{ctu}$		2.93	Low risk of early age cracking if $\varepsilon_{r(ea)}/\varepsilon_{ctu}$ < 1 .
Early-age crack-inducing strain	$\varepsilon_{cr(ea)}$	με	91	$\varepsilon_{c(ea)} = R_1 K_1 (T_1 \alpha_c + \varepsilon_{ca}) - 0.5 \varepsilon_{ctu}$
Long term strain (excluding early-age strain)				
Autogenous shrinkage (residual up to 28 days)	$\delta\varepsilon_{ca(lt)}$	με	18	$\delta\varepsilon_{ca(lt)} = \varepsilon_{ca(28)} - \varepsilon_{ca(ea)}$
Long term temperature change	T_2	°C	**20**	T_2 and ε_{cd} only apply when causing differential contraction or when the sections
Drying shrinkage	ε_{cd}	με	**103**	acting integrally are subject to external restraint.
Long term free contraction	$\varepsilon_{free(lt)}$	με	361	$\varepsilon_{free(lt)} = \delta\varepsilon_{ca} + T_2 \alpha_c + \varepsilon_{cd}$
Restrained long term strain				
Restraint to long term thermal strains	R_2		**0.20**	Restraint will reduce as E_n / E_o approaches 1 in the long term
Restraint to drying shrinkage	R_3		**0.20**	
Long term restrained strain	$\varepsilon_{free(lt)}$	με	72	$\varepsilon_{c(lt)} = K_1 \{R_2 T_2 \alpha_c + R_3 (\delta\varepsilon_{ca} + \varepsilon_{cd})\}$
Increase in tensile strain capacity	$\delta\varepsilon_{ctu}$	με	21	$\delta\varepsilon_{ctu} = \varepsilon_{ctu(28)} - \varepsilon_{ctu(ea)}$
Long term crack-inducing strain	$\varepsilon_{cr(lt)}$		51	$\varepsilon_{c(lt)} = K_1 \{R_2 T_2 \alpha_c + R_3 (\delta\varepsilon_{ca} + \varepsilon_{cd})\} - \delta\varepsilon_{ctu}$
Total strain (early-age + long term)				
Free contraction	$\varepsilon_{r(total)}$	με	592	$\varepsilon_{free(total)} = \varepsilon_{free(ea)} + \varepsilon_{free(lt)}$
Restrained contraction	$\varepsilon_{r(total)}$	με	188	$\varepsilon_{r(total)} = \varepsilon_{r(ea)} + \varepsilon_{r(lt)}$
Crack-inducing strain	$\varepsilon_{cr(total)}$	με	142	$\varepsilon_{cr(total)} = \varepsilon_{cr(ea)} + \varepsilon_{cr(lt)}$
Reinforcement details				
Bar diameter	φ	mm	**10**	
Bar spacing	s	mm	**100**	
Cover	c	mm	**45**	
Area of steel per face per m	A_s	mm²	785	
Cracking initiated at early age strain				
Minimum area of reinforcement As,min				
Steel ratio for early age cracking	f_{ctm}/f_{yk}		0.00347	$f_{ctm} / f_{yk} = \rho_{crit}$
Coefficient	k		1.00	k = 1.0 for h ≤ 300mm; k = 0.75 for h ≥ 800mm; intermediate values are interpolated
Coefficient	k_c		1	For pure tension $k_c = 1$
Surface zone used in calculating As,min	$h_{s,min}$	mm	94	$h_{s,min} = k k_c h/2$
Minimum area of steel per face per m	$A_{s,min}$	mm²	325	$A_{s,min} = (h_{s,min} \times 1000) (f_{ctm} / f_{yk})$ Highlighted if $A_s < A_{s,min}$
Crack spacing and width				
Surface zone defining the effective area of concrete in tens	$h_{e,ef}$	mm	125	$h_{e,ef}$ = 2.5 (c + φ/2) [NOTE: $h_{s,min}$ and $h_{e,ef}$ are not the same]
Steel ratio for estimating crack spacing	$\rho_{p,eff}$		0.00628	$\rho_{p,eff} = A_s / A_{c,eff} = A_s / (h_{e,ef} \times 1000)$
Coefficient for bond characteristics	k_1		**1.14**	EN1992-1-1 recommends k_1 = 0.8 but provides a factor of 0.7 where good bond cannot be guaranteed. Hence k_1 = 0.8/0.7 = 1.14
Crack spacing	$S_{r,max}$	mm	924	$S_{r,max}$ = 3.4c + 0.425 k_1 φ/$\rho_{p,eff}$
Early age crack width	w_k	mm	**0.08**	$w_k = \varepsilon_{c(ea)} S_{r,max}$
Long term crack width	w_k	mm	**0.13**	$w_k = \varepsilon_{c(total)} S_{r,max}$
Minimum reinforcement requirement for late-life cracking only				
Steel ratio for late-life cracking	f_{ctm}/f_{yk}		0.0058	$f_{ctm} / f_{yk} = \rho_{crit}$
Minimum area of steel per face	$A_{s,min}$	mm²	543	Highlighted if $A_s < A_{s,min}$

5. ROOF SLAB UNITS
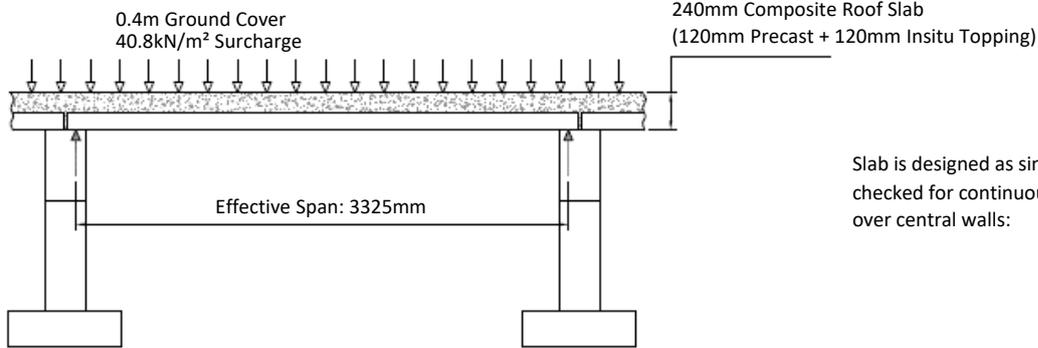
0.4m Ground Cover
40.8kN/m² Surcharge

240mm Composite Roof Slab
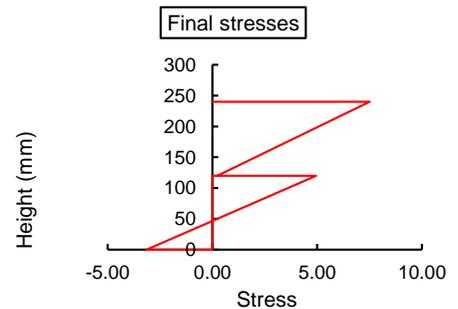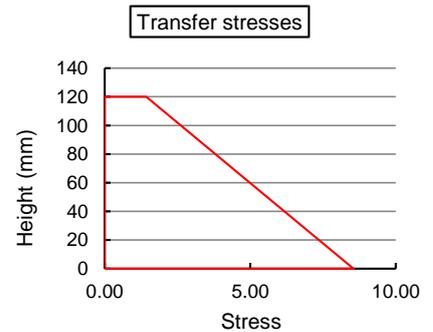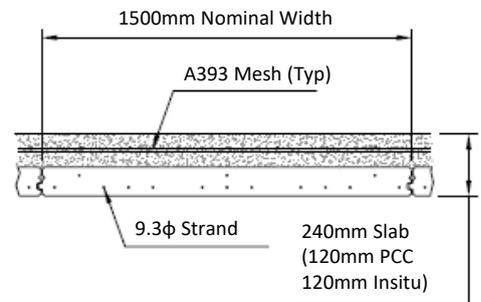(120mm Precast + 120mm Insitu Topping)

Effective Span: 3325mm

Slab is designed as simply supported but checked for continuous support moments over central walls:

5.1 - Prestressed Slab Units

1500mm Nominal Width

A393 Mesh (Typ)

9.3φ Strand

240mm Slab
(120mm PCC
120mm Insitu)

Slab Stress Combinations (Midspan)	Top Insitu f_{ti} (N/mm²)	Btm Insitu f_{bi} (N/mm²)	Top PC f_{tp} (N/mm²)	Btm PC f_{bp} (N/mm²)
Loss of prestress	0.17	-0.19	-0.19	-0.55
TRANSFER on bed exc s/w	Top Insitu f_{ti} (N/mm²)	Btm Insitu f_{bi} (N/mm²)	Top PC f_{tp} (N/mm²)	Btm PC f_{bp} (N/mm²)
Pt/A+Pt ep/Z	-	-	**1.42**	**8.55**
Allowable	-	-	-2.66	17.50
Check	-	-	**OK**	**OK**
TRANSFER on bed inc s/w	Top Insitu f_{ti} (N/mm²)	Btm Insitu f_{bi} (N/mm²)	Top PC f_{tp} (N/mm²)	Btm PC f_{bp} (N/mm²)
Pt/A+Pt ep/Z	-	-	1.42	8.55
s/w stress	-	-	1.89	-0.61
Total	-	-	**3.32**	**7.93**
Allowable	-	-	-2.66	17.50
Check	-	-	**OK**	**OK**
TRANSFER lift	Top Insitu f_{ti} (N/mm²)	Btm Insitu f_{bi} (N/mm²)	Top PC f_{tp} (N/mm²)	Btm PC f_{bp} (N/mm²)
Pt/A+Pt ep/Z	-	-	1.42	8.55
s/w stress	-	-	0.61	-0.61
Total	-	-	**2.04**	**7.93**
Allowable	-	-	-2.66	17.50
Check	-	-	**OK**	**OK**
FINAL	Top Insitu f_{ti} (N/mm²)	Btm Insitu f_{bi} (N/mm²)	Top PC f_{tp} (N/mm²)	Btm PC f_{bp} (N/mm²)
Pf/A+Pf ep/Z	0.00	0.00	1.23	7.41
Critical stress	7.58	0.23	3.68	-10.58
Total	7.58	0.23	**4.92**	**-3.18**
Allowable	18.50	18.50	18.15	-3.34
Check	**OK**	**OK**	**OK**	**OK**

SLS resistance moment (top fibre)	KNm	6985.84
SLS resistance moment (bottom fibre)	KNm	113.75
SLS resistance moment (min of above)	KNm	**113.75**
SLS actual moment	KNm	**111.94**	**OK**

Transfer stresses

Final stresses

5.2 Precast Slabs (With opening)

Cover Slab consists 120mm precast slab + 120mm insitu concrete topping.
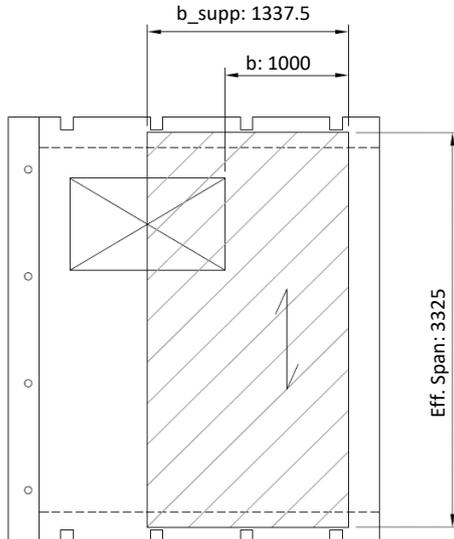
b_supp: 1337.5

b: 1000

Eff. Span: 3325

Details:

Slab Consists:	120	Precast
	120	Insitu Topping

Width Considered:	1,000	mm
Width Supported:	1,338	mm
Effective Span:	3,325	mm

Precast:	f_{ckp}	40	N/mm²
	f_y	500	N/mm²

Insitu:	f_{cki}	30	N/mm²
	f_y	500	N/mm²

For design purposes of composite, take Fck as 30N/mm²

f_{ctm}	2.90	N/mm²
$A_{s,min}$	0.0015	b.d.

Permanent Loading: Slab is designed as simply supported but checked for continuous support moments over central walls:

h =	240	mm	Surcharge:			γ_{f_g}	1.35
C_nom =	30	mm	Assume w	40.8 kN/m²	+ 0.40m Ground	γ_{f_q}	1.50
						ψ_2	0.30

UDL = (0.24 x 1.3375 x 25 x 1.35) + (40.8 x 1.3375 x 1.5) + (0.4 x 1.3375 x 18 x 1.35)

= 105.7 kN/m   34 kN/m (QP)

Check Bending: Sag Moment: Mid Span

M_{ult} =	105.7 x 3.325² / 8	M_{qp}
=	**146.1** kNm	**47** kNm

Check Shear: @ d from support face

R_{max} =	105.7 x 3.325 / 2 =	**175.7** kN
V_{Ed} =	175.7 - (0.192+ 0.07) x 105.7 =	**148.0** kN

Midspan - Sagging

M_{ult}	146.1	kNm	f_{ck}	30	N/mm²	b	1000	mm	f_{ctm}		2.90	N/mm²
M_{qp}	47.0	kNm	f_y	500	N/mm²	d	192	mm	$A_{s,min}$		0.0015	b.d.
V_{max}	175.7	kN	V_{Ed}	148.0	kN							

Moment:			Shear		
K = M / fck•b•d² =	0.132		v = V / (0.9•b•d) =	0.86	N/mm²
z/d = ½ • [1 + (1 - 3.53•K)^½] =	0.87		$v_{Rd,c}$ =	0.83	N/mm²
As = M / (0.87•fy•z) =	2023	mm²	Cot(theta) =	2.5	Ok
As,min = 0.0015•b•d =	288	mm²	Asv/sv =	0.791	
Use B16 @	**75**	**ctrs**	**Use 4 Legs**	**B8**	**@ 200 ctrs.**
As prov =	2681	mm²	Actual Asv/sv =	1.005	
Satisfactory			**Satisfactory**		

Crack width (See Appendix)			Limiting Crack Width: Tightness Class 1		
w_k =	**0.06 mm**		Ht. water	0	mm
<	0.20	mm	Thickness	250	mm
Satisfactory			wk1	0.20	mm

Transverse Reinforcement

Provide Minimum Steel / 20% Main Steel

Slab:	240	mm thick, composite	**Use B10 @**	**150**	**ctrs**
As,min = 0.0015•b•d =	288	mm²/m	As prov =	524	mm²
20% Main Steel =	536	mm²/m	**Negligible, Satisfactory**		

5.3 Precast Slabs (No Openings)

Cover Slab consists 120mm precast slab + 120mm insitu concrete topping.

b: 1000

Eff. Span: 3325

<u>Details:</u>

Slab Consists:	120	Precast
	120	Insitu Topping

Width Considered:	1,000	mm
Width Supported:	1,000	mm
Effective Span:	3,325	mm

<u>Precast:</u>	f_{ckp}	40	N/mm²
	f_y	500	N/mm²

<u>Insitu:</u>	f_{cki}	30	N/mm²
	f_y	500	N/mm²

For design purposes of composite, take Fck as 30N/mm²

f_{ctm}	2.90	N/mm²
$A_{s,min}$	0.0015	b.d.

Permanent Loading: Slab is designed as simply supported but checked for continuous support moments over central walls:

h =	240	mm	<u>Surcharge:</u>			γ_{f_g}	1.35
C_nom =	30	mm	Assume w	40.8 kN/m²	+ 0.40m Ground	γ_{f_q}	1.5
						ψ_2	0.3

UDL =	(0.24 x 1 x 25 x 1.35) + (40.8 x 1 x 1.5) + (0.4 x 1 x 18 x 1.35)	
=	79 kN/m	25.4 kN/m (QP)

<u>Check Bending:</u>	Sag Moment: Mid Span			<u>Check Shear:</u>	@ d from support face	
M_{ult} =	79 x 3.325² / 8	M_{qp}		R_{max} =	79 x 3.325 / 2 =	**131.3** kN
=	**109.2** kNm	**35.1** kNm		V_{Ed} =	131.3 - (0.192+ 0.07) x 79 =	**110.6** kN

Midspan - Sagging

M_{ult}	109.2	kNm	f_{ck}	30	N/mm²	b	1000	mm	f_{ctm}	2.90	N/mm²
M_{qp}	35.1	kNm	f_y	500	N/mm²	d	192	mm	$A_{s,min}$	0.0015	b.d.
V_{max}	131.3	kN	V_{Ed}	110.6	kN						

<u>Moment:</u>			<u>Shear</u>		
$K = M / f_{ck} \cdot b \cdot d^2 =$	0.099		$v = V / (0.9 \cdot b \cdot d) =$	0.64	N/mm²
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{\frac{1}{2}}] =$	0.90		$v_{Rd,c} =$	0.76	N/mm²
$As = M / (0.87 \cdot f_y \cdot z) =$	1448	mm²	**No Links req.**		
$As,min = 0.0015 \cdot b \cdot d =$	288	mm²			
Use B16 @	**100**	**ctrs**			
As prov =	2011	mm²			
Satisfactory					

<u>Crack width (See Appendix)</u>			<u>Limiting Crack Width: Tightness Class 1</u>		
$w_k =$	**0.06**	**mm**	Ht. water	0	mm
<	0.20	mm	Thickness	250	mm
Satisfactory			wk1	0.20	mm

Transverse Reinforcement

Provide Minimum Steel / 20% Main Steel

	Slab:	240	mm thick, composite	**Use B10 @**	**150**	**ctrs**
$As,min = 0.0015 \cdot b \cdot d =$		288	mm²	As prov =	524	mm²
20% Main Steel =		402	mm²	**Satisfactory**		

F.P. McCann
Bullhurst Lane
Weston Underwood
Derbyshire , DE6 4PH

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By: PM   Chk: Sheet: **19 of 38**

Contract Name: Skelmanthorpe, Saville Road
Contract Number: 05-BYL-xxxx
Client: Lovell Homes
Reference: Attenuation Tank

5.4 Insitu Topping, Hogging over supports

Cover Slab consists 120mm precast slab + -120mm insitu concrete topping.
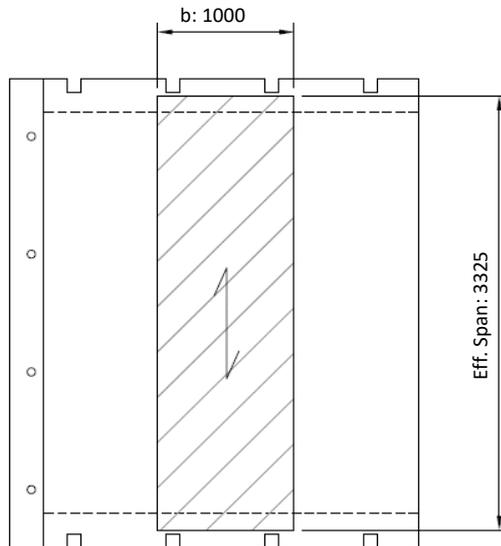
b: 1000

Eff. Span: 3325

Details:

| Slab Consists: | 120 | Precast |
| | 120 | Insitu Topping |

Width Considered:	1,000	mm
Width Supported:	1,000	mm
Effective Span:	3,325	mm

| Insitu: | f_{cki} | 30 | N/mm² |
| | f_y | 500 | N/mm² |

For design purposes of composite, take Fck as 30N/mm²

| f_{ctm} | 2.90 | N/mm² |
| $A_{s,min}$ | 0.0015 | b.d. |

Permanent Loading:

h =	240	mm	Surcharge:				γ_{f_g}	1.35
C_nom =	45	mm	Assume w	40.8	kN/m²	+ 0.40m Ground	γ_{f_q}	1.5
							ψ_2	0.3

UDL =   (0.24 x 1 x 25 x 1.35) + (40.8 x 1 x 1.5) + (0.4 x 1 x 18 x 1.35)
=   79 kN/m   25.4 kN/m (QP)

Provide minimum reinforcement to top of slab as mesh, with additional loose rebar over joints for hogging.

Slab:	240	mm thick, composite	**Use B10 @**	**200**	**ctrs**
As,min = 0.0015•b•d =	281	mm²	As prov =	393	mm²
			Satisfactory		

Check Bending: Hog Moment: Supports

| M_{ult} = | 79 x 3.325² / 10 | | M_{qp} | |
| = | **87.3** | kNm | **28.1** | kNm |

Supports: Hogging

| M_{ult} | 87.3 | kNm | f_{ck} | 30 | N/mm² | b | 1000 | mm | f_{ctm} | | 2.90 | N/mm² |
| M_{qp} | 28.1 | kNm | f_y | 500 | N/mm² | d | 187 | mm | $A_{s,min}$ | | 0.0015 | b.d. |

Moment:

$K = M / f_{ck}•b•d^2$ =	0.083
$z/d = \frac{1}{2} • [1 + (1 - 3.53•K)^{1/2}]$ =	0.92
$A_s = M / (0.87•f_y•z)$ =	1167	mm²
$A_{s,min} = 0.0015•b•d$ =	281	mm²
Use B10 @	**200**	**ctrs**	(Mesh)
and B16 @	**200**	**ctrs**	(Additional @ Supports)
As prov =	1398	mm²
Satisfactory		

Crack width (See Appendix)		Limiting Crack Width: Tightness Class 1	
w_k =	**0.08 mm**	Ht. water	0	mm
<	0.20 mm	Thickness	250	mm
Satisfactory		wk1	0.20	mm

		Version: 01/11/2022	05-May-23	**F.P. McCann**
Contract Name:	Skelmanthorpe, Saville Road			Bullhurst Lane
Contract Number:	05-BYL-xxxx		Rev: P-01	Weston Underwood
Client:	Lovell Homes			Derbyshire , DE6 4PH
Reference:	Attenuation Tank		By: PM	Chk:	Sheet: **20 of 38**

5.5 Precast Slabs, Temporary Loading

Cover Slab consists 120mm precast slab

b: 1000
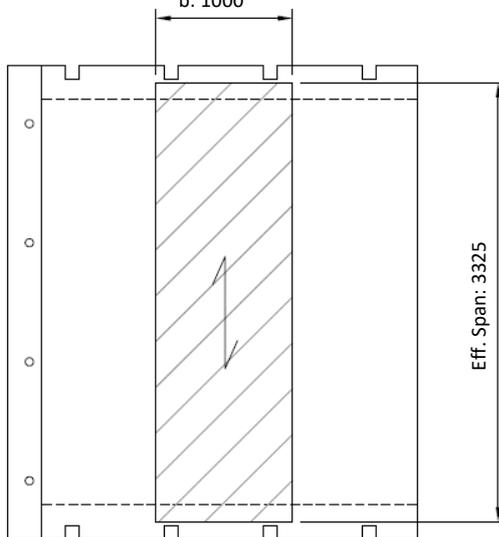
Eff. Span: 3325

Details:

Slab Consists:	120	Precast
Width Considered:	1,000	mm
Width Supported:	1,000	mm
Effective Span:	3,325	mm

Precast:
f_{ckp} = 40 N/mm²
f_y = 500 N/mm²

For design purposes of composite, take Fck as 40N/mm²
f_{ctm} = 3.51 N/mm²
$A_{s,min}$ = 0.0018 b.d.

Temporary Loading: Slab is designed as simply supported

Supporting 120mm wet concrete plus nominal construction loading of 5kN/m²

h =	120 mm	Surcharge:			γ_{f_g}	1.35
C_nom =	30 mm	Assume w	5.0 kN/m²	+ 0.12m Wet Conc.	γ_{f_q}	1.5

UDL = (0.12 x 1 x 25 x 1.35) + (5 x 1 x 1.5) + (0.12 x 1 x 26 x 1.35)

= 15.8 kN/m

Check Bending:	Sag Moment: Mid Span	Check Shear:	@ d from support face	
M_{ult} =	15.8 x 3.325² / 8	R_{max} =	15.8 x 3.325 / 2 =	**26.3** kN
=	**21.8** kNm	V_{Ed} =	26.3 - (0.072+ 0.07) x 15.8 =	**24.1** kN

Midspan - Sagging

M_{ult}	21.8 kNm	f_{ck}	40 N/mm²	b	1000 mm	f_{ctm}	3.51 N/mm²
V_{max}	26.3 kN	f_y	500 N/mm²	d	72 mm	$A_{s,min}$	0.0018 b.d.
V_{Ed}	24.1 kN						

Moment:		Shear	
$K = M / f_{ck} \cdot b \cdot d^2$ =	0.105	$v = V / (0.9 \cdot b \cdot d)$ =	0.37 N/mm²
$z/d = \frac{1}{2} \cdot [1 + (1 - 3.53 \cdot K)^{\frac{1}{2}}]$ =	0.90	$v_{Rd,c}$ =	1.03 N/mm²
$A_s = M / (0.87 \cdot f_y \cdot z)$ =	777 mm²	**No Links req.**	
$A_{s,min} = 0.0018 \cdot b \cdot d$ =	130 mm²		
Use B16 @	**100** ctrs		
As prov =	2011 mm²		
Satisfactory			

5.6 Horizontal Shear   (Designed in line with BS8110)

Prestressed Slab Units

Insitu Cube Strength	37	N/mm²
Section Width Considered	1500	mm
Depth to interface	120	mm
Depth to N.A. (x)	56.9	mm
Interface in tension zone		
Required Ultimate M_R	173.6	kNm
Max M_R for full connection	214.9	kNm
Factor, M_{Rreq} / M_{Rprov}	0.808	
Design Horizontal Shear Force		
(0.45•1.5•0.9•56.87•37) • 0.808	**1033**	kN

Slab Span 3325 mm

Dist. between points of min & max Mt. 1662.5 mm

Average design shear stress

1033•1000 / (1662.5•1500)   **0.41** N/mm²

Design shear stress at d from support face   **0.70** N/mm²
(250mm from bearing)
Without links, max design shear stress   **0.75** N/mm²   **Satisfactory**

R/C Slab Units

Insitu Cube Strength	37	N/mm²
Section Width Considered	1000	mm
Depth to interface	120	mm
Lever Arm z	173	mm
Depth to N.A. (x)	42.1	mm
Interface in compression zone		
Design Horizontal Shear Force		
(0.45•37•1000•0.9•42.1 / 1000	**631**	kN

Slab Span 3325 mm

Dist. between points of min & max Mt. 1662.5 mm

Average design shear stress

631•1000 / (1662.5•1000)   **0.38** N/mm²

Design shear stress at d from support face   **0.64** N/mm²
(250mm from bearing)
Without links, max design shear stress   **0.75** N/mm²   **Satisfactory**

Table 5.5 — Design ultimate horizontal shear stresses at interface

Precast unit	Surface type	Strength class of in-situ concrete		
		C20/25	C25/30	C32/40 and over
Without links	As-cast or as-extruded	0.4	0.55	0.65
	Brushed, screeded or rough-tamped	0.6	0.65	0.75
	Washed to remove laitance or treated with retarder and cleaned	0.7	0.75	0.80
With nominal links projecting into in-situ concrete	As-cast or as-extruded	1.2	1.8	2.0
	Brushed, screeded or rough-tamped	1.8	2.0	2.2
	Washed to remove laitance or treated with retarder and cleaned	2.1	2.2	2.5

NOTE 1   The description "as-cast" covers those cases where the concrete is placed and vibrated leaving a rough finish. The surface is rougher than would be required for finishes to be applied directly without a further finishing screed but not as rough as would be obtained if tamping, brushing or other artificial roughening had taken place.

NOTE 2   The description "as-extruded" covers those cases in which an open-textured surface is produced direct from an extruding machine.

NOTE 3   The description "brushed, screeded or rough-tamped" covers those cases where some form of deliberate surface roughening has taken place but not to the extent of exposing the aggregate.

NOTE 4   For structural assessment purposes, it may be assumed that the appropriate value of γ_m included in the table is 1.5.

6. FLOATATION

Floatation is checked in the ULS based on BS EN 1997-1
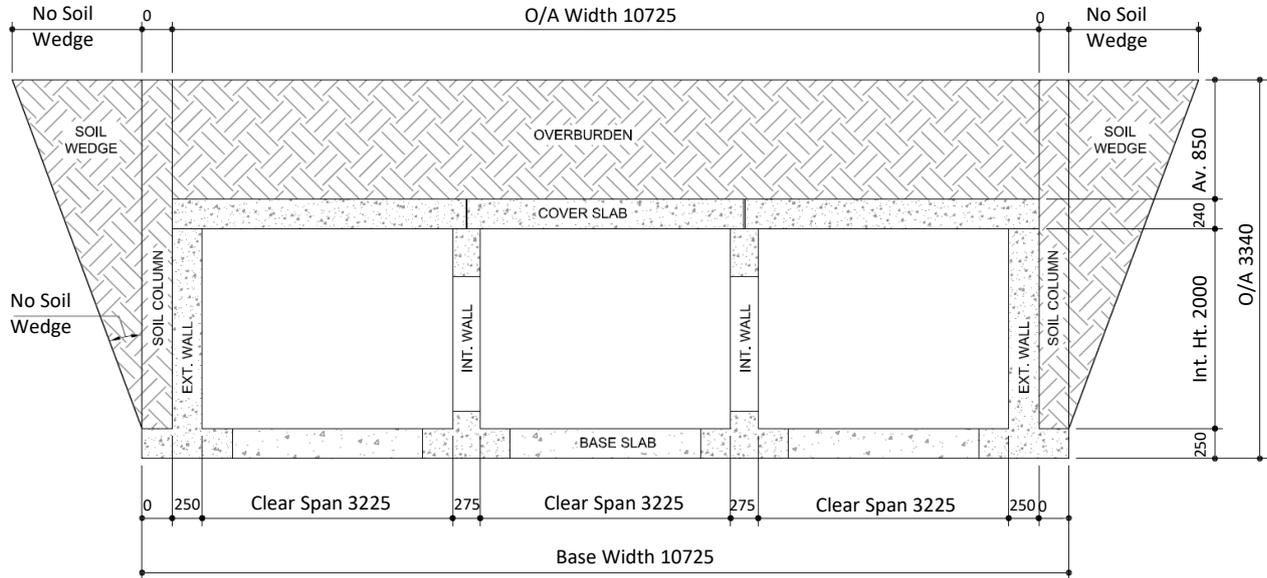
Consider entire tank: Allow   0 mm toe

Element	Length (mm)	Width (mm)	Height (mm)	Volume (m³)	Density (kN/m³)	Total Wt. (kN/m)	
Av. Overburden	12,300	10,725	850	112.13	18	2018.34	
Cover Slab	12,300	10,725	240	31.66	25	791.51	
External Walls	45,050	250	2,000	22.53	25	563.13	
Internal Walls x 2	23,600	275	2,000	9.41	25	235.25	(Adjusted for openings)
Soil Column	46,050	0	3,090	0.00	18	0.00	
Soil Wedge	46,050	Av. 0	3,090	0.00	8	0.00	
Base Slab	12,300	10,725	250	32.98	25	824.48	
Total						4432.7	

For favourable actions γ =   0.9   **Net**   **3989.4** kN

Consider water table at 250mm above cover slab
(i.e. at 150mm below minimum ground level)

hw =   2.74 m

Uplift = 2.74 x 10 x 12.3 x 10.725

=   3614.5 kN

For unfavourable actions γ =   1.1   **Net**   **3976.0** kN

3976 < 3989.4   **Therefore satisfactory**

Note: To ensure the tank does not become buoyant, the ground water level must not exceed the levels indicated above.
Additional drainage may be required, this is not the responsibility of FP McCann

APPENDIX A:
CRACK WIDTH CALCULATION TO BS EN 1991-1: 2004
EXTERNAL WALLS

		2A) External Walls: Outer Face (At Base)	2B) External Walls: Inner Face (Mid Height)	2C) External Walls: Inner Face (At Base)		
Concrete	f_{ck}	40	40	40		
Steel	f_{yk}	500	500	500		
Section width	b	1000	1000	1000		
Section height	h	250	250	250		
QP moment	M	14.0	10.3	4.0		
Age at cracking	=	14	14	14		
Cement type	=	R	R	R		
Creep factor	ϕ	2	2	2		
Area of tension steel	A_s	524	524	524		
Depth to tension steel	d	205	205	205		
Area of comp steel	A_{s2}	0	0	0		
Depth to compression steel	d_2	0	0	0		
Max tension bar c/c	S	150	150	150		
Max tension bar dia	$\emptyset_{eq}$	10	10	10		
Short term or long term		L	L	L		
Cover to As	c	40	40	40		
modulus of elasticity of concrete = $22[(fck+8)/10]^{0.3}$	E_{cm}	35.2	35.2	35.2		(Table 3.1)
moduli of elasticity of steel	E_s	200.0	200.0	200.0		
Modular ratio	α_e	17.04	17.04	17.04		
mean concrete strength at cracking	$f_{cm,t}$	44.18	44.18	44.18		Table 3.1 & equation (3.4)
mean concrete tensile strength	$f_{ct,eff}$	3.23	3.23	3.23		Table 3.1
fully cracked neutral axis depth $(-A_s\alpha_e-A_{s2}(\alpha_e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{-A_s\alpha_e d-A_{s2}d_2(\alpha_e-1)\}]^{\frac{1}{2}})/b$	x_c	52.2	52.2	52.2		
concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$	σ_c	2.87 ✔	2.11 ✔	0.82 ✔		✔ Denotes $\sigma_c < 0.6f_{ck}$
stress in tension steel = $\sigma c \cdot \alpha e(d-x)/x$	σ_s	143.03 ✔	104.98 ✔	40.72 ✔		✔ Denotes $\sigma_s < 0.8f_{yk}$
effective tension area = $min[2.5(h-d), (h-x)/3, h/2]b - A_s$	$A_{c,eff}$	65407	65407	65407		7.3.2 (3)
$A_s/A_{c,eff}$	$\rho_{p,eff}$	0.0080	0.0080	0.0080		7.3.4 (2)
max final crack spacing $IF(S>5(C+\emptyset/2),1.3(h-x),k_3C+k_1k_2k_4\emptyset/\rho_{p,eff})$	$s_{r,max}$	279.3	279.3	279.3		Equations (7.11) & (7.14)
average strain for crack width calculation	$\varepsilon_{sm}-\varepsilon_{cm}$	429.1	314.9	122.2		Equation (7.9) & PD 6687
CALCULATED CRACK WIDTH	W_k	**0.12**	**0.09**	**0.03**		Equation (7.8)
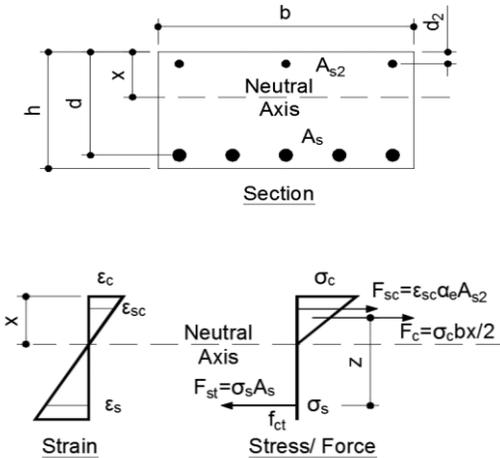
Version: 01/11/2022

	F.P. McCann
05-May-23	Bullhurst Lane
Rev: P-01	Weston Underwood
	Derbyshire , DE6 4PH
By: PM	Chk:	Sheet: **24 of 38**

Contract Name:	Skelmanthorpe, Saville Road
Contract Number:	05-BYL-xxxx
Client:	Lovell Homes
Reference:	Attenuation Tank

APPENDIX A: CRACK WIDTH CALCULATION TO BS EN 1991-1: 2004 INTERNAL WALLS		3A) Internal Walls: Top Beam, Hogging	3B) Internal Walls: Top Beam, Sagging	3C) Internal Walls: Bottom Beam, Hogging	3D) Internal Walls: Bottom Beam, Sagging	
Concrete	f_{ck}	40	40	40	40	
Steel	f_{yk}	500	500	500	500	
Section width	b	275	275	775	775	
Section height	h	475	475	250	250	
QP moment	M	21.5	10.8	21.5	10.8	
Age at cracking	=	14	14	14	14	
Cement type	=	R	R	R	R	
Creep factor	ϕ	2	2	2	2	
Area of tension steel	A_s	628	402	1206	679	
Depth to tension steel	d	427	429	204	206	
Area of comp steel	A_{s2}	0	0	0	0	
Depth to compression steel	d_2	0	0	0	0	
Max tension bar c/c	S	167	167	133.4	133.4	
Max tension bar dia	$\varnothing_{eq}$	20	16	16	12	
Short term or long term		L	L	L	L	
Cover to As	c	38	38	38	38	
modulus of elasticity of concrete = $22[(fck+8)/10]^{0.3}$	E_{cm}	35.2	35.2	35.2	35.2	(Table 3.1)
moduli of elasticity of steel	E_s	200.0	200.0	200.0	200.0	
Modular ratio	α_e	17.04	17.04	17.04	17.04	
mean concrete strength at cracking	$f_{cm,t}$	44.18	44.18	44.18	44.18	Table 3.1 & equation (3.4)
mean concrete tensile strength	$f_{ct,eff}$	3.23	3.23	3.23	3.23	Table 3.1
fully cracked neutral axis depth $(-A_s\alpha_e-A_{s2}(\alpha_e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{-A_s\alpha_e d-A_{s2}d_2(\alpha_e-1)\}]^{\frac{1}{2}})/b$	x_c	147.5	123.4	80.8	64.9	
concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$	σ_c	2.81 ✔	1.64 ✔	3.88 ✔	2.32 ✔	✔ Denotes $\sigma_c < 0.6f_{ck}$
stress in tension steel = $\sigma c \cdot \alpha e(d-x)/x$	σ_s	90.56 ✔	68.99 ✔	100.66 ✔	86.01 ✔	✔ Denotes $\sigma_s < 0.8f_{yk}$
effective tension area = min[2.5(h-d), (h-x)/3, h/2]b - A_s	$A_{c,eff}$	29392	31223	42497	47143	7.3.2 (3)
$A_s / A_{c,eff}$	$\rho_{p,eff}$	0.0214	0.0129	0.0284	0.0144	7.3.4 (2)
max final crack spacing IF(S>5(C+Ø/2),1.3(h-x),k_3C+$k_1$$k_2$$k_4$Ø/$\rho_{p,eff}$)	$s_{r,max}$	236.6	271.8	193.9	224.9	Equations (7.11) & (7.14)
average strain for crack width calculation	ε_{sm}-ε_{cm}	271.7	207.0	302.0	258.0	Equation (7.9) & PD 6687
CALCULATED CRACK WIDTH	W_k	**0.06**	**0.06**	**0.06**	**0.06**	Equation (7.8)

Version: 01/11/2022

Contract Name:	Skelmanthorpe, Saville Road	05-May-23	**F.P. McCann**
Contract Number:	05-BYL-xxxx		Bullhurst Lane
Client:	Lovell Homes	Rev: P-01	Weston Underwood
Reference:	Attenuation Tank		Derbyshire , DE6 4PH
		By: PM Chk: Sheet:	**25 of 38**

APPENDIX A:
CRACK WIDTH CALCULATION TO BS EN 1991-1: 2004
BASE SLAB

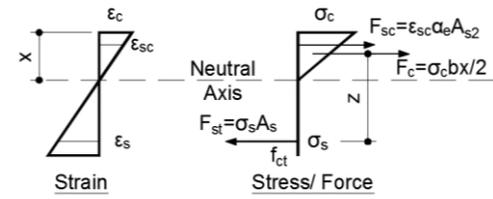|		4B) Base Slab: Hogging under internal wall edges:	4A) Base Slab: Hogging under internal wall midpoint:	4C) Base Slab: Sag Mt. @ Ext Wall Proj.	4D) Base Slab: Sagging in Insitu	
Concrete	f_{ck}	40	30	30	30	
Steel	f_{yk}	500	500	500	500	
Section width	b	1000	1000	1000	1000	
Section height	h	250	250	250	250	
QP moment	M	12.5	19.1	5.2	11.8	
Age at cracking	=	14	14	14	14	
Cement type	=	R	R	R	R	
Creep factor	φ	2	2	2	2	
Area of tension steel	A_s	785	1178	785	785	
Depth to tension steel	d	190	190	190	190	
Area of comp steel	A_{s2}	0	0	0	0	
Depth to compression steel	d_2	0	0	0	0	
Max tension bar c/c	S	100	66.66667	100	100	
Max tension bar dia	$\varnothing_{eq}$	10	10	10	10	
Short term or long term		L	L	L	L	
Cover to As	c	55	55	55	55	
modulus of elasticity of concrete = $22[(fck+8)/10]^{0.3}$	E_{cm}	35.2	32.8	32.8	32.8	(Table 3.1)
moduli of elasticity of steel	E_s	200.0	200.0	200.0	200.0	
Modular ratio	α_e	17.04	18.27	18.27	18.27	
mean concrete strength at cracking	$f_{cm,t}$	44.18	34.98	34.98	34.98	Table 3.1 & equation (3.4)
mean concrete tensile strength	$f_{ct,eff}$	3.23	2.67	2.67	2.67	Table 3.1
fully cracked neutral axis depth $(-A_s\alpha_e-A_{s2}(\alpha_e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{-A_s\alpha_e d-A_{s2}d_2(\alpha_e-1)\}]^{\frac{1}{2}})/b$	x_c	59.2	71.4	60.9	60.9	
concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$	σ_c	2.47 ✔	3.22 ✔	1.00 ✔	2.29 ✔	✔ Denotes $\sigma_c < 0.6f_{ck}$
stress in tension steel = $\sigma c \cdot \alpha e(d-x)/x$	σ_s	93.13 ✔	97.78 ✔	38.91 ✔	88.59 ✔	✔ Denotes $\sigma_s < 0.8f_{yk}$
effective tension area = $min[2.5(h-d), (h-x)/3, h/2]b - A_s$	$A_{c,eff}$	62825	58341	62255	62255	7.3.2 (3)
$A_s/A_{c,eff}$	$\rho_{p,eff}$	0.0125	0.0202	0.0126	0.0126	7.3.4 (2)
max final crack spacing $IF(S>5(C+\varnothing/2),1.3(h-x),k_3C+k_1k_2k_4\varnothing/\rho_{p,eff})$	$s_{r,max}$	278.8	243.8	278.0	278.0	Equations (7.11) & (7.14)
average strain for crack width calculation	$\varepsilon_{sm}-\varepsilon_{cm}$	279.4	293.3	116.7	265.8	Equation (7.9) & PD 6687
CALCULATED CRACK WIDTH	W_k	**0.08**	**0.07**	**0.03**	**0.07**	Equation (7.8)
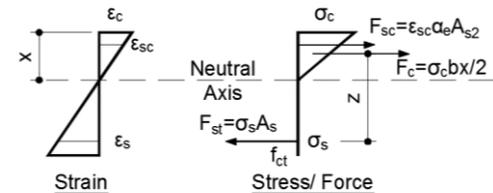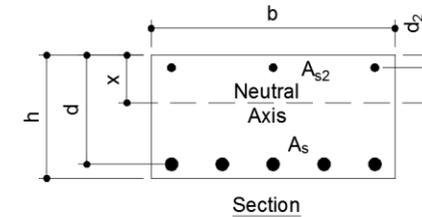
| APPENDIX A: CRACK WIDTH CALCULATION TO BS EN 1991-1: 2004 COVER SLAB		4E) Base Slab: Sagging in Insitu - DWF	5.2 Precast Slabs (With opening) Sagging	5.3 Precast Slabs (No Openings) Sagging	5.4 Insitu Topping, Hogging over supports	
Concrete	f_{ck}	30	30	30	30	
Steel	f_{yk}	500	500	500	500	
Section width	b	1000	1000	1,000	1000	
Section height	h	200	240	240	240	
QP moment	M	11.8	47.0	35.1	28.1	
Age at cracking	=	14	14	14	14	
Cement type	=	R	R	R	R	
Creep factor	ϕ	2	2	2	2	
Area of tension steel	A_s	1131	2681	2011	1398	
Depth to tension steel	d	149	192	192	187	
Area of comp steel	A_{s2}	0	0	0	0	
Depth to compression steel	d_2	0	0	0	0	
Max tension bar c/c	S	100	75	100	200	
Max tension bar dia	$\varnothing_{eq}$	12	16	16	16	
Short term or long term		L	L	L	L	
Cover to As	c	45	40	40	45	
modulus of elasticity of concrete = $22[(fck+8)/10]^{0.3}$	E_{cm}	32.8	32.8	32.8	32.8	(Table 3.1)
moduli of elasticity of steel	E_s	200.0	200.0	200.0	200.0	
Modular ratio	α_e	18.27	18.27	18.27	18.27	
mean concrete strength at cracking	$f_{cm,t}$	34.98	34.98	34.98	34.98	Table 3.1 & equation (3.4)
mean concrete tensile strength	$f_{ct,eff}$	2.67	2.67	2.67	2.67	Table 3.1
fully cracked neutral axis depth $(-A_s\alpha_e-A_{s2}(\alpha_e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{-A_s\alpha_e d-A_{s2}d_2(\alpha_e-1)\}]^{\frac{1}{2}})/b$	x_c	60.5	96.7	87.6	75.5	
concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$	σ_c	3.03 ✔	6.09 ✔	4.92 ✔	4.60 ✔	✔ Denotes $\sigma_c < 0.6f_{ck}$
stress in tension steel = $\sigma c \cdot \alpha e(d-x)/x$	σ_s	81.04 ✔	109.72 ✔	107.23 ✔	124.20 ✔	✔ Denotes $\sigma_s < 0.8f_{yk}$
effective tension area = $min[2.5(h-d), (h-x)/3, h/2]b - A_s$	$A_{c,eff}$	45374	45102	48793	53442	7.3.2 (3)
$A_s / A_{c,eff}$	$\rho_{p,eff}$	0.0249	0.0594	0.0412	0.0262	7.3.4 (2)
max final crack spacing $IF(S>5(C+\varnothing/2),1.3(h-x),k_3C+k_1k_2k_4\varnothing/\rho_{p,eff})$	$s_{r,max}$	208.2	166.9	180.6	223.2	Equations (7.11) & (7.14)
average strain for crack width calculation	$\varepsilon_{sm}-\varepsilon_{cm}$	243.1	361.5	321.7	372.6	Equation (7.9) & PD 6687
CALCULATED CRACK WIDTH	W_k	**0.05**	**0.06**	**0.06**	**0.08**	Equation (7.8)
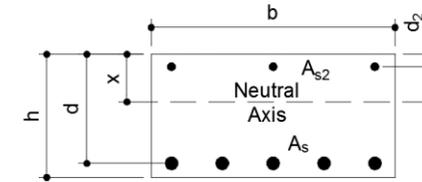
APPENDIX B - LIVE LOADING

Tank is designed to suit most onerous case of:

a) 10kN/m² as a UDL

b) 38 tonne, five axle articulated - designation 5A-H, in line with table NA.5 in the UK National Annex to BS EN 1991-2:2003 (Traffic loads on bridges)

c) Accidental vehicle in line with cl. 5.6.3 in BS EN 1991-2:2003 (Traffic loads on bridges)

38 tonne 5 Axle articulated designation 5A-H
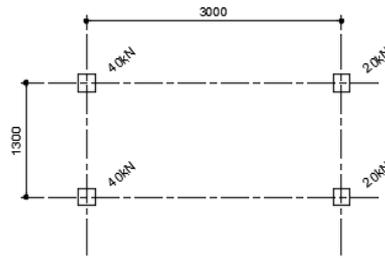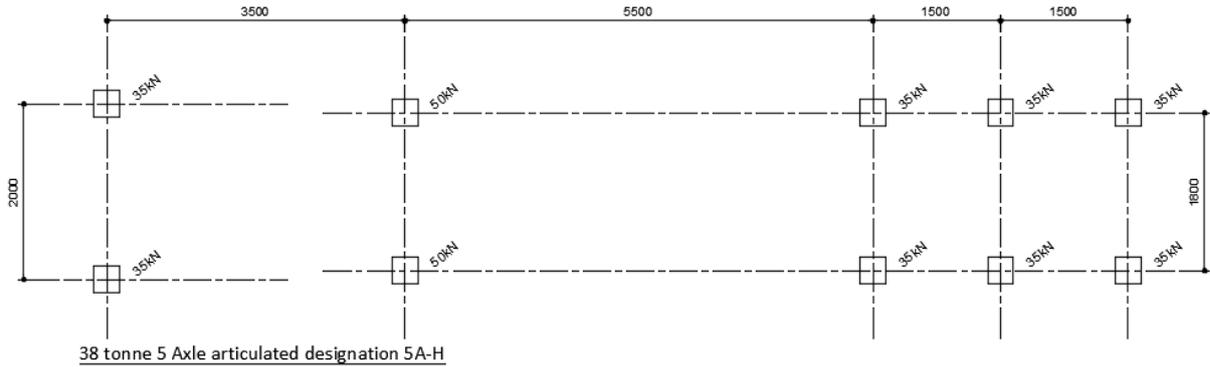
Accidental

Consider 38 tonne vehicle:

Assume wheel loads are distributed through fill, and act as UDL on cover slab

Most onerous section being either the central 50kN wheels or the end 35kN wheels.
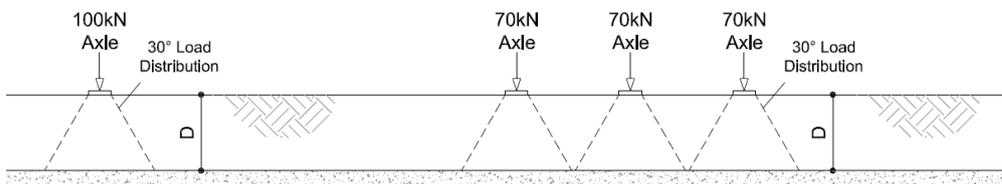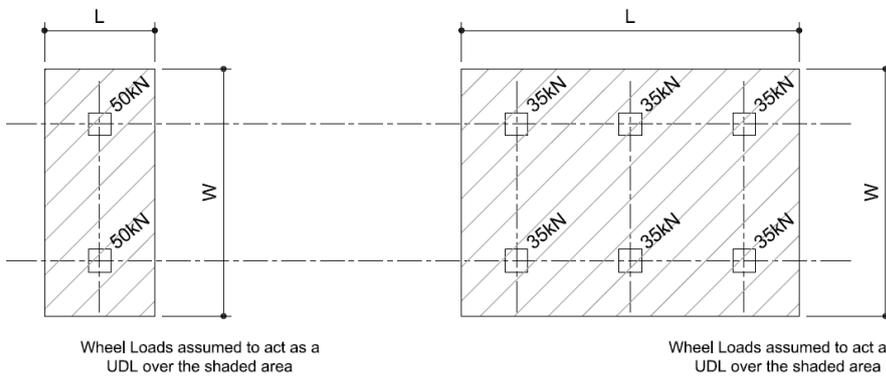
Wheel Loads assumed to act as a UDL over the shaded area

Wheel Loads assumed to act as a UDL over the shaded area

Version: 01/11/2022

F.P. McCann
Bullhurst Lane
Weston Underwood
Derbyshire , DE6 4PH

Contract Name: Skelmanthorpe, Saville Road
Contract Number: 05-BYL-xxxx
Client: Lovell Homes
Reference: Attenuation Tank

05-May-23

Rev: P-01

By: PM   Chk: Sheet: **28 of 38**

<u>Consider depths of cover between 300mm and 1500mm in 100mm increments.</u>   Roof Unit Width Considered: 1.00 m

Depth (mm)	Ground (kN/m²)	50kN Wheels:				35kN Wheels:			
		L (m)	W (m)	UDL (kN/m²)	Total (kN/m²)	L (m)	W (m)	UDL (kN/m²)	Total (kN/m²)
300	5.4	1.00	2.45	40.88	46.28	3.65	2.45	23.54	28.94
400	7.2	1.00	2.56	39.03	46.23	3.76	2.56	21.79	28.99
500	9.0	1.00	2.68	37.35	46.35	3.88	2.68	20.23	29.23
600	10.8	1.00	2.79	35.81	46.61	3.99	2.79	18.83	29.63
700	12.6	1.11	2.91	31.02	43.62	4.11	2.91	17.58	30.18
800	14.4	1.22	3.02	27.02	41.42	4.22	3.02	16.44	30.84
900	16.2	1.34	3.14	23.79	39.99	4.34	3.14	15.42	31.62
1000	18.0	1.45	3.25	21.12	39.12	4.45	3.25	14.48	32.48
1100	19.8	1.57	3.37	18.90	38.70	4.57	3.37	13.63	33.43
1200	21.6	1.69	3.49	17.02	38.62	4.69	3.49	12.86	34.46
1300	23.4	1.80	3.60	15.42	38.82	4.80	3.60	12.15	35.55
1400	25.2	1.92	3.72	14.04	39.24	4.92	3.72	11.49	36.69
1500	27.0	2.03	3.83	12.84	39.84	5.03	3.83	10.89	37.89

Similarly for the accidental vehicle

Uniform Surchage 10kN/m²

	Depth (mm)	Ground (kN/m²)	40kN Wheels:			
			L (m)	W (m)	UDL (kN/m²)	Total (kN/m²)
	300	5.4	1.00	1.85	43.33	48.73
*	400	7.2	1.00	1.96	40.78	47.98
	500	9.0	1.00	2.08	38.51	47.51
	600	10.8	1.00	2.19	36.48	47.28
	700	12.6	1.01	2.31	34.37	46.97
	800	14.4	1.12	2.42	29.37	43.77
	900	16.2	1.24	2.54	25.42	41.62
	1000	18.0	1.35	2.65	22.24	40.24
	1100	19.8	1.47	2.77	19.64	39.44
	1200	21.6	1.59	2.89	17.48	39.08
*	1300	23.4	1.70	3.00	15.67	39.07
	1400	25.2	1.82	3.12	14.13	39.33
	1500	27.0	1.93	3.23	12.81	39.81

Depth (mm)	Ground (kN/m²)	Live (kN/m²)	Total (kN/m²)
300	5.4	10.00	15.40
400	7.2	10.00	17.20
500	9.0	10.00	19.00
600	10.8	10.00	20.80
700	12.6	10.00	22.60
800	14.4	10.00	24.40
900	16.2	10.00	26.20
1000	18.0	10.00	28.00
1100	19.8	10.00	29.80
1200	21.6	10.00	31.60
1300	23.4	10.00	33.40
1400	25.2	10.00	35.20
1500	27.0	10.00	37.00

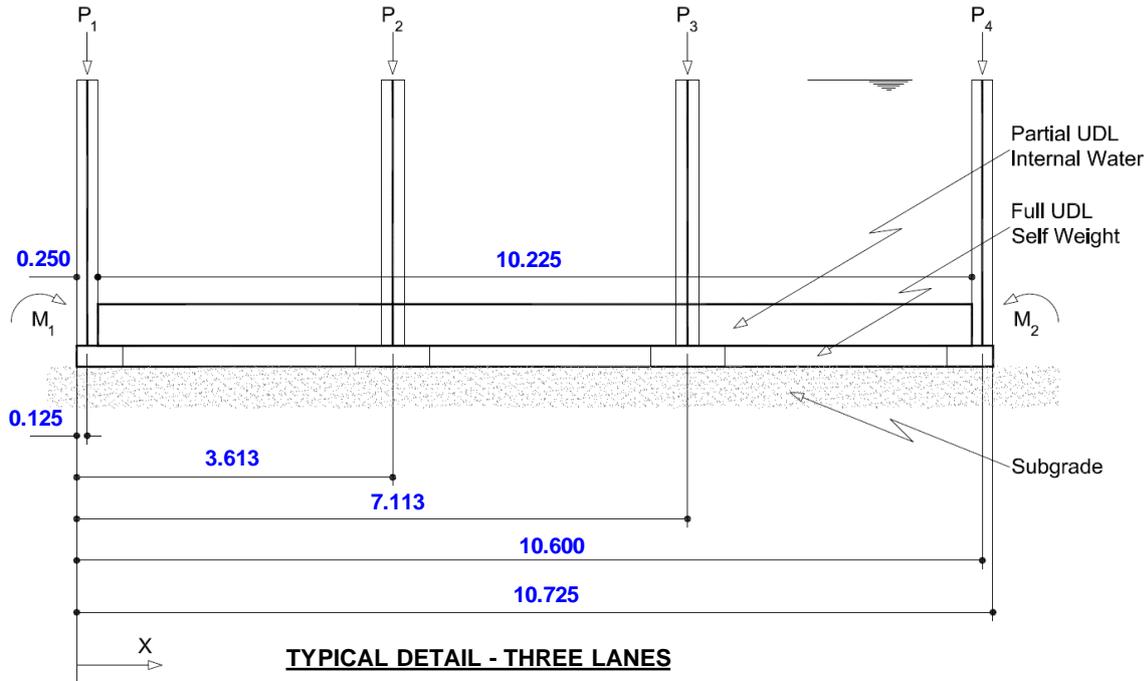For the maximum chosen depth of 1300mm the most onerous loading is:
Ground: 23.4 kN/m²
Surcharge: 15.7 kN/m²   Accidental Vehicle
Total: 39.1 kN/m²

This scenario used for:
Horizontal Loading

For the minimum chosen depth of 400mm the most onerous loading is:
Ground: 7.2 kN/m²
Surcharge: 40.8 kN/m²   Accidental Vehicle
Total: 48.0 kN/m²

This scenario used for:
Vertical Loading

Version: 01/11/2022

05-May-23	**F.P. McCann**
	Bullhurst Lane
Rev: P-01	Weston Underwood
	Derbyshire , DE6 4PH
By: PM	Chk:	Sheet: **29 of 38**

Contract Name:	Skelmanthorpe, Saville Road
Contract Number:	05-BYL-xxxx
Client:	Lovell Homes
Reference:	Attenuation Tank

APPENDIX C1

BEAM ON ELASTIC FOUNDATION - ULTIMATE LOADS   **0.4m Fill + 40.8kN/m² surcharge**

TYPICAL DETAIL - THREE LANES

Plate Data:

Int. Height, H =	2.000	m
Length, L =	10.725	m
Width, B =	1.000	m
Thickness, T =	0.250	m
Modulus, E =	15000	MPa
Subgrade, ks =	25000	kN/m³

Uniform Loads:

Full Uniform:		
Self Weight =	8.4	
Partial UDL: (Internal Water:)		
Start x =	0.250	
End x =	10.475	
Load w =	24.0	kN/m

Point Loads and Moments:

x (m)	P (kN)	M (kNm)
0.125	P1= 110.6	M1 =-20.1
3.613	P2= 304.2	-
7.113	P3= 304.2	-
10.600	P4= 110.6	M2= 20.1
-	-	-

Beam Flexibility Criteria:

for β•L <= π/4	beam is rigid
for π/4 < β•L < π	beam is semi-rigid
for β•L >= π	beam is flexible
for β*L >= 6	beam is semi-infinite long

Inertia, I =	0.00130	m⁴ I = B•T³/12
β =	0.752	β = ((ks•B)/(4•E•I))^{0.25}
β•L =	8.066	β•L = Flexibility Factor

Beam is semi-infinite long

Max. Shears and Locations:

V(max) =	114.32	kN @ x =	6.73	m
V @ d - int	95.56	kN @ x =	6.54	m
V@ d- ext	66.99	kN @ x =	10.29	m

Max. Moments and Locations:

+M(max) =	60.12	kNm @ x =	3.61	m
M @ Int. wall centre=	60.12	kNm @ x =	3.61	m
M @ Int. wall edge=	39.25	kNm @ x =	3.23	m
M @ Ext Wall Proj =	-23.75	kNm @ x =	0.80	m
-M(max) =	-39.51	kNm @ x =	1.61	m

Max. Deflection and Location:

Δ(max) =	-5.5	mm @ x =	3.65	m

Soil Pressures, Locations, and %Brg. Area:

Q(max) =	136.8	kPa @ x =	3.65	m
Q(min) =	80.9	kPa @ x =	1.61	m
%Brg. Area =	100.0	%		

Satisactory

Version: 01/11/2022

Contract Name:	Skelmanthorpe, Saville Road	05-May-23	**F.P. McCann**
Contract Number:	05-BYL-xxxx		Bullhurst Lane
Client:	Lovell Homes	Rev: P-01	Weston Underwood
Reference:	Attenuation Tank		Derbyshire , DE6 4PH

By: PM | Chk: | Sheet: **30 of 38**

Shear Diagram

Moment Diagram

Bearing Pressure Diagram

Version: 01/11/2022

	Contract Name:	Skelmanthorpe, Saville Road	05-May-23
	Contract Number:	05-BYL-xxxx	
	Client:	Lovell Homes	Rev: P-01
	Reference:	Attenuation Tank	
			By: PM	Chk:	Sheet: **31 of 38**

F.P. McCann
Bullhurst Lane
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Derbyshire , DE6 4PH
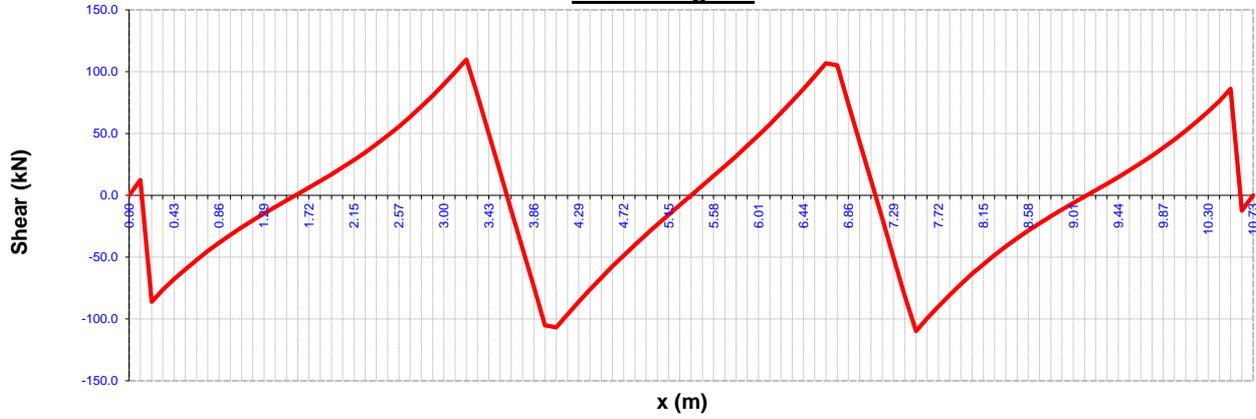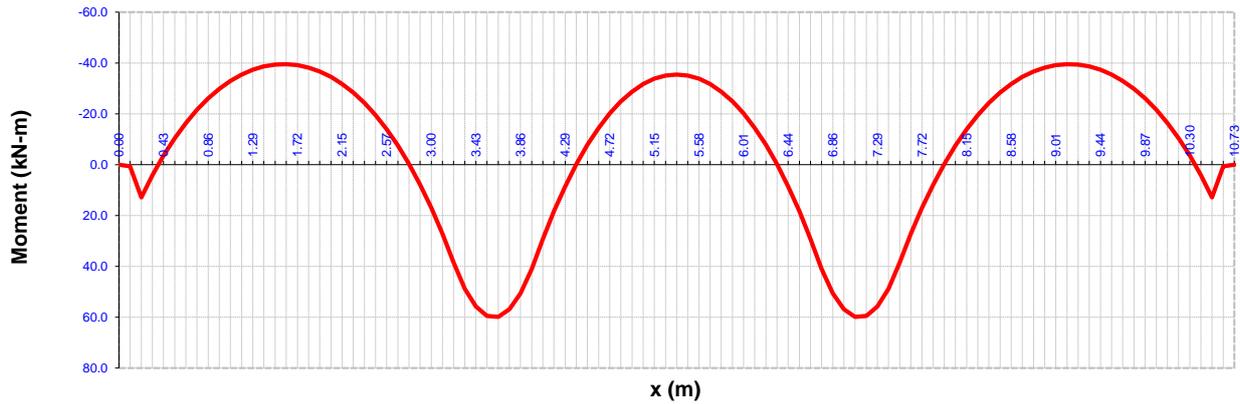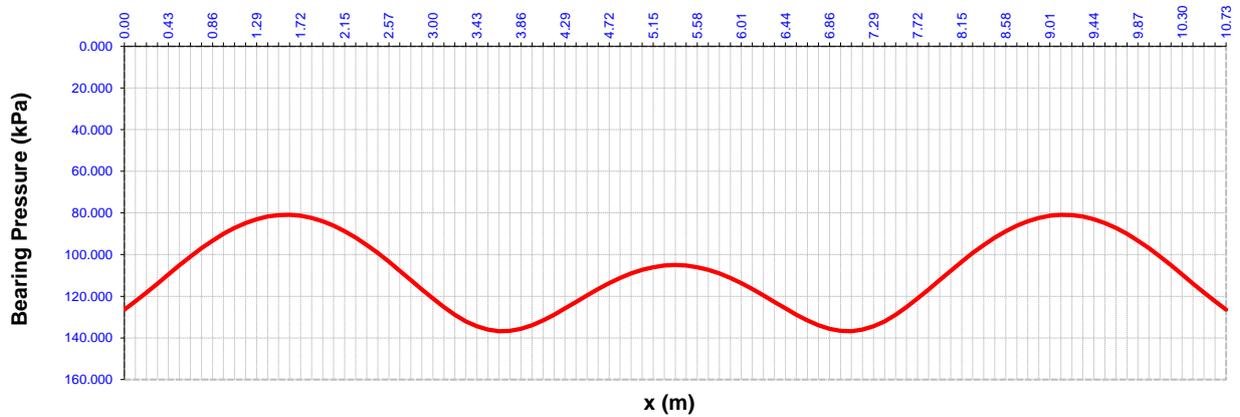
APPENDIX C2

BEAM ON ELASTIC FOUNDATION - ALTERNATE ULTIMATE / SERVICE   **0.4m Fill + 40.8kN/m² surcharge**

TYPICAL DETAIL - THREE LANES

Plate Data:			Uniform Loads:		Point Loads and Moments:		
Int. Height, H =	2.000	m	**Full Uniform:**		x (m)	P (kN)	M (kNm)
Length, L =	10.725	m	Self Weight =	8.4	0.125	P1= 110.6	M1 =-20.1
Width, B =	1.000	m	**Partial UDL:** (Internal Water:)		3.613	P2= 256.1	-
Thickness, T =	0.250	m	Start x =	0.250	7.113	P3= 256.1	-
Modulus, E =	15000	MPa	End x =	10.475	10.600	P4= 75.6	M2= 14.3
Subgrade, ks =	25000	kN/m³	Load w =	24.0	kN/m	-	-	-

Beam Flexibility Criteria:

for β•L <= π/4	beam is rigid	Inertia, I =	0.00130	m⁴ I = B•T³/12
for π/4 < β•L < π	beam is semi-rigid	β =	0.752	β = ((ks•B)/(4•E•I))$^{0.25}$
for β•L >= π	beam is flexible	β•L =	8.066	β•L = Flexibility Factor
for β*L >= 6	beam is semi-infinite long			

$$\text{Beam is semi-infinite long}$$

Max. Shears and Locations:					Max. Moments and Locations:				
V(max) =	97.13	kN @ x =	6.73	m	+M(max) =	51.53	kNm @ x =	7.11	m
V @ d	81.15	kN @ x =	6.54	m	M @ Int. wall centre=	51.53	kNm @ x =	7.11	m
V@ d- ext	75.81	kN @ x =	10.41	m	M @ Int. wall edge=	34.56	kNm @ x =	7.50	m
					M @ Ext Wall Proj =	-22.82	kNm @ x =	0.80	m
					-M(max) =	-37.37	kNm @ x =	1.61	m

Max. Deflection and Location:					Soil Pressures, Locations, and %Brg. Area:				
Δ(max) =	-5.2	mm @ x =	0.00	m	Q(max) =	130.6	kPa @ x =	0.00	m
					Q(min) =	68.4	kPa @ x =	9.33	m
					%Brg. Area =	100.0	%		
						Satisactory			

Shear Diagram

Moment Diagram

Bearing Pressure Diagram

Contract Name:	Skelmanthorpe, Saville Road	05-May-23
Contract Number:	05-BYL-xxxx	Rev: P-01
Client:	Lovell Homes	
Reference:	Attenuation Tank	By: PM Chk: Sheet: **33** of **38**
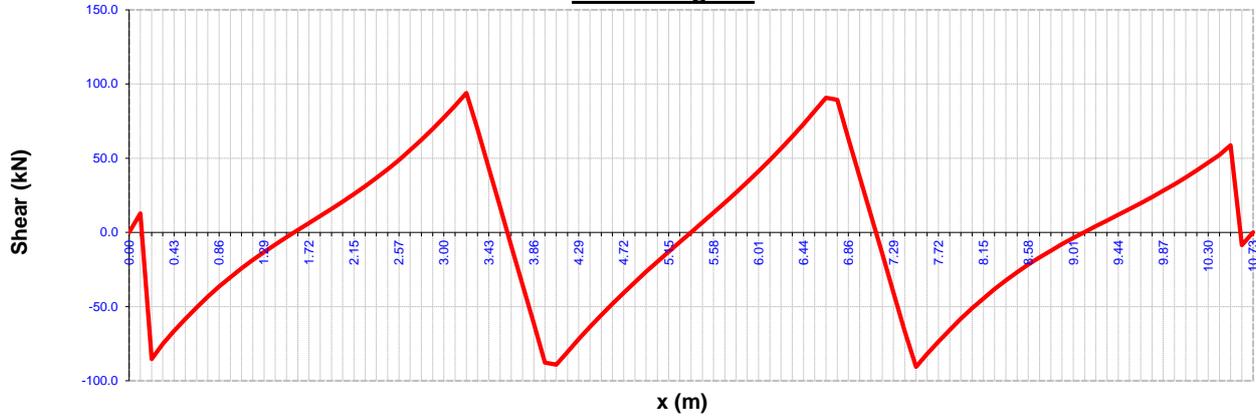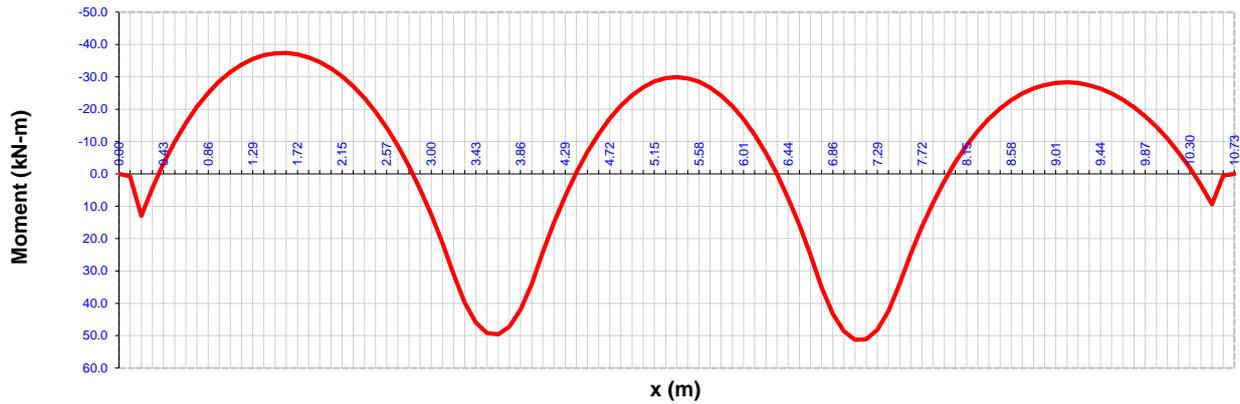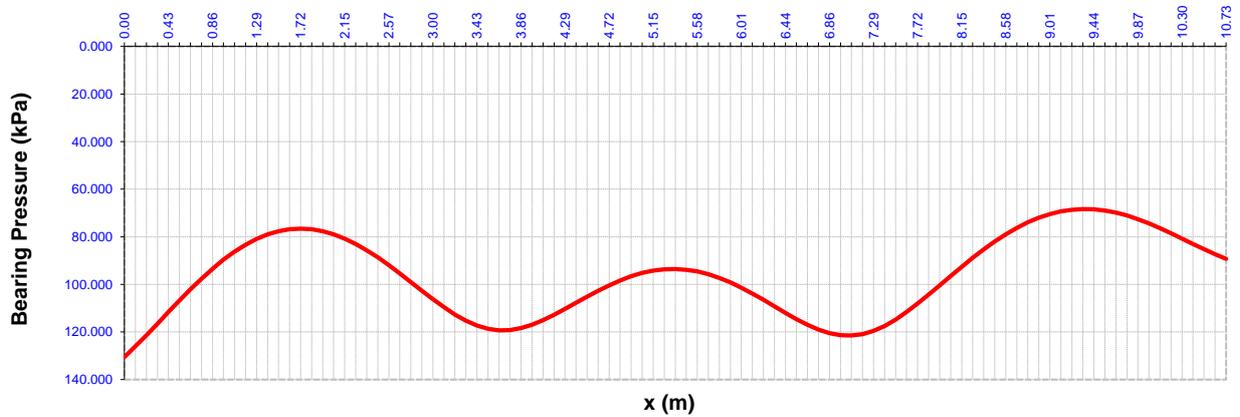
APPENDIX C3

BEAM ON ELASTIC FOUNDATION - SERVICE   **0.4m Fill + 40.8kN/m² surcharge**

TYPICAL DETAIL - THREE LANES

Plate Data:

Int. Height, H =	2.000	m
Length, L =	10.725	m
Width, B =	1.000	m
Thickness, T =	0.250	m
Modulus, E =	15000	MPa
Subgrade, ks =	25000	kN/m³

Uniform Loads:

Full Uniform:

Self Weight =	6.3	
Partial UDL: (Internal Water:)		
Start x =	0.250	
End x =	10.475	
Load w =	0.0	kN/m

Point Loads and Moments:

x (m)	P (kN)	M (kNm)
0.125	P1= 75.6	M1 =-14.3
3.613	P2= 207.9	-
7.113	P3= 207.9	-
10.600	P4= 75.6	M2= 14.3
-	-	-

Beam Flexibility Criteria:

for β•L <= π/4	beam is rigid
for π/4 < β•L < π	beam is semi-rigid
for β•L >= π	beam is flexible
for β*L >= 6	beam is semi-infinite long

Inertia, I =	0.00130	m⁴ I = B•T³/12
β =	0.752	β = ((ks•B)/(4•E•I))$^{0.25}$
β•L =	8.066	β•L = Flexibility Factor

Beam is semi-infinite long

Max. Shears and Locations:

V(max) =	77.89	kN @ x =	6.73	m
V @ d	65.11	kN @ x =	6.54	m
V@ d- ext	55.24	kN @ x =	10.41	m

Max. Moments and Locations:

+M(max) =	40.93	kNm @ x =	3.61	m
M @ Int. wall centre=	40.93	kNm @ x =	3.61	m
M @ Int. wall edge=	26.51	kNm @ x =	3.23	m
M @ Ext Wall Proj =	-17.11	kNm @ x =	0.80	m
-M(max) =	-28.11	kNm @ x =	1.61	m

Max. Deflection and Location:

Δ(max) =	-3.1	mm @ x =	3.65	m

Soil Pressures, Locations, and %Brg. Area:

Q(max) =	77.4	kPa @ x =	3.65	m
Q(min) =	40.3	kPa @ x =	1.61	m
%Brg. Area =	100.0	%		

Satisactory

Version: 01/11/2022

			05-May-23		**F.P. McCann**
Contract Name:	Skelmanthorpe, Saville Road				Bullhurst Lane
Contract Number:	05-BYL-xxxx		Rev: P-01		Weston Underwood
Client:	Lovell Homes				Derbyshire , DE6 4PH
Reference:	Attenuation Tank		By: PM	Chk:	Sheet: **34 of 38**

Shear Diagram

Moment Diagram

Bearing Pressure Diagram

Version: 01/11/2022

F.P. McCann

Bullhurst Lane

Weston Underwood

Derbyshire , DE6 4PH

05-May-23

Rev: P-01

By: PM | Chk: | Sheet: **35 of 38**

Contract Name:	Skelmanthorpe, Saville Road
Contract Number:	05-BYL-xxxx
Client:	Lovell Homes
Reference:	Attenuation Tank
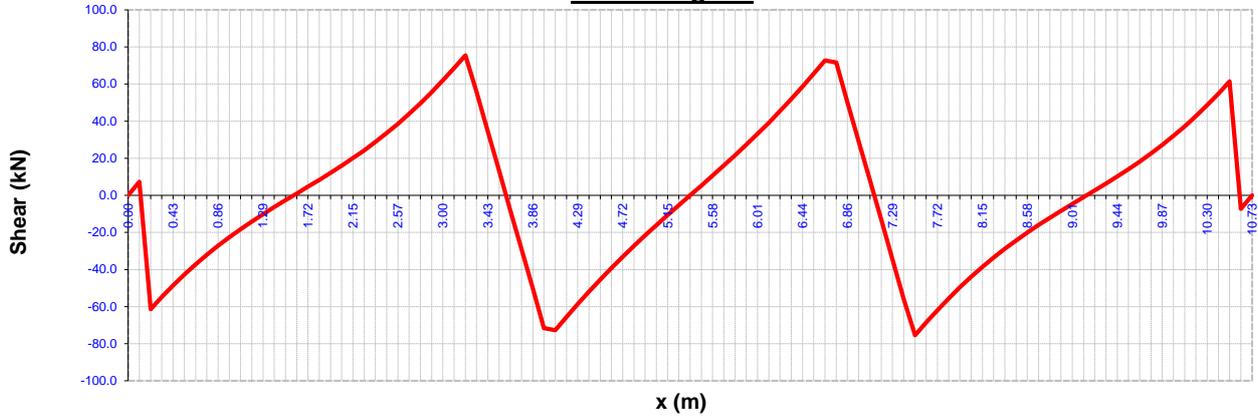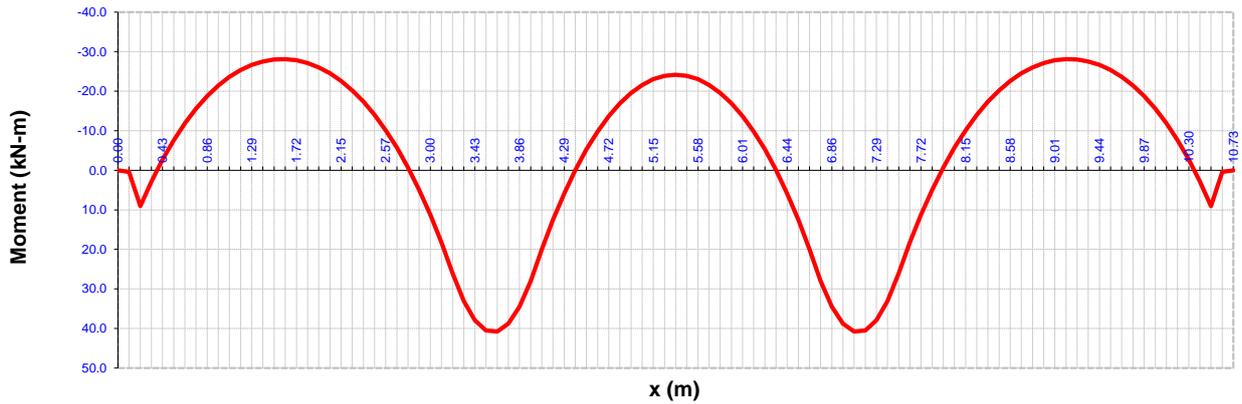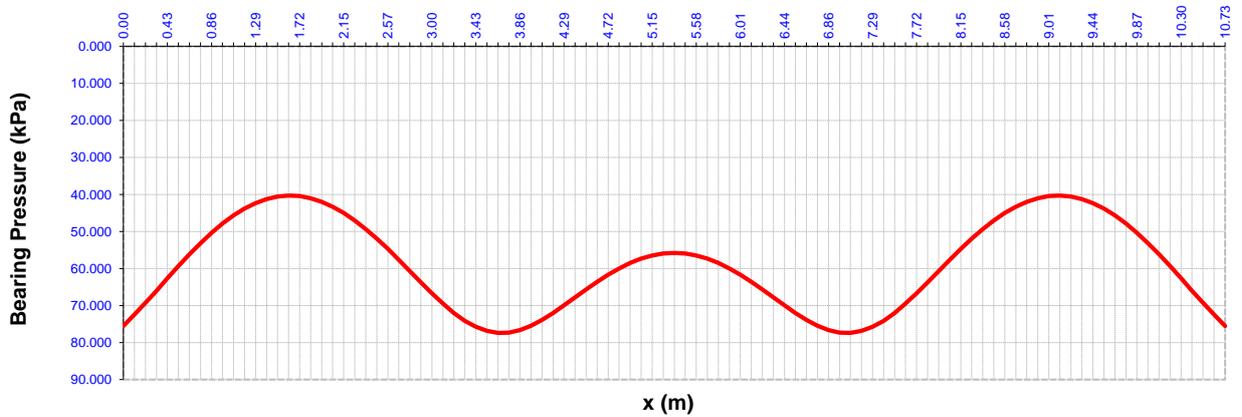
APPENDIX C4

BEAM ON ELASTIC FOUNDATION - QUASI PERMANENT   **0.4m Fill + 40.8kN/m² surcharge**

TYPICAL DETAIL - THREE LANES

Plate Data:

Int. Height, H =	2.000	m
Length, L =	10.725	m
Width, B =	1.000	m
Thickness, T =	0.250	m
Modulus, E =	15000	MPa
Subgrade, ks =	25000	kN/m³

Uniform Loads:

Full Uniform:

Self Weight =	6.3	
Partial UDL: (Internal Water:)		
Start x =	0.250	
End x =	10.475	
Load w =	0.0	kN/m

Point Loads and Moments:

x (m)	P (kN)	M (kNm)
0.125	P1= 35.6	M1 =-10.5
3.613	P2= 97.9	-
7.113	P3= 97.9	-
10.600	P4= 35.6	M2= 10.5
-	-	-

Beam Flexibility Criteria:

for β•L <= π/4	beam is rigid
for π/4 < β•L < π	beam is semi-rigid
for β•L >= π	beam is flexible
for β*L >= 6	beam is semi-infinite long

Inertia, I =	0.00130	m⁴ I = B•T³/12
β =	0.752	β = ((ks•B)/(4•E•I))$^{0.25}$
β•L =	8.066	β•L = Flexibility Factor

Beam is semi-infinite long

Max. Shears and Locations:

V(max) =	36.75	kN @ x =	6.73	m
V @ d	30.70	kN @ x =	6.54	m
V@ d- ext	27.06	kN @ x =	10.41	m

Max. Moments and Locations:

+M(max) =	19.14	kNm @ x =	3.61	m
M @ Int. wall centre=	19.14	kNm @ x =	3.61	m
M @ Int. wall edge=	12.45	kNm @ x =	3.23	m
M @ Ext Wall Proj =	-5.19	kNm @ x =	0.80	m
-M(max) =	-11.81	kNm @ x =	1.72	m

Max. Deflection and Location:

Δ(max) =	-1.6	mm @ x =	3.65	m

Soil Pressures, Locations, and %Brg. Area:

Q(max) =	40.1	kPa @ x =	3.65	m
Q(min) =	23.1	kPa @ x =	1.61	m
%Brg. Area =	100.0	%		

Satisactory

Version: 01/11/2022

Contract Name:	Skelmanthorpe, Saville Road	05-May-23		**F.P. McCann**
Contract Number:	05-BYL-xxxx			Bullhurst Lane
Client:	Lovell Homes	Rev: P-01		Weston Underwood
Reference:	Attenuation Tank			Derbyshire , DE6 4PH
		By: PM	Chk:	Sheet: **36 of 38**

Shear Diagram

Moment Diagram

Bearing Pressure Diagram

Version: 01/11/2022

Contract Name:	Skelmanthorpe, Saville Road	05-May-23	**F.P. McCann**	
Contract Number:	05-BYL-xxxx		Bullhurst Lane	
Client:	Lovell Homes	Rev: P-01	Weston Underwood	
Reference:	Attenuation Tank		Derbyshire , DE6 4PH	
		By: PM	Chk:	Sheet: **37 of 38**
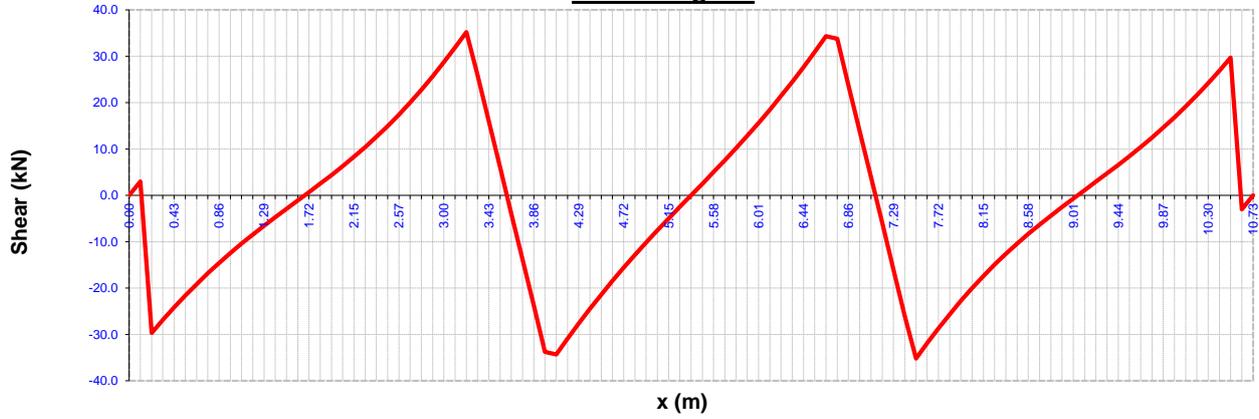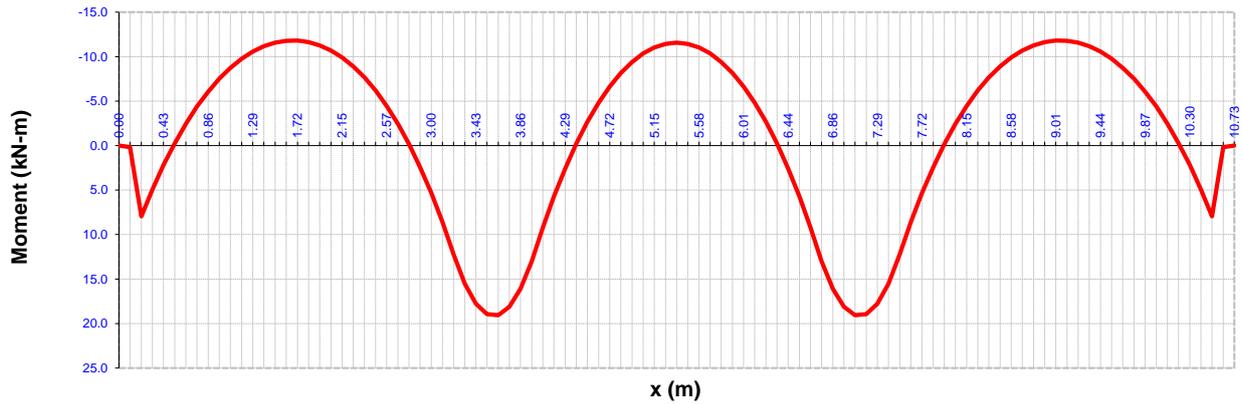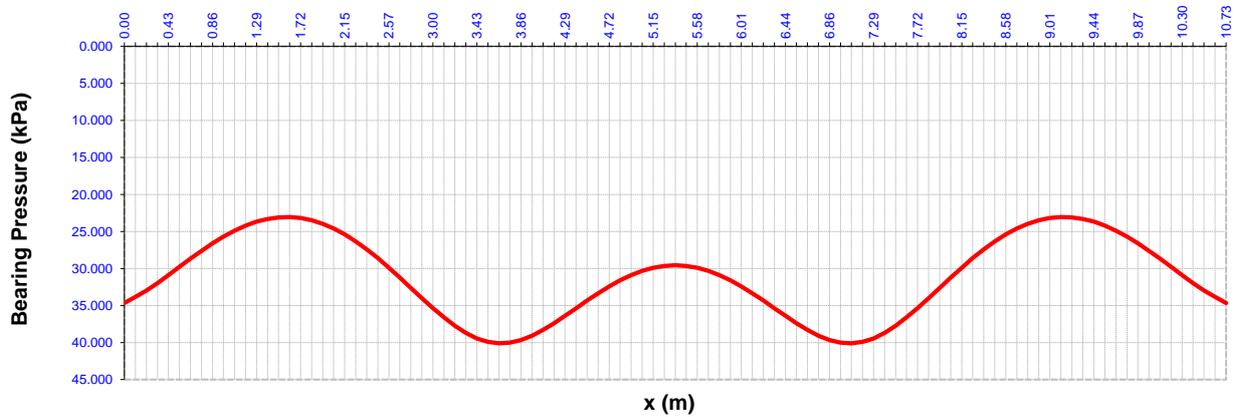
REINFORCEMENT SUMMARY

Intended working life at least: **50 Years**

XC3/4   XD1

Precast: **C40/50**

Minimum Cover: **25mm**

Nominal Cover: **30mm**

Insitu: **C30/37**

Minimum Cover: **35mm**

Nominal Cover: **45mm**

250

110

250

Mesh: B10 @ 150 ctrs.

Transverse: B10 @ 200 ctrs.

2,000

Front L Bars: B10 @ 150 ctrs.

Min. Leg 750

Back L Bars: B10 @ 150 ctrs.

250

Projection min. 400

EXTERNAL WALL

275

2 B20

2 B16

2 B16

B8 Links @ 250 ctrs.

475

8 B12 (4 E/F)

1250

B8 Links @ max. 250 ctrs.

2 B8 Links @ 250 ctrs.

250

6 B12

6 B16

775

INTERNAL WALL
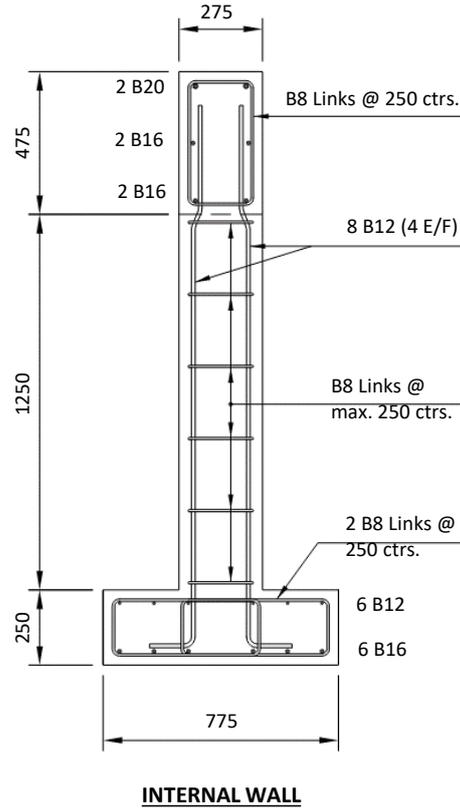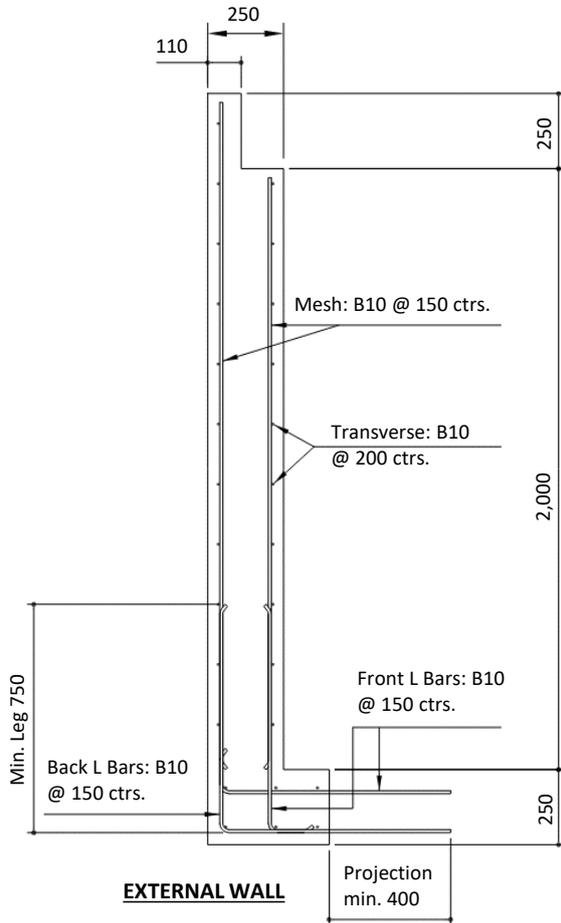
Mesh: Transverse Steel B10 @ 100 ctrs.

Top Mesh: B10 @ 100 ctrs.

Btm. Mesh: B10 @ 100 ctrs.

250 Insitu Base

1000

1000

Additional loose bar under internal walls
B10 @ 200 ctrs. - 2000 Long

BASE SLAB

Version: 01/11/2022

			05-May-23	**F.P. McCann**
	Contract Name:	Skelmanthorpe, Saville Road		Bullhurst Lane
	Contract Number:	05-BYL-xxxx	Rev: P-01	Weston Underwood
	Client:	Lovell Homes		Derbyshire , DE6 4PH
	Reference:	Attenuation Tank	By: PM	Chk:	Sheet: **38 of 38**

PRESTRESSED SLAB UNITS

600 · 600 · 35 · 50 · 35

200 · 100 · 100 · 200 · 100 · 100 · 200 · 100 · 100 · 200

14 No. 9.3 Dia. Strands (3 Top, 11 Btm)

B8 Links @ 200 ctrs.

B8 Stirrups @ 200 ctrs. along span,
Transverse spacing nominally 225
(To suit main steel)

160 · 120 · 225

3 B12

3 B12

R/C SLAB UNITS (With Opening)

Mesh B16 @ 75 ctrs. on B10 @
150 ctrs. (Cut to suit openings)

B8 Links @ 200 ctrs.

3 B12

3 B12

R/C SLAB UNITS (Without Opening)

Mesh B16 @ 100 ctrs.
on B10 @ 150 ctrs.

Additional loose bar
above internal walls
B16 @ 200 ctrs. - 1400 Long

240mm Composite Roof Slab
(120mm Precast + 120mm Insitu Topping)

Mesh (Top Face): B10
@ 200 ctrs. E/W

700 · 700

B20 dowel bars @ max.
875 ctrs.

B20 dowel bars @ max.
875 ctrs.

ROOF SLAB - Insitu topping