Job Number: 150122
6th July 2016

CROFT STRUCTURAL ENGINEERS

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London SE25 5EH

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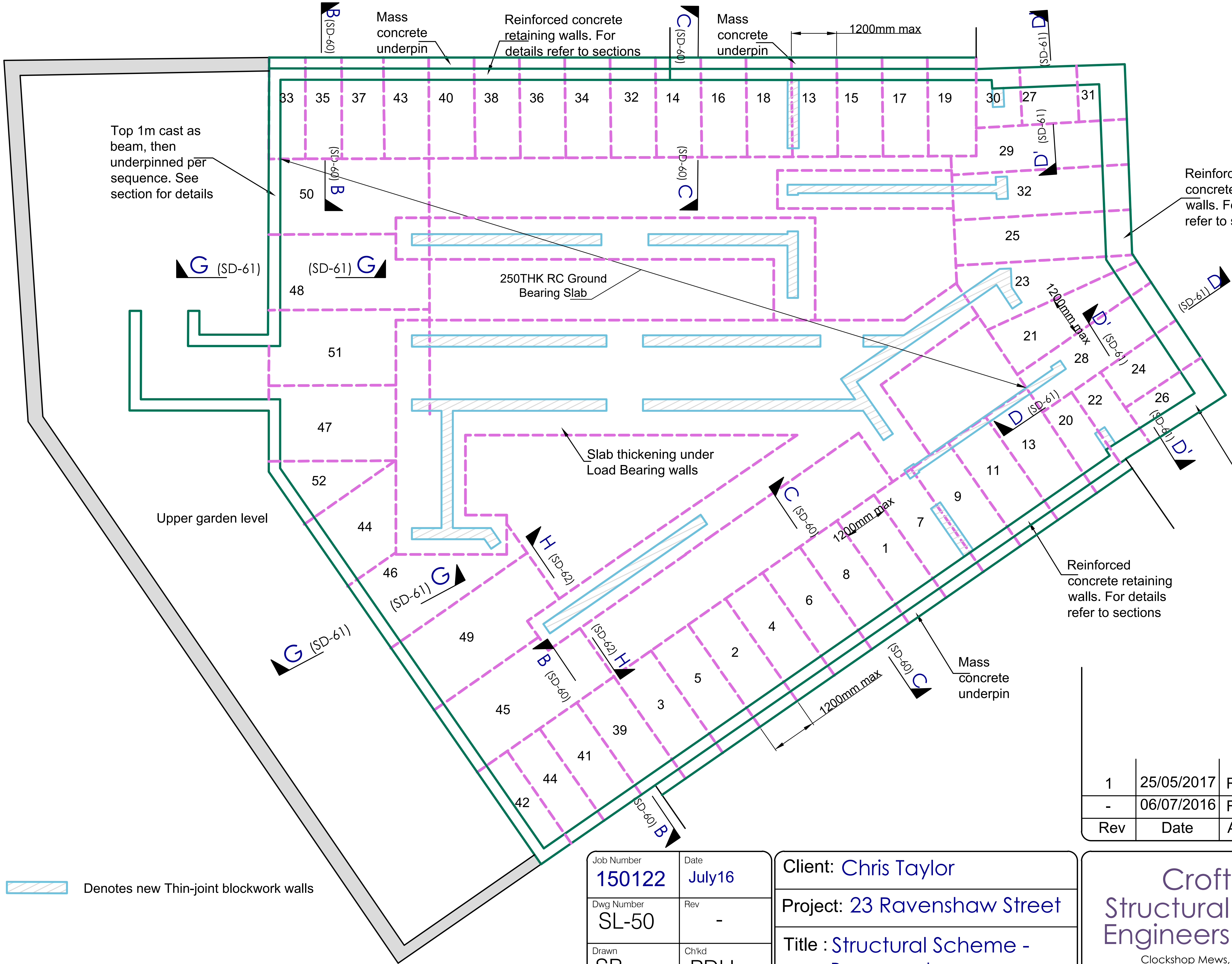
Scheme Structural Calculations for Planning

Site:
23A Ravenshaw Street
London
NW6 1NP

Client:
Chris Taylor

Structural Design Reviewed by	**Above Ground Drainage Reviewed by**
Chris Tomlin MEng CEng MIStructE	Phil Henry BEng MEng MICE

Revision	Date	Comment
-	06/07/2016	First issue for comment
1	11/07/16	Sketches updated
2	23/05/17	Movement calcs updated



Rev	Date	Amendments
1	25/05/2017	Rear wall sequence added
-	06/07/2016	First issue for comment

FOR PLANNING

Job Number	Date
150122	July16
Dwg Number: SL-50	Rev: -
Drawn: SB	Ch'kd: PDH
Scale: As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Structural Scheme - Basement

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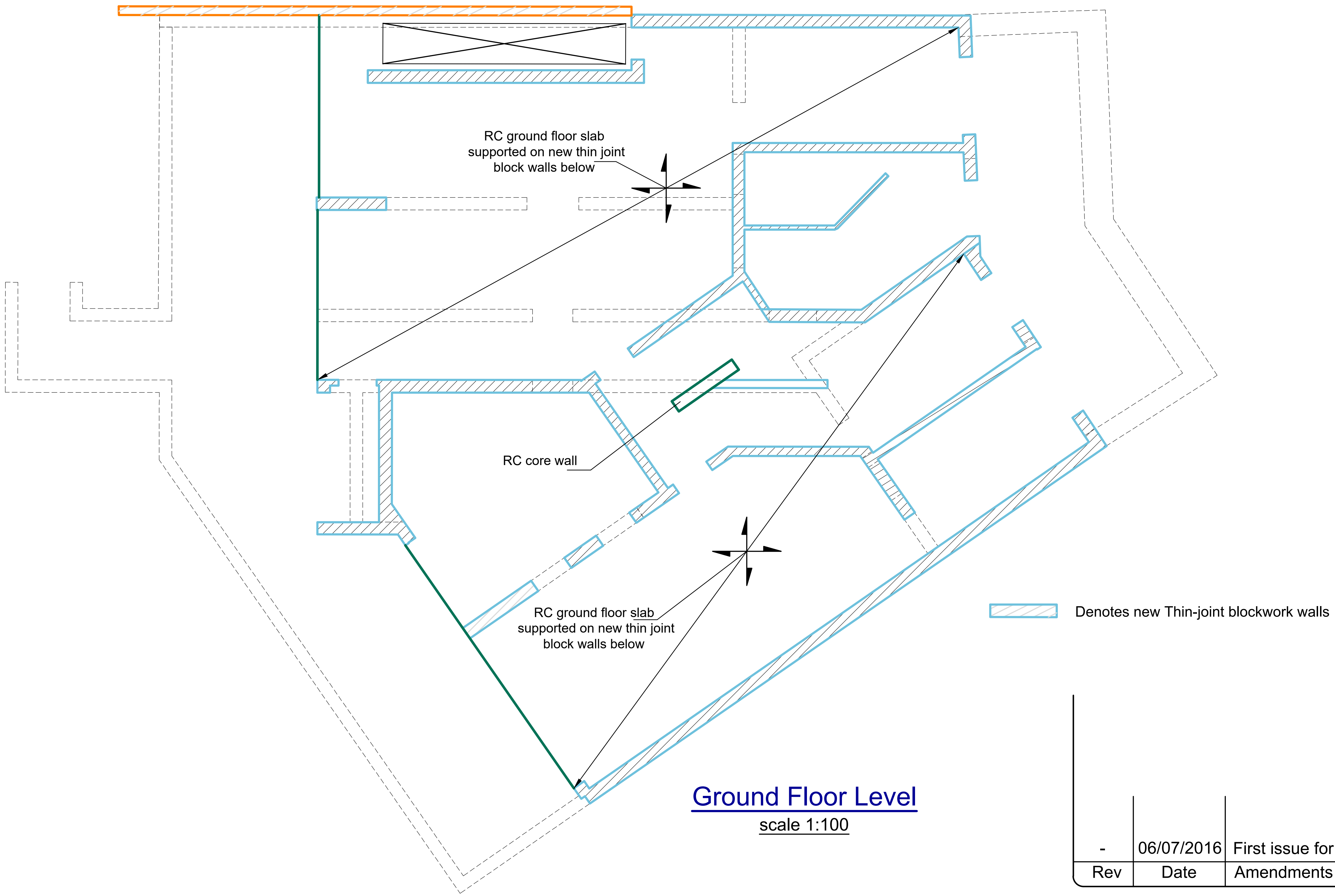

Ground Floor Level

scale 1:100

Rev	Date	Amendments
-	06/07/2016	First issue for comment

Job Number 150122	Date July16
Dwg Number SL-51	Rev -
Drawn EP	Ch'kd PDH
Scale As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Structural Scheme Design Ground Floor Plan

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FOR PLANNING

First Floor Level

(scale 1:100)

Denotes new Thin-joint blockwork walls

Rev	Date	Amendments
-	06/07/2016	First issue for comment

Job Number: 150122
Date: July16
Dwg Number: SL-52
Rev: -
Drawn: EP
Ch'kd: PDH
Scale: As shown @ A3

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Structural Scheme Design First Floor Plan

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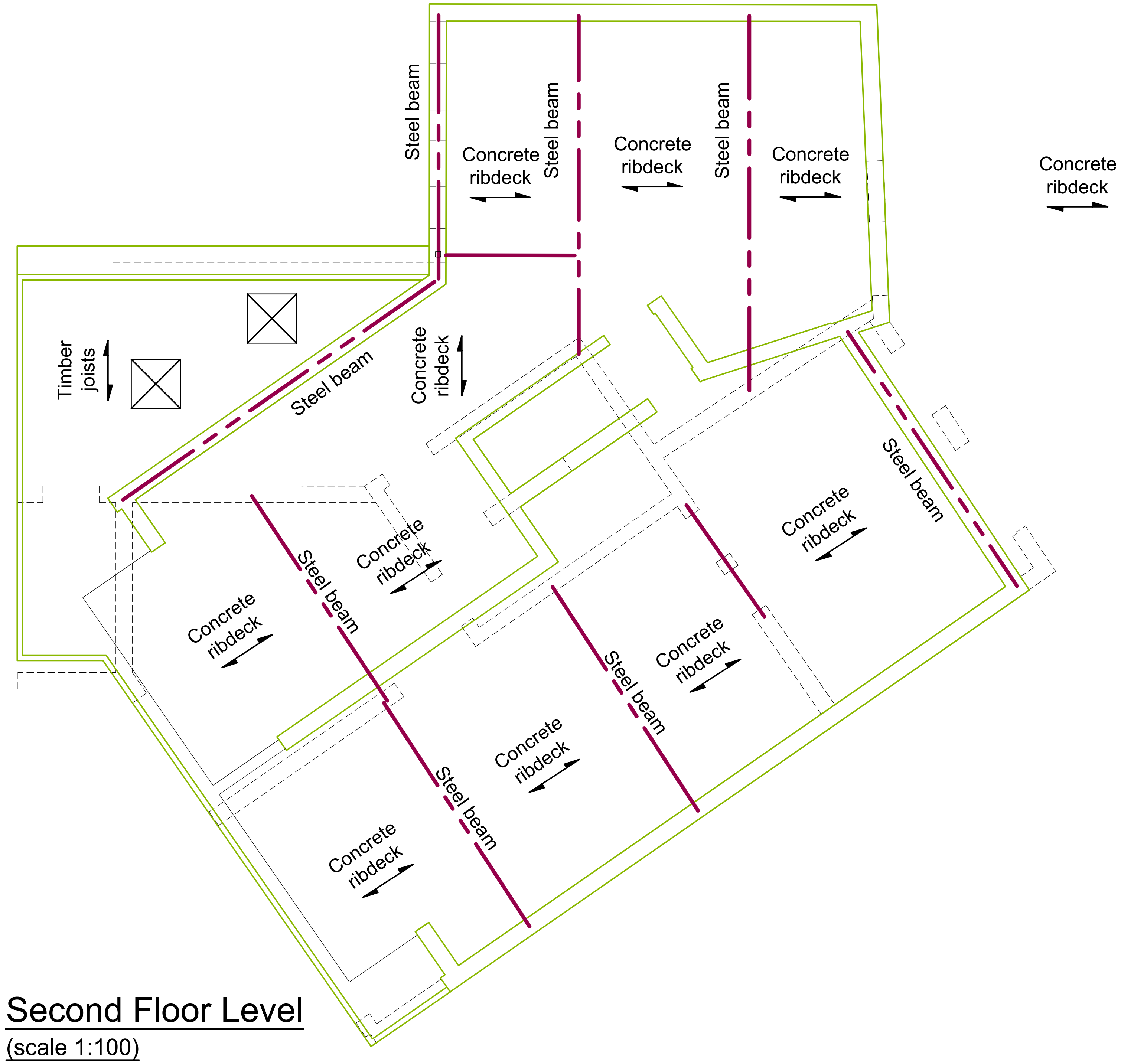

Second Floor Level

(scale 1:100)

Rev	Date	Amendments
-	06/07/2016	First issue for comment

Job Number 150122	Date July16
Dwg Number SL-53	Rev -
Drawn EP	Ch'kd PDH
Scale As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Structural Scheme Design Second Floor Plan

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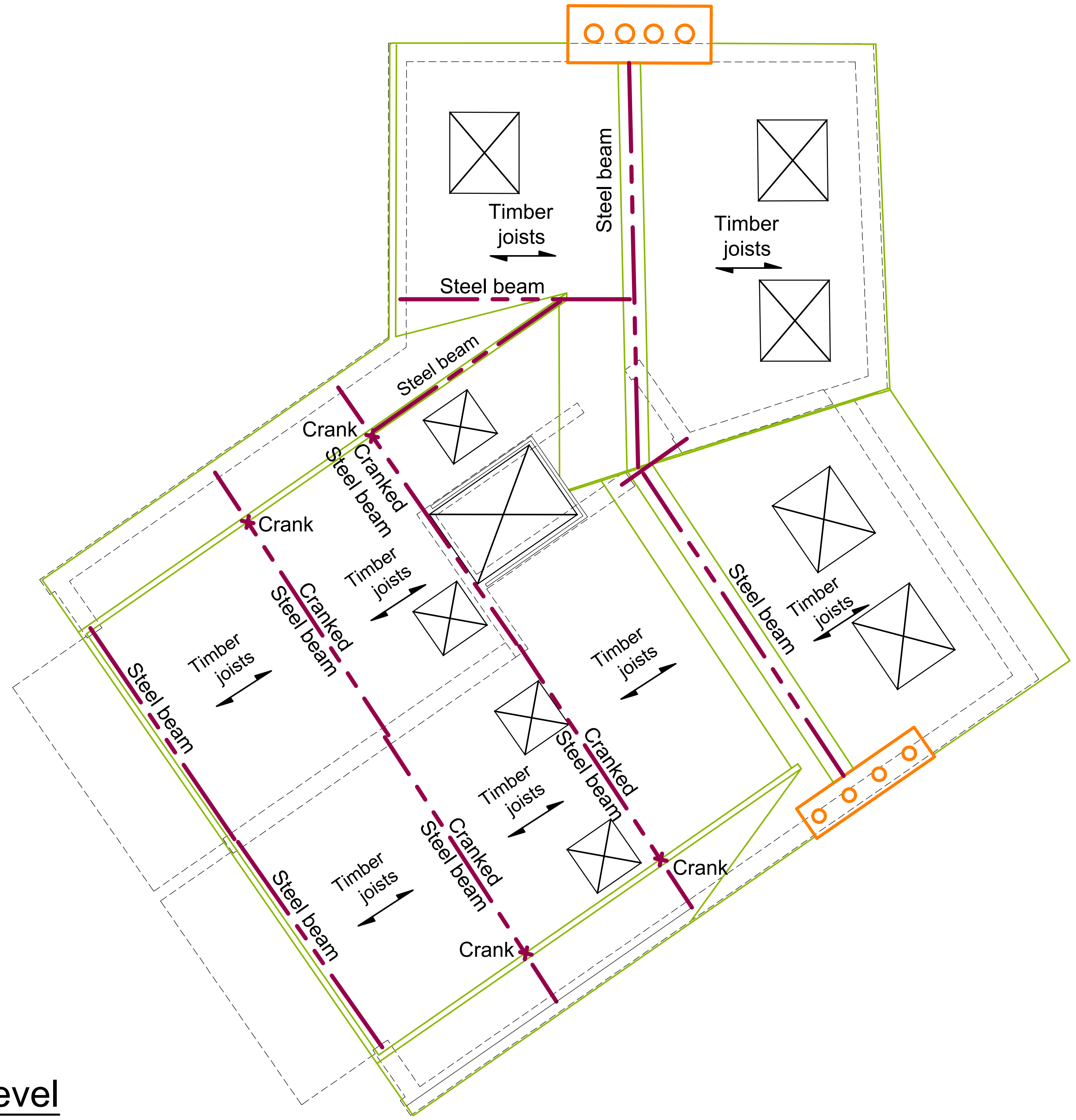

Roof Level
(scale 1:100)

Rev	Date	Amendments
-	06/07/2016	First issue for comment

Job Number: 150122	Date: July16
Dwg Number: SL-54	Rev: -
Drawn: EP	Ch'kd: PDH
Scale: As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Structural Scheme Design Roof Plan

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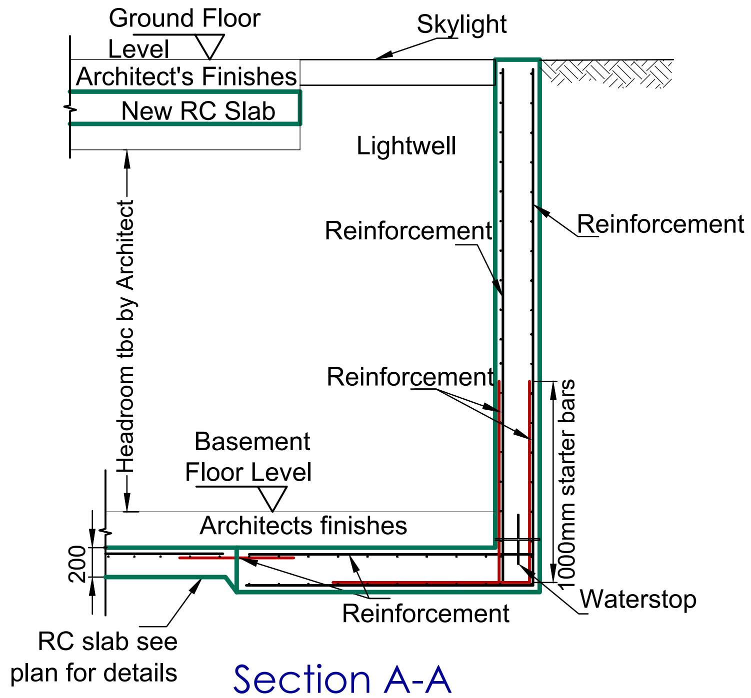
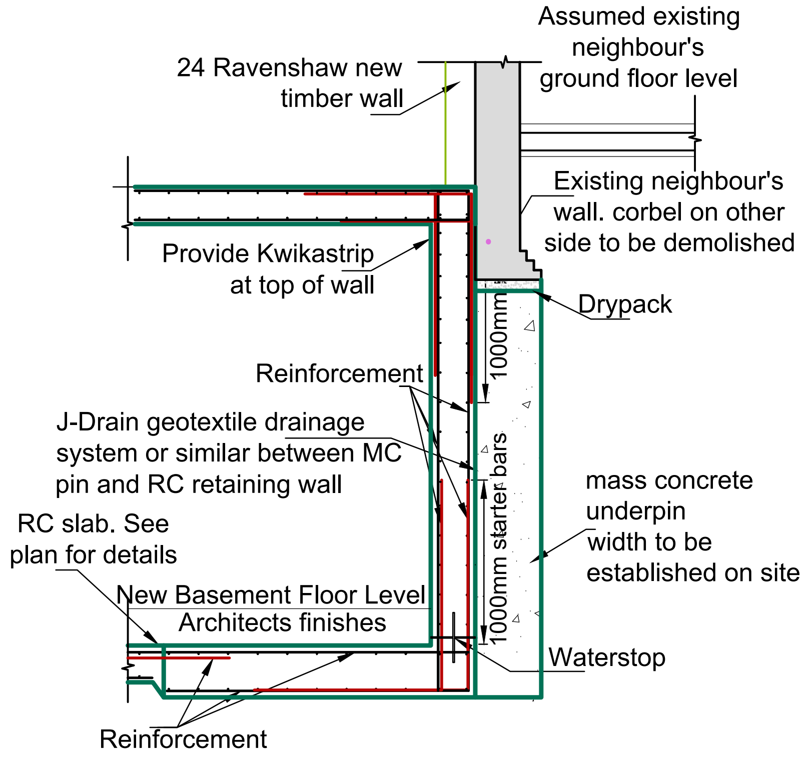


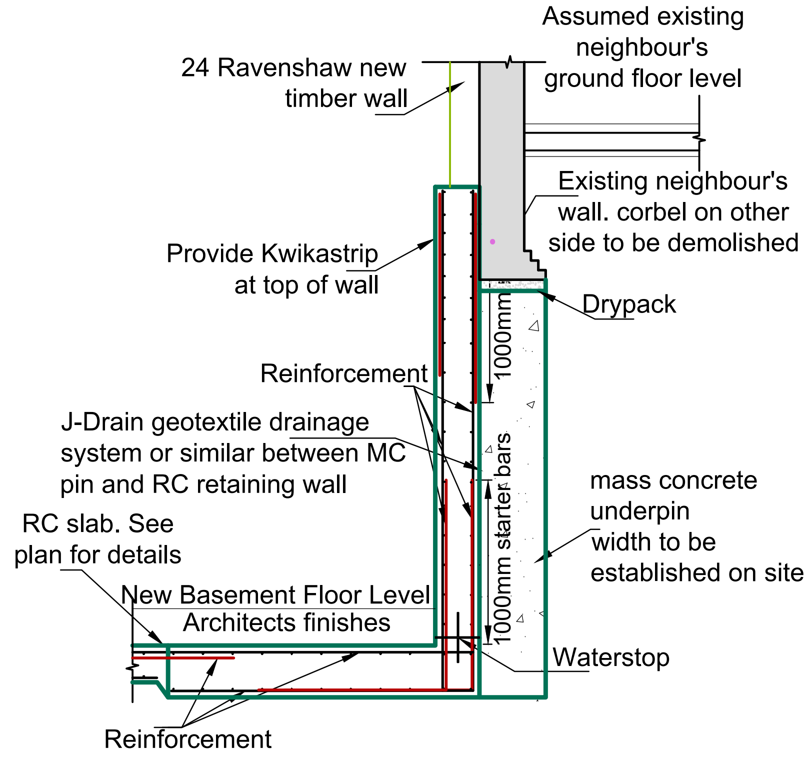
Section A-A

scale 1:50



Section B-B

scale 1:50



Section C-C

scale 1:50

Rev	Date	Amendments
-	06/07/2016	First issue for comment

FOR PLANNING

Job Number: 150122	Date: July16
Dwg Number: SD-60	Rev: -
Drawn: EP	Ch'kd: PDH
Scale: As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Sections and Details 1

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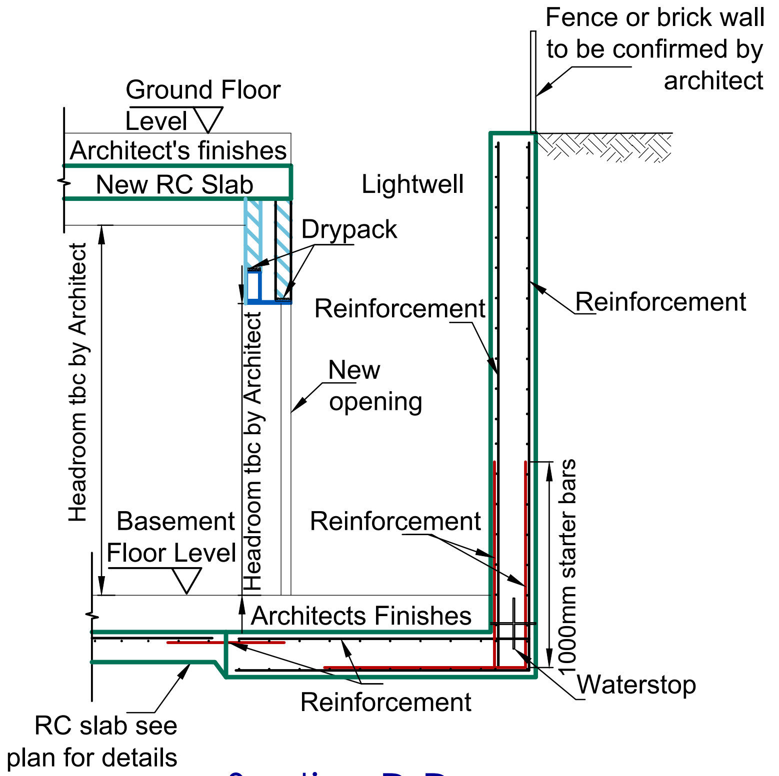
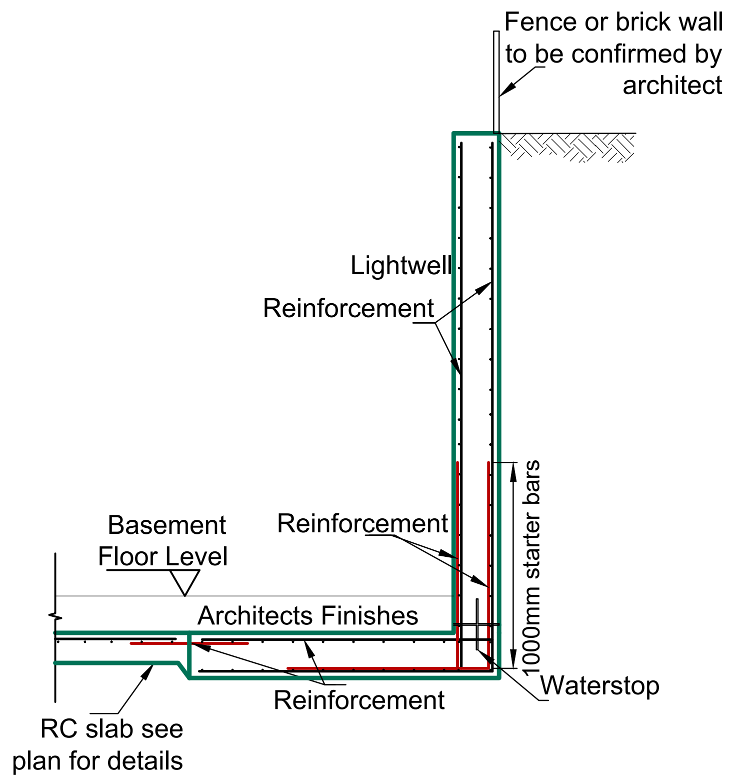
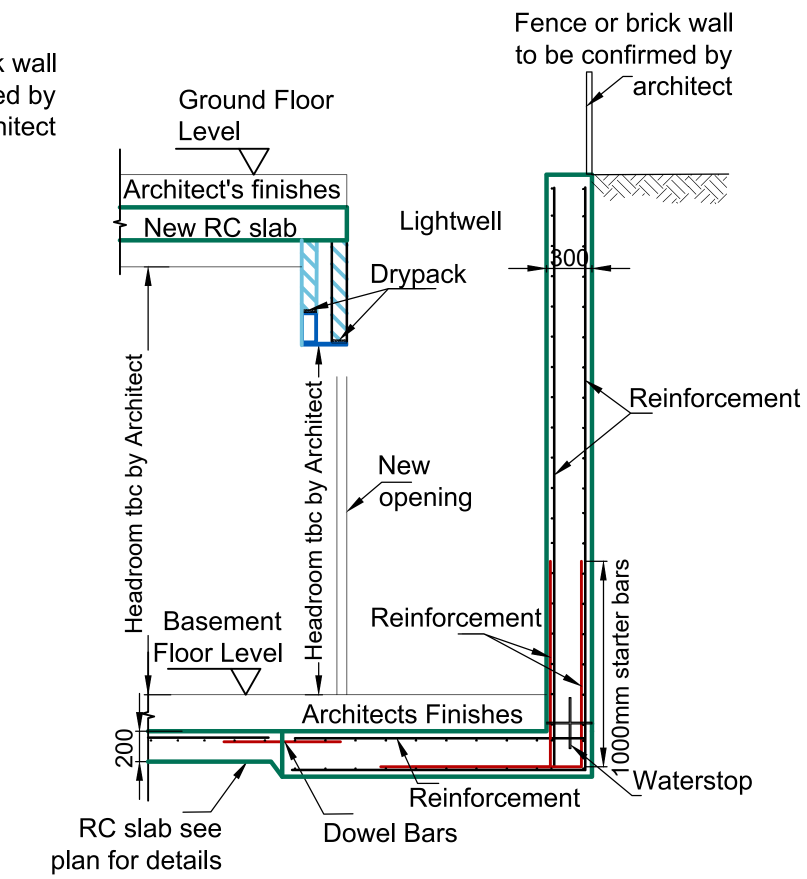


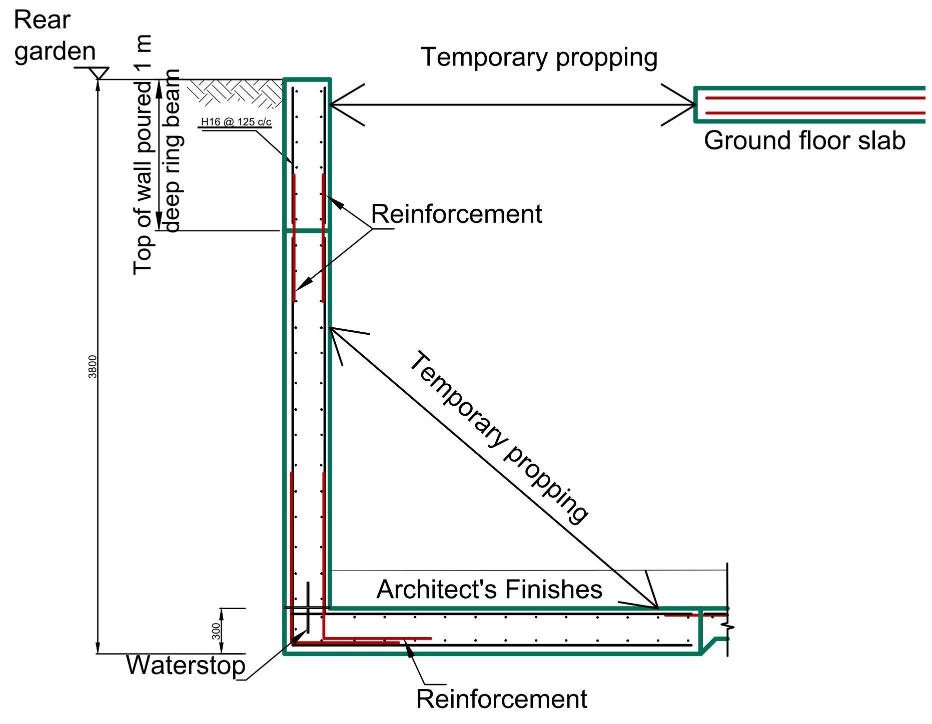
Section D-D
scale 1:50



Section D'-D'
scale 1:50



Section E-E
scale 1:50



Section G-G
scale 1:50

Rev	Date	Amendments
1	25/05/2017	Section G-G added
-	06/07/2016	First issue for comment

FOR PLANNING

Job Number: 150122	Date: July16
Dwg Number: SD-61	Rev: -
Drawn: EP	Ch'kd: PDH
Scale: As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Sections and Details 2

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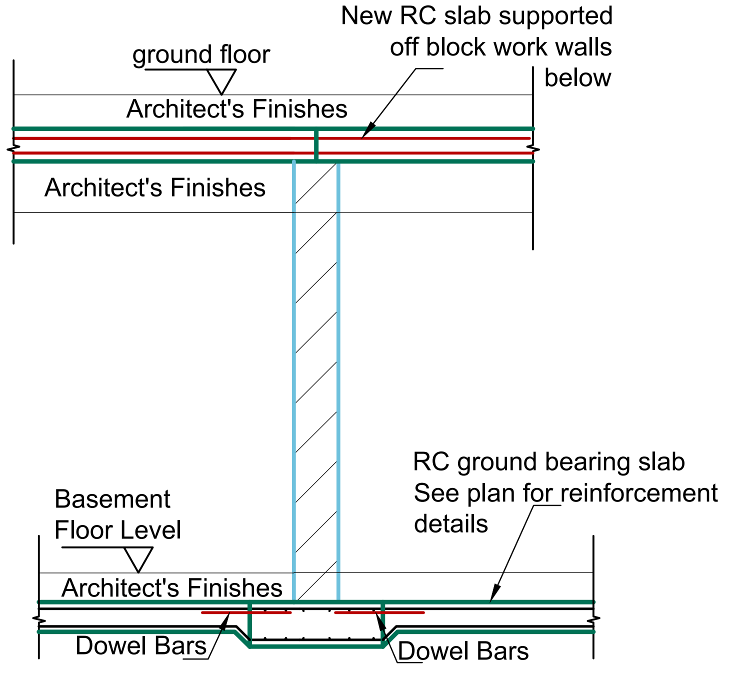

Section H-H
scale 1:50

Rev	Date	Amendments
-	06/07/2016	First issue for comment

Job Number 150122	Date July16
Dwg Number SD-62	Rev -
Drawn EP	Ch'kd PDH
Scale As shown @ A3	

Client: Chris Taylor

Project: 23 Ravenshaw Street

Title : Sections and Details 3

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FOR PLANNING

CROFT STRUCTURAL ENGINEERS
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Project:	23A Ravenshaw Road	Section: L	Sheet: 00
Date: Feb-15	Rev: 1	Date: Jul-16	Description: New scheme
By: EP			
Cheked: PDH			
Job Number: 150122	Status:		Rev: 1

Reference

General Actions on Building Structure

Sloped Roof

Slate =	0.60	
Battens =	0.02	
50x150@400c/c =	0.10	
Felt =	0.02	
Insulation =	0.02	
	0.76	
Roof Angle =	35	deg
Plan perm., g_k =	**0.93**	**kN/m^2**
Plan Var., q_k =	**0.60**	**kN/m^2**

Flat Roof

20mm Asphalt =	0.46	
Felt underlay =	0.02	
insulation =	0.04	
Ply Sheeting =	0.10	
Firring =	0.10	
oof joists 50x200@400 =	0.13	
Plaster & Skim =	0.18	
Plan perm., g_k =	**1.03**	**kN/m^2**
Plan Var., q_k =	**0.75**	**kN/m^2**

Mansard Roof

Slate Tiles =	0.40	
Battens =	0.02	
Ply Sheeting =	0.10	
Rafters =	0.12	
100 Insulation =	0.06	
plaster & Skim =	0.18	
Felt =	0.02	
	0.90	
Roof Angle =	75	deg
Plan perm., g_k =	**3.48**	**kN/m^2**
Plan Var., q_k =	**0.00**	**kN/m^2**

PC Ground FloorsFloors

300thk slab =	5.00	
Screed =	1.88	
Insulation =	0.07	
Finishes =	0.05	
Perm., g_k =	**7.00**	**kN/m^2**
Var., q_k =	**1.50**	**kN/m^2**

Cavity Walls

100 Facing Brick =	2.20	
100 Block (16kN/m^3)=	1.60	
Plaster & Skim =	0.18	
Perm., g_k =	**3.98**	**kN/m^2**

Internal Walls

140 Block (12kN/m3)=	1.68	
Plaster & Skim =	0.36	
Perm., g_k =	**2.04**	**kN/m^2**

Timber Floors

Sound insulation	0.15	
18mm Ply	0.10	
Joists 50x225@400 =	0.15	
100 Insulation =	0.05	
Plaster & Skim =	0.18	
Perm., g_k =	**0.63**	**kN/m^2**
Var., q_k =	**1.50**	**kN/m^2**

Terrace Floor

Promonade Tiles =	0.40	
20mm Asphalt =	0.46	
Felt underlay =	0.02	
insulation =	0.04	
Ply Sheeting =	0.10	
Firring =	0.10	
Roof joists 50x200@400 =	0.13	
Plaster & Skim =	0.18	
Perm., g_k =	**1.43**	**kN/m^2**
Var., q_k =	**1.50**	**kN/m^2**

Ceiling

50x100 Joists =	0.07	
100 Insulation =	0.06	
Plaster & Skim =	0.18	
Perm., g_k =	**0.31**	**kN/m^2**
Var., q_k =	**0.25**	**kN/m^2**

Timber Partitions

Height:	3.00	m
50x100 Studs @ 400 =	0.12	
Insulation =	0.04	
Plaster & Skim =	0.36	
Perm., g_k =	**0.52**	**kN/m**

Existing Brick Walls

225 Facing Brick =	4.50	
External Render =	0.35	
Plaster & Lathe =	0.15	
Perm., g_k =	**5.00**	**kN/m^2**

PC Ground FloorsFloors

Beam & Block =	3.10	
Screed =	1.40	
Insulation =	0.07	
Finishes =	0.05	
Perm., g_k =	**4.62**	**kN/m^2**
Var., q_k =	**1.50**	**kN/m^2**

Standing Seam

Roof Sheet =	0.08	
Insulation =	0.07	
Decking =	0.20	
Steelwork =	0.60	
Perm., g_k =	**0.95**	**kN/m^2**
Var., q_k =	**0.60**	**kN/m^2**

Filler joist Floor

Finishes =	1.20	
Filler Joist Floor =	2.50	
Ceiling =	0.18	
Steel =	0.30	
Perm., g_k =	**4.18**	**kN/m^2**
Var., q_k =	**1.50**	**kN/m^2**

Moveable Partitions - Additional q_k

Lightweight (screens, etc) ,1 kN/m =	0.5	kN/m^2
Timber/metal stud walls , 1<2 kN/m =	0.8	kN/m^2
Solid paritions, 2<3 kN/m =	1.2	kN/m^2

Table 3 Live Load Reduction

Area		Floors	
0	0%	1	0%
50	5%	2	10%
100	10%	3	20%
150	15%	4	30%
200	20%	5 to 10	40%

Engineering Information Sheet/ Load Run Down

CROFT STRUCTURAL ENGINEERS	Project: 23A Ravenshaw Road	Section L	Sheet 02
Tel 0208 684 4744	Date Feb-15; By EP; Cheked PDH	Rev 1; Date Jul-16; Description New scheme	
enquiries@croftse.co.uk	Job Number 150122	Status	Rev 1

Reference

Location	Area L	Area W	Area m^2	Type	L	Action kN/m^2	Perm., g_k	%	Var., q_k	Total
retaining wall A/A'										
brick wall/fence	2	1	2	g_k		5.00	10.0			
							10.0	kN/m	0.0	kN/m
2.5kN/m2 surcharge										
retaining wall B/B'										
brick wall/fence	2	1	2	g_k		5.00	10.0			
							10.0	kN/m	0.0	kN/m
2.5kN/m2 surcharge										
retaining wall C										
ground floor slab	4.5	0.5	2.25	g_k		7.00	15.7			
				q_k		1.50			3.4	
1st and 2nd	4.5	0.5	2.25	g_k	2	4.18	18.8			
				q_k		1.50			6.8	
timber roof	4.5	0.5	2.25	g_k		1.03	2.3			
				q_k		0.75			1.7	
timber wall	3	1	3	g_k		0.52	1.6			
block walls	9	1	9	g_k	2	4.08	36.7			
							75.1	kN/m	11.8	kN/m
retaining wall D/D'										
brick wall/fence	0.5	1	0.5	g_k		5.00	2.5			
							2.5	kN/m	0.0	kN/m
10.0kN/m2 surcharge										
Internal walls										
ground floor slab	3	1	3	g_k		7.00	21.0			
				q_k		1.50			4.5	
basement slab	1	1	1	g_k		7.00	7.0			
				q_k		1.50			1.5	
1st and 2nd	3	1	3	g_k	2	4.18	25.1			
				q_k		1.50			9.0	
timber roof	5.5	1	5.5	g_k		1.03	5.7			
				q_k		0.75			4.1	
timber wall	3	1	3	g_k		0.52	1.6			
block walls	9	1	9	g_k		4.08	36.7			
							97.0	kN/m	19.1	kN/m

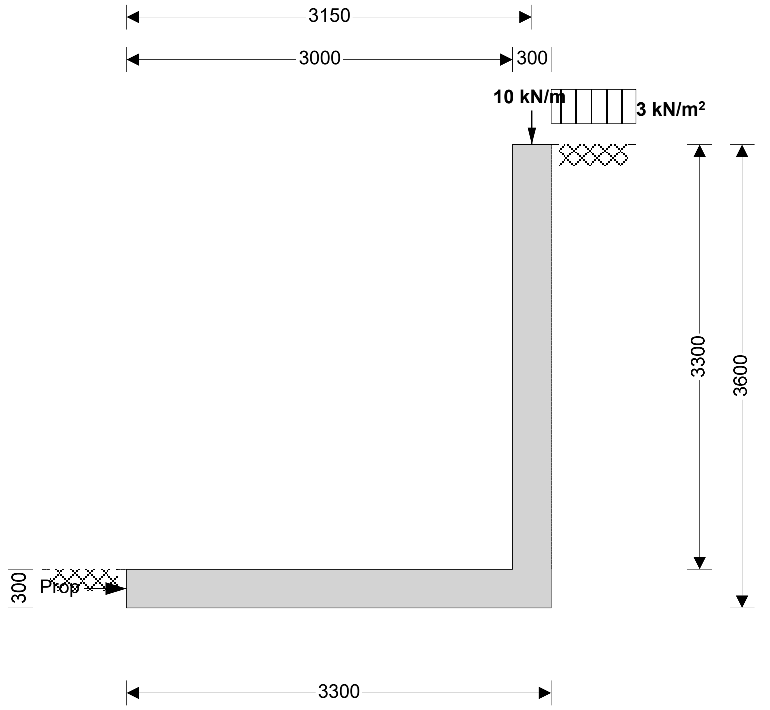
RETAINING WALL A/A'/B/B' DESIGN

Loading

retaining wall A/A'										
brick wall/fence	2	1	2	g_k		5.00	10.0			
							10.0	kN/m	0.0	kN/m
2.5kN/m2 surcharge										

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3300** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **3000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **3300** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **0** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3600** mm

Depth of cover in front of wall d_{cover} = **0** mm

Depth of unplanned excavation d_{exc} = **0** mm

Height of ground water behind wall h_{water} = **0** mm

Height of saturated fill above base $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **0** mm

Density of wall construction γ_{wall} = **23.6** kN/m^3

Density of base construction γ_{base} = **23.6** kN/m^3

Angle of rear face of wall α = **90.0** deg

Angle of soil surface behind wall β = **0.0** deg

Effective height at virtual back of wall $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3600** mm

Retained material details

Mobilisation factor M = **1.5**

Moist density of retained material γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **0.0** deg

Base material details

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.419}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **2.5** kN/m^2

Applied vertical dead load on wall W_{dead} = **10.0** kN/m

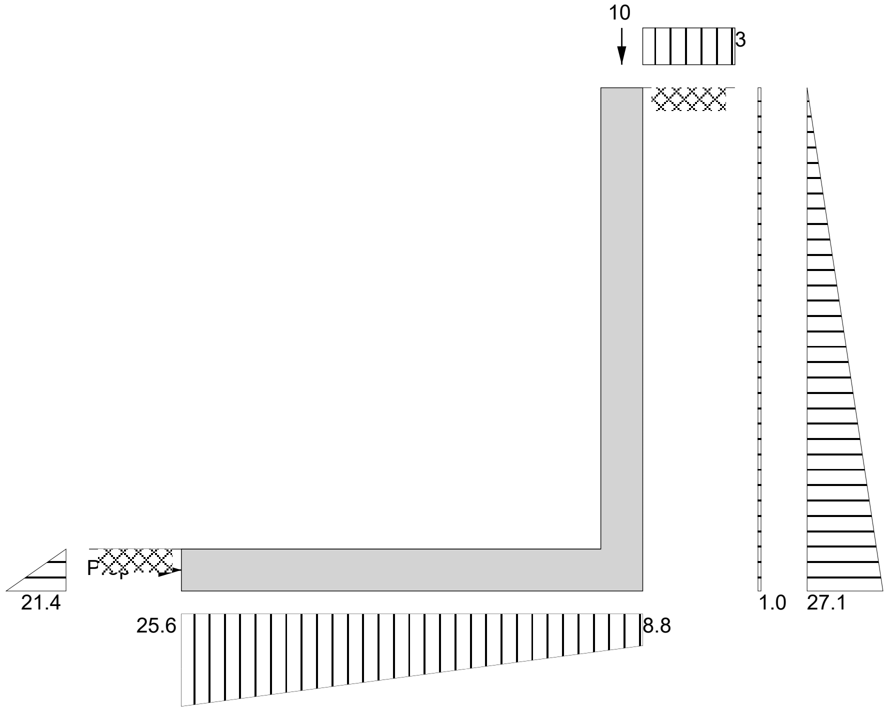
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **3150** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **23.4** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **23.4** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **10** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **56.7** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **3.8** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **48.8** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a}$ = **52.6** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **3.2** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop} = **30.3** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.8** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **58.6** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a}$ = **65.4** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **73.6** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **38.6** kNm/m
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load}$ = **31.5** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **143.6** kNm/m

Check bearing pressure

Total moment for bearing	$M_{total} = M_{rest} - M_{ot}$ = **78.3** kNm/m
Total vertical reaction	$R = W_{total}$ = **56.7** kN/m

Distance to reaction $x_{bar} = M_{total} / R =$ **1380** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) =$ **270** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) =$ **25.6** kN/m^2

Bearing pressure at heel $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) =$ **8.8** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **32.7** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **32.7** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **14** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **79.4** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **8.5** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **96.4** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f}$ = **104.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **73.6** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **15.3** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **115.6** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f}$ = **130.9** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **103** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **54** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **44.1** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **201.1** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **70.2** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **79.4** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **884** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **766** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **59.9** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction $rate = p_{toe\_f} / (3 \times x_{bar\_f})$ = **22.60** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **0** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **0** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **0** kN/m^2

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe c_{toe} = **75** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} / 2$ = **79.4** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **29.7** kN/m

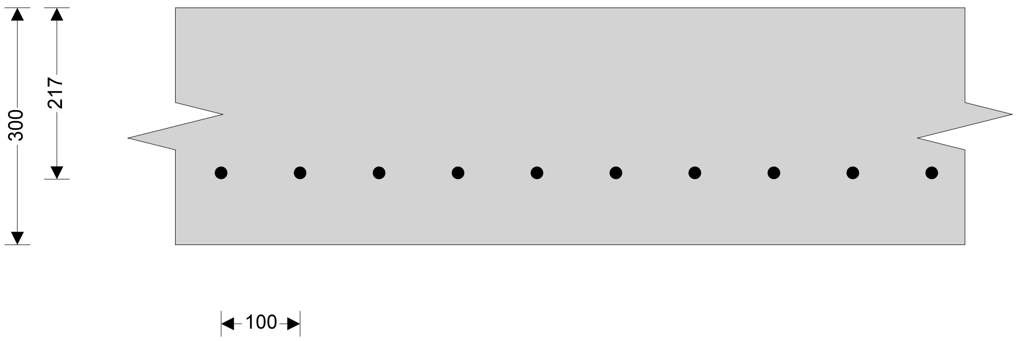
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base}$ = **49.7** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} \times (l_{toe} - x_{bar\_f} + t_{wall} / 2) / 2$ = **180** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **49.2** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base}$ = **130.8** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **217.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.069**

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

z_{toe} = **199** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **1513** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base}$ = **390** mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **1513** mm^2/m

Reinforcement provided **16 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov}$ = **2011** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.229** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.840** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **30** mm

Cover to reinforcement in wall c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **7.8** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **81** kN/m

Calculate shear for stem design

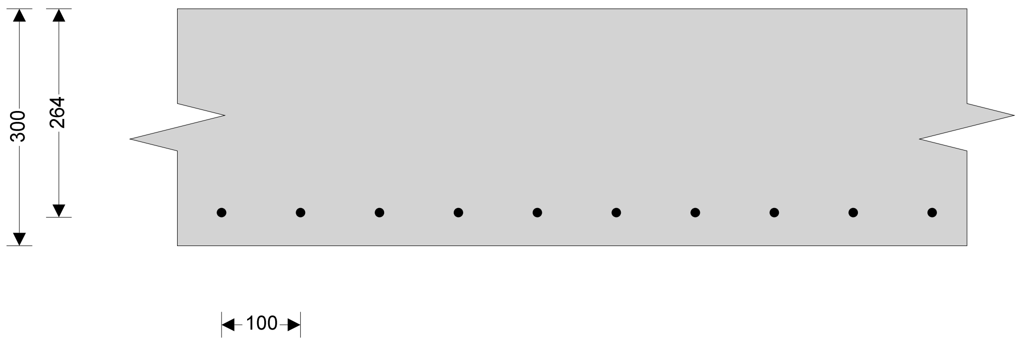
Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} - F_{prop\_f}$ = **15.1** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **14** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **101.2** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a}$ = **115.2** kNm/m



Check wall stem in bending

Width of wall stem b = **1000** mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **264.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.041**

Compression reinforcement is not required

Lever arm $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **251** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **1056** mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **390** mm^2/m

Area of tension reinforcement required $A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **1056** mm^2/m

Reinforcement provided **B1131 mesh**

Area of reinforcement provided $A_{s\_stem\_prov}$ = **1131** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.057** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm^2

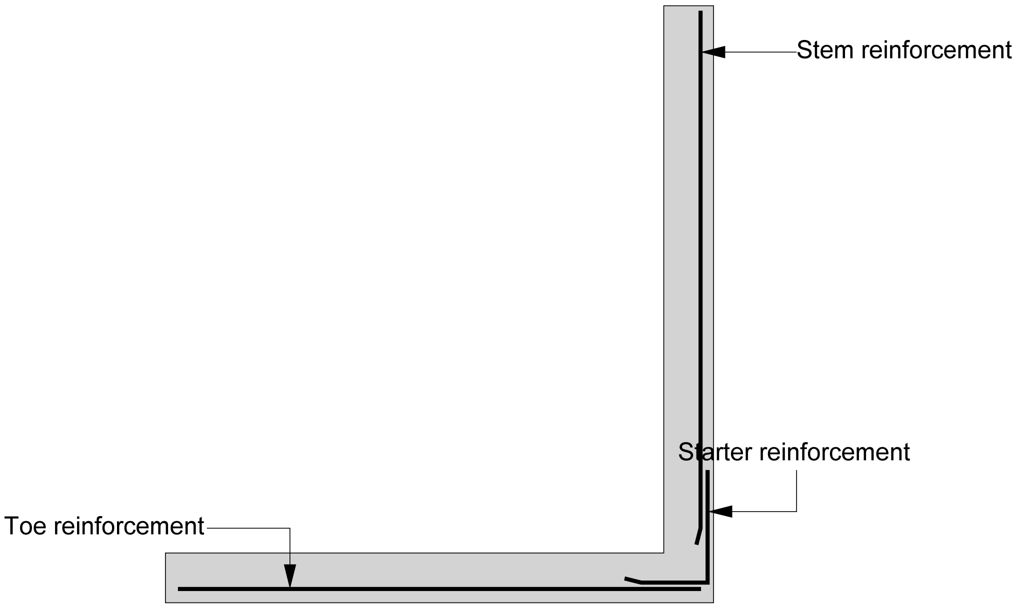
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_stem} = **0.618** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 100 mm centres - (2011 mm^2/m)

Stem mesh - B1131 - (1131 mm^2/m)

RETAINING WALL C DESIGN

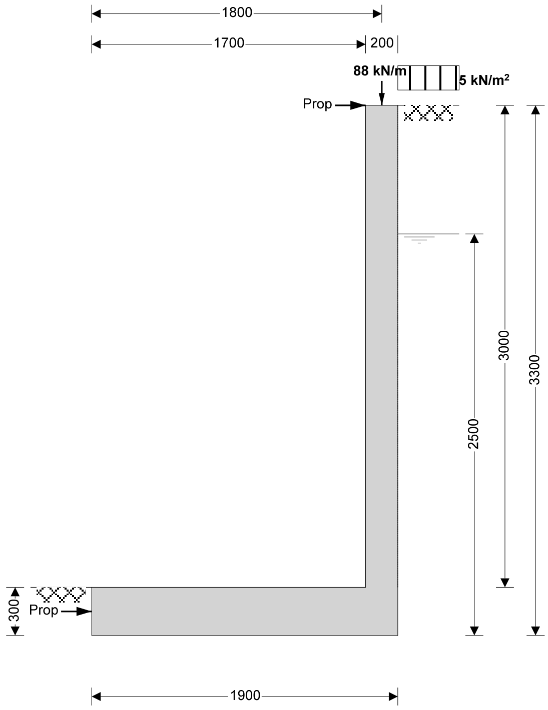
Loading

retaining wall C										
ground floor slab	4.5	0.5	2.25	g_k		7.00	15.7			
				q_k		1.50			3.4	
1st and 2nd	4.5	0.5	2.25	g_k	2	4.18	18.8			
				q_k		1.50			6.8	
timber roof	4.5	0.5	2.25	g_k		1.03	2.3			
				q_k		0.75			1.7	
timber wall	3	1	3	g_k		0.52	1.6			
block walls	9	1	9	g_k	2	4.08	36.7			
							75.1	kN/m	11.8	kN/m

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Croft Structural Engineers Rear of 60 Saxon Rd Selhurst SE25 5EH	Project 23A Ravenshaw Street			Job Ref. 150122	
	Section Scheme Design Structural Calculations			Sheet no./rev. 9 1	
	Calc. by EP	Date 05/07/2016	Chk'd by PDH	Date	App'd by	Date



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **200** mm
Length of toe	l_{toe} = **1700** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1900** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3300** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2500** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **2200** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3300** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.419}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 – \sin(\phi') = \mathbf{0.590}$

Loading details

Surcharge load on plan Surcharge = **5.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **76.0** kN/m

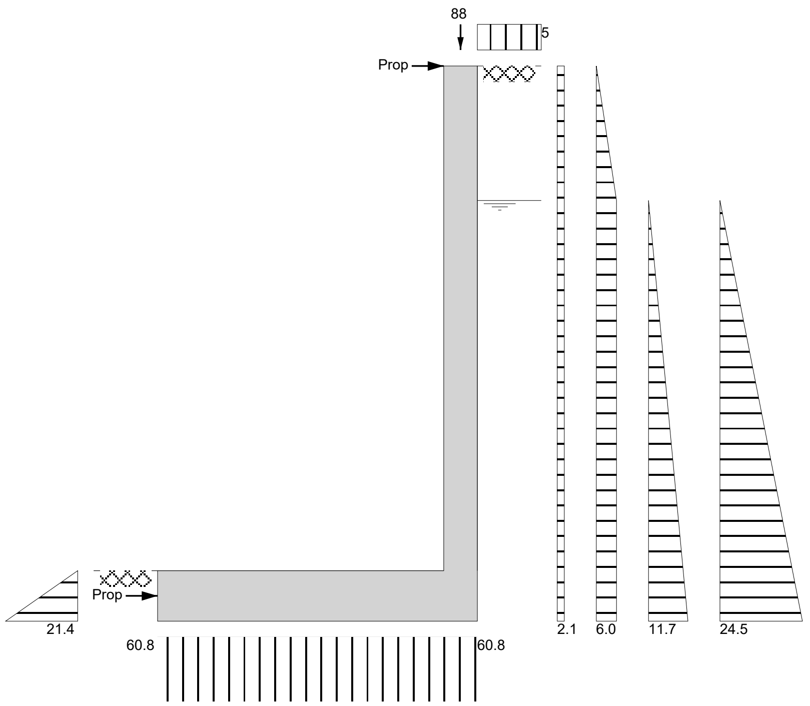
Applied vertical live load on wall W_{live} = **12.0** kN/m

Position of applied vertical load on wall l_{load} = **1800** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **14.2** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **13.5** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **88** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **115.6** kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = \mathbf{6.9}$ kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = \mathbf{2.4}$ kN/m

Moist backfill below water table — $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water} = \mathbf{15.1}$ kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = \mathbf{14.6}$ kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water} = \mathbf{30.7}$ kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water} = \mathbf{69.7}$ kN/m

Calculate total propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = \mathbf{3.2}$ kN/m

Propping force — $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

$F_{prop} = \mathbf{31.6}$ kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{11.4}$ kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \mathbf{6.7}$ kNm/m

Moist backfill below water table — $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2 = \mathbf{18.8}$ kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{12.2}$ kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{25.5}$ kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water} = \mathbf{74.6}$ kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \mathbf{25.5}$ kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2 = \mathbf{12.8}$ kNm/m

Design vertical dead load — $M_{dead} = W_{dead} \times l_{load} = \mathbf{136.8}$ kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_{dead} = \mathbf{175.1}$ kNm/m

Check bearing pressure

Total vertical reaction — $R = W_{total} = \mathbf{115.6}$ kN/m

Distance to reaction — $x_{bar} = l_{base} / 2 = \mathbf{950}$ mm

Eccentricity of reaction — $e = \text{abs}((l_{base} / 2) - x_{bar}) = \mathbf{0}$ mm

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = \mathbf{60.8}$ kN/m^2

Bearing pressure at heel — $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = \mathbf{60.8}$ kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{1.481}$ kN/m

Propping force to base of wall — $F_{prop\_base} = F_{prop} - F_{prop\_top} = \mathbf{30.110}$ kN/m

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **19.8** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **18.8** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **125.6** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **164.3** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **15.6** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **4.8** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **29.7** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **28.9** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **42.9** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **121.9** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0\ kN/m)$

F_{prop_f} = **68.6** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25.7** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **13.2** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **37.2** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **24.1** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.8** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **135.9** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **35.7** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **17.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **226.1** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **279.7** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **164.3** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **950** mm

Eccentricity of reaction $e_f = abs((l_{base} / 2) - x_{bar\_f})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **86.5** kN/m^2

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **86.5** kN/m^2

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0\ kN/m^2)$ = **86.5** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2)$ = **86.5** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) = \mathbf{86.5}\ kN/m^2$

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{0.631}\ kN/m$

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = \mathbf{67.936}\ kN/m$

<u>Design of reinforced concrete retaining wall toe (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}\ N/mm^2$

Characteristic strength of reinforcement $f_y = \mathbf{500}\ N/mm^2$

Base details

Minimum area of reinforcement $k = \mathbf{0.13}\ \%$

Cover to reinforcement in toe $c_{toe} = \mathbf{75}\ mm$

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{147}\ kN/m$

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{16.9}\ kN/m$

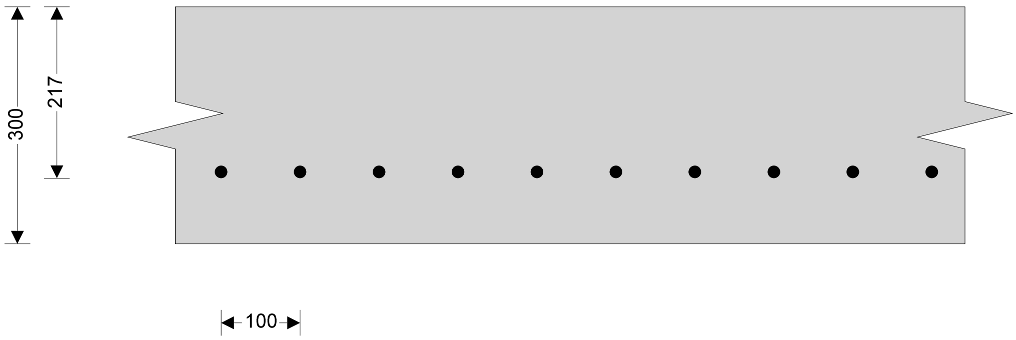
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{130.1}\ kN/m$

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{140.1}\ kNm/m$

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{16.1}\ kNm/m$

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{124}\ kNm/m$



Check toe in bending

Width of toe $b = \mathbf{1000}\ mm/m$

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{217.0}\ mm$

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.066}$

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

$z_{toe} = \mathbf{200}\ mm$

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{1427}\ mm^2/m$

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{390}\ mm^2/m$

Area of tension reinforcement required $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{1427}\ mm^2/m$

Reinforcement provided **16 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{2011}\ mm^2/m$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.600}\ N/mm^2$

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.840** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **50** mm

Cover to reinforcement in wall c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **14.2** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **4.8** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **26.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **22.4** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **33.2** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **8.9** kN/m

Moist backfill above water table $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b_l^2) / (5 \times L^3)$ = **1.2** kN/m

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8$ = **20.2** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **19.7** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **29.3** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f}$ = **79.3** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **5.6** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **1.2** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8$ = **12.1** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **9.2** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **13.6**
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **41.7** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **3.1** kNm/m

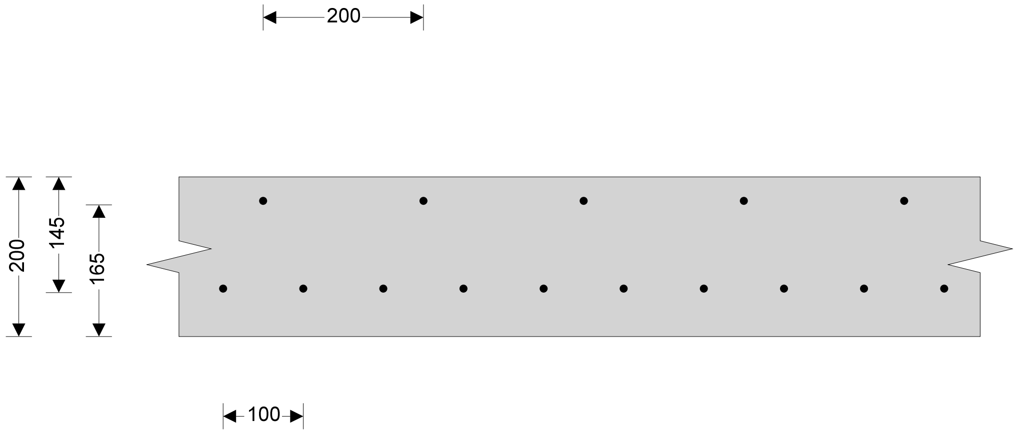
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3]$ = **1.4**
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4-n))^2 / 16) - 4 + n \times (4-n)]/8$ = **6.3** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **3.5** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **5.3**
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water}$ = **19.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **145.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.050**

Compression reinforcement is not required

Lever arm — $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **137** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **702** mm^2/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **260** mm^2/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **702** mm^2/m

Reinforcement provided — **B785 mesh**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **785** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.547** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \mathrm{N/mm^2})}, 5) \times 1\ \mathrm{N/mm^2}$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.777** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check mid height of wall in bending

Depth of reinforcement — $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **165.0** mm

Constant — $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.018**

Compression reinforcement is not required

Lever arm — $z_{wall} = \mathrm{Min}(0.5 + \sqrt{(0.25 - (\min(K_{wall}, 0.225) / 0.9))}, 0.95) \times d_{wall}$

z_{wall} = **157** mm

Area of tension reinforcement required — $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **288** mm^2/m

Minimum area of tension reinforcement — $A_{s\_wall\_min} = k \times b \times t_{wall}$ = **260** mm^2/m

Area of tension reinforcement required — $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min})$ = **288** mm^2/m

Reinforcement provided — **A393 mesh**

Area of reinforcement provided — $A_{s\_wall\_prov}$ = **393** mm^2/m

PASS - Reinforcement provided to the retaining wall at mid height is adequate

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **20**

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **298.1** N/mm²

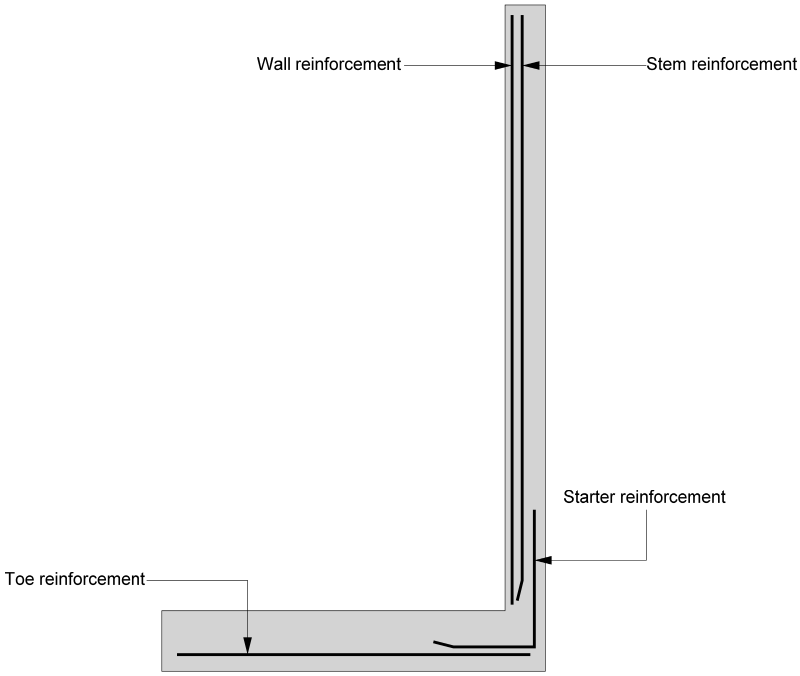
Modification factor $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.07**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **21.34**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **20.69**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 100 mm centres - (2011 mm^2/m)

Wall mesh - A393 - (393 mm^2/m)

Stem mesh - B785 - (785 mm^2/m)

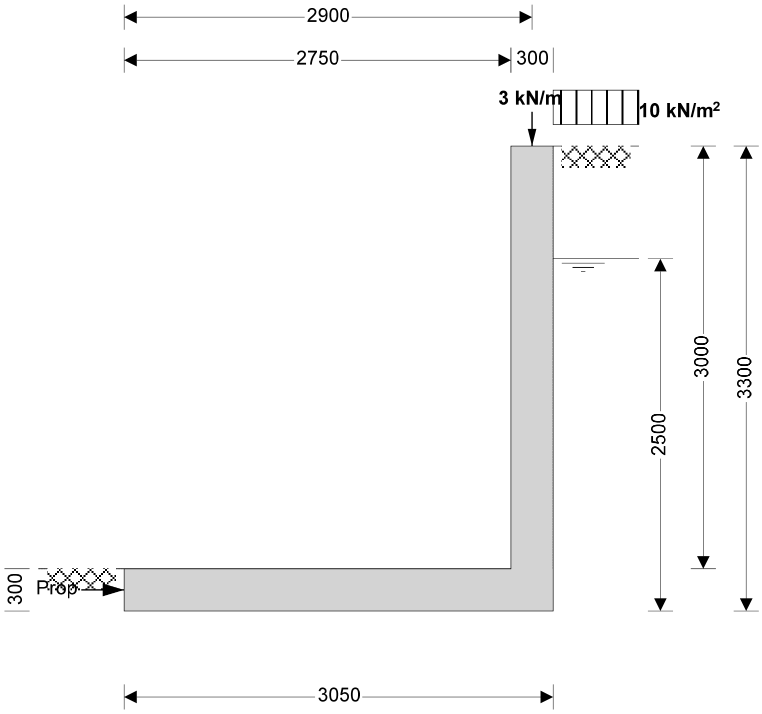
RETAINING WALL D/D'

Loading

retaining wall D/D'/E/E'/G										
brick wall/fence	0.5	1	0.5	g_k		5.00	2.5			
							2.5	kN/m	0.0	kN/m
5.0kN/m2 surcharge										

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **2750** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **3050** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3300** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2500** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **2200** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3300** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density — γ_{mb} = **18.0** kN/m^3

Design shear strength — ϕ'_b = **24.2** deg

Design base friction — δ_b = **18.6** deg

Allowable bearing pressure — $P_{bearing}$ = **100** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.419}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material — $K_0 = 1 - \sin(\phi') = \mathbf{0.590}$

Loading details

Surcharge load on plan — Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall — W_{dead} = **2.5** kN/m

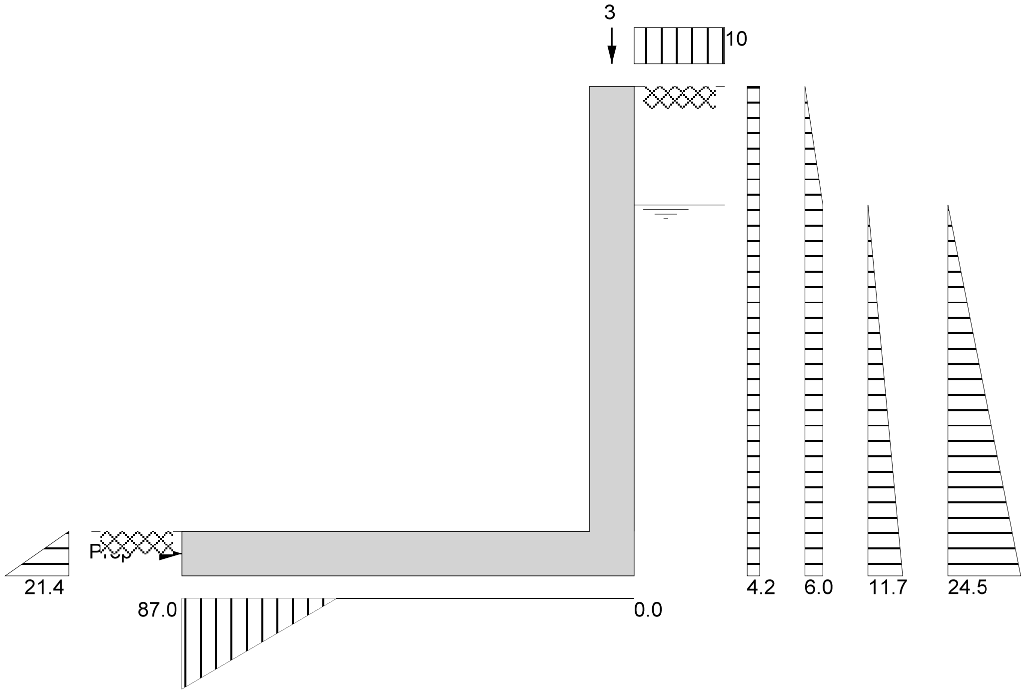
Applied vertical live load on wall — W_{live} = **0.0** kN/m

Position of applied vertical load on wall — l_{load} = **2900** mm

Applied horizontal dead load on wall — F_{dead} = **0.0** kN/m

Applied horizontal live load on wall — F_{live} = **0.0** kN/m

Height of applied horizontal load on wall — h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **21.2** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **21.6** kN/m

Applied vertical load — $W_v = W_{dead} + W_{live}$ = **2.5** kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v$ = **45.3** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = \mathbf{13.8}$ kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = \mathbf{2.4}$ kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water} = \mathbf{15.1}$ kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = \mathbf{14.6}$ kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water} = \mathbf{30.7}$ kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water} = \mathbf{76.6}$ kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = \mathbf{3.2}$ kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total}) \times \tan(\delta_b), 0 \text{ kN/m})$

$F_{prop} = \mathbf{58.1}$ kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{22.8}$ kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \mathbf{6.7}$ kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2 = \mathbf{18.8}$ kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{12.2}$ kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{25.5}$ kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water} = \mathbf{86}$ kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \mathbf{61.6}$ kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2 = \mathbf{32.9}$ kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load} = \mathbf{7.3}$ kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead} = \mathbf{101.8}$ kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot} = \mathbf{15.7}$ kNm/m

Total vertical reaction $R = W_{total} = \mathbf{45.3}$ kN/m

Distance to reaction $x_{bar} = M_{total} / R = \mathbf{347}$ mm

Eccentricity of reaction $e = \text{abs}((l_{base} / 2) - x_{bar}) = \mathbf{1178}$ mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe} = R / (1.5 \times x_{bar}) = \mathbf{87}$ kN/m^2

Bearing pressure at heel $p_{heel} = 0$ kN/m^2 $= \mathbf{0}$ kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **29.7** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **30.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **3.5** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **63.5** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **31.2** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **4.8** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **29.7** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **28.9** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **42.9** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **137.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **111.6** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **51.4** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **13.2** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **37.2** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **24.1** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.8** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **161.6** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **86.2** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **46.1** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **10.2** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **142.5** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **-19.1** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **63.5** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **-301** mm

Eccentricity of reaction $e_f = abs((l_{base} / 2) - x_{bar\_f})$ = **1826** mm

WARNING - Beyond scope of calculation

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **-140.6** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction $rate = p_{toe\_f} / (3 \times x_{bar\_f})$ = **155.76** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **0** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) = \mathbf{0}\ kN/m^2$

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) = \mathbf{0}\ kN/m^2$

<u>Design of reinforced concrete retaining wall toe (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}\ N/mm^2$

Characteristic strength of reinforcement $f_y = \mathbf{500}\ N/mm^2$

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe $c_{toe} = \mathbf{75}$ mm

Calculate shear for toe design

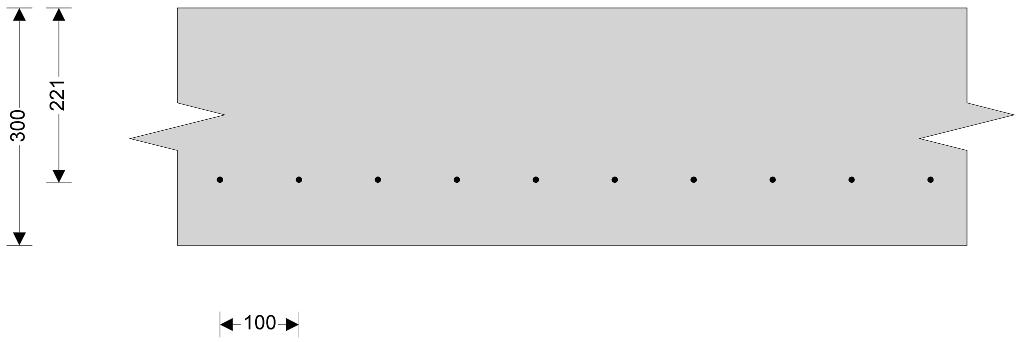
Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{27.3}\ kN/m$

Total shear for toe design $V_{toe} = V_{toe\_wt\_base} = \mathbf{27.3}\ kN/m$

Calculate moment for toe design

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{41.7}\ kNm/m$

Total moment for toe design $M_{toe} = M_{toe\_wt\_base} = \mathbf{41.7}\ kNm/m$



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{221.0}$ mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.021}$

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

$z_{toe} = \mathbf{210}$ mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{456}\ mm^2/m$

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{390}\ mm^2/m$

Area of tension reinforcement required $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{456}\ mm^2/m$

Reinforcement provided **B503 mesh**

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{503}\ mm^2/m$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.123}\ N/mm^2$

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 = \mathbf{5.000}\ N/mm^2$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_toe} = \mathbf{0.523}\ N/mm^2$

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **75** mm

Cover to reinforcement in wall c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **28.3** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **4.8** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **26.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **22.4** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **33.2** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **3.3** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **46.7** kNm/m

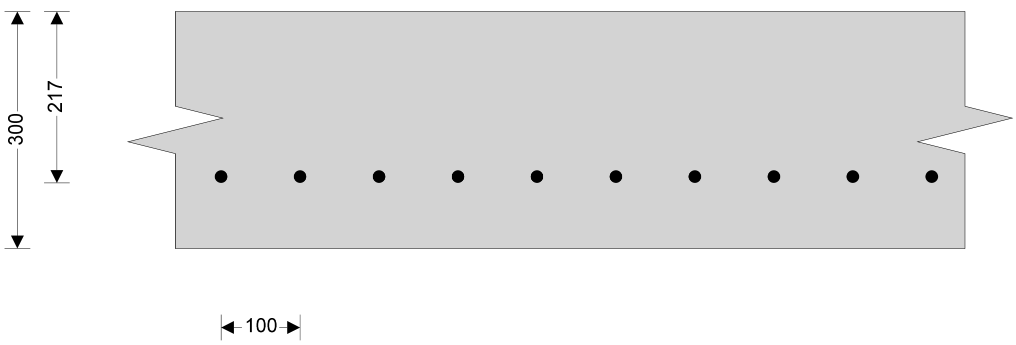
Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **12.5** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **28.8** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **16.4** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **24.4** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **128.8** kNm/m



Check wall stem in bending

Width of wall stem b = **1000** mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **217.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.068**

Compression reinforcement is not required

Lever arm $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **199** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **1487** mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **390** mm^2/m

Area of tension reinforcement required $A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **1487** mm^2/m

Reinforcement provided **16 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s\_stem\_prov}$ = **2011** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.015** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2$ = **5.000** N/mm^2

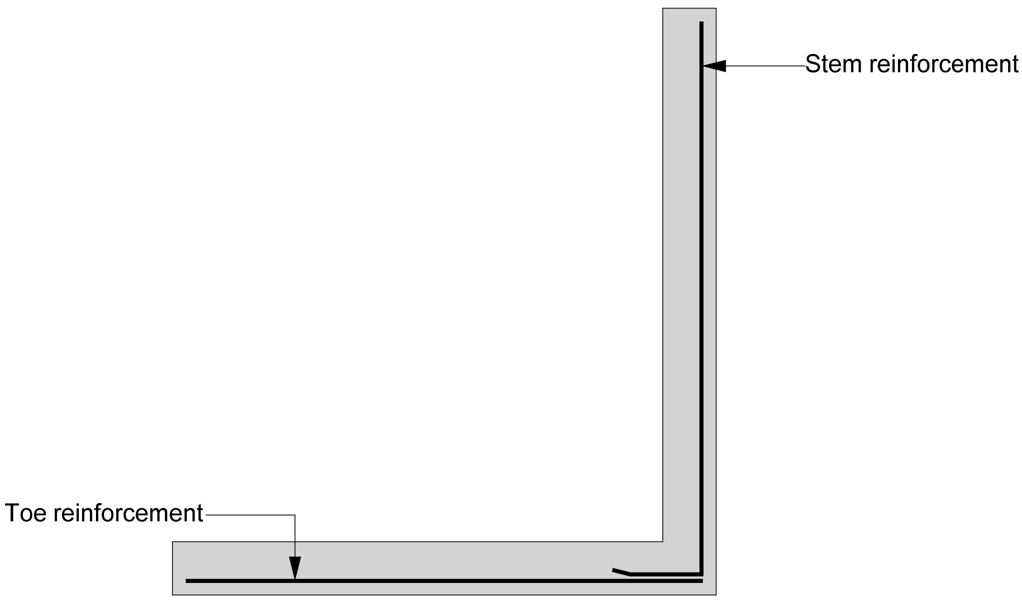
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_stem} = **0.840** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Indicative retaining wall reinforcement diagram

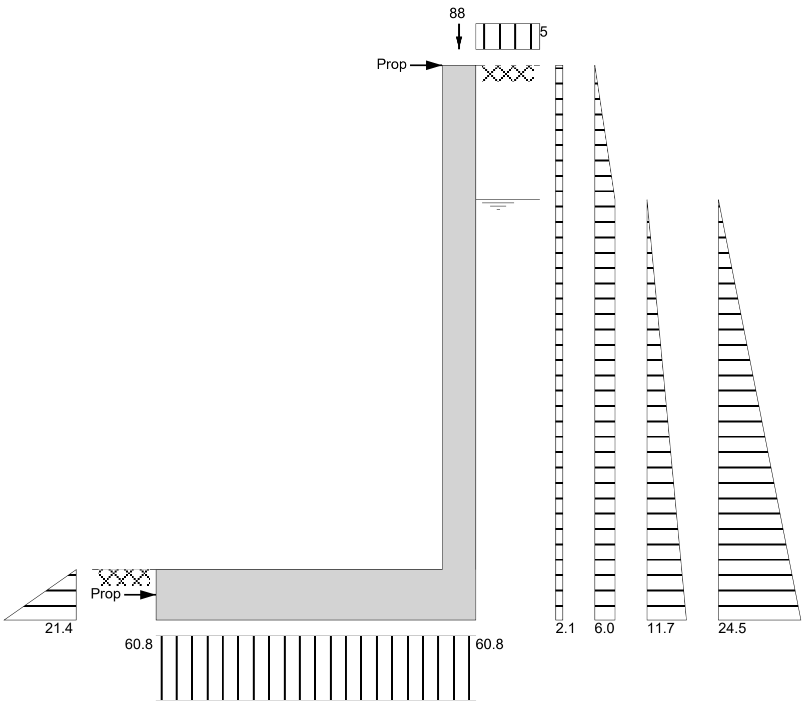


Toe mesh - B503 - (503 mm^2/m)

Stem bars - 16 mm dia.@ 100 mm centres - (2011 mm^2/m)

RETAINING WALL DEFLECTION DESIGN

Loading



CONCRETE BEAM ANALYSIS

Concrete beam dimensions:-

Beam width b = **300** mm

Beam depth h = **1000** mm

Cross-section area A = b × h = **300000** mm^2

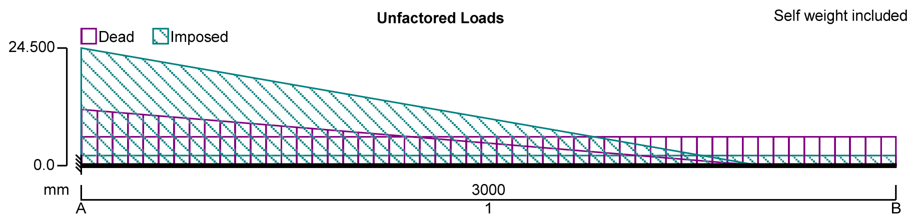
Major axis second moment of area I_{xx} = b × h^3 / 12 = **25.0×10⁹** → 25.0×10^9 mm^4

f_{cu} = **35** N/mm^2

E = 20 kN/mm^2 + 200 × f_{cu} = **27.0** kN/mm^2

Ref BS8110:1985:Pt 2 - Eq 17

$\rho = \rho_{C.norm}$ = **2400** kg/m^3



CONTINUOUS BEAM ANALYSIS - INPUT

BEAM DETAILS

Number of spans = **1**

Material Properties:

Modulus of elasticity = **27** kN/mm^2 Material density = **2400** kg/m^3

Support Conditions:

Support A Vertically **"Restrained"** Rotationally **"Restrained"**

Support B Vertically **"Free"** Rotationally **"Free"**

Span Definitions:

Span 1 Length = **3000** mm Cross-sectional area = **300000** mm^2 Moment of inertia = **25.0×10⁹** mm^4

LOADING DETAILS

Beam Loads:

Load 1 Self weight Dead load = **1.000**

Load 2 UDL Imposed load **2.1** kN/m

Load 3 UDL Dead load **6.0** kN/m

Load 4 Partial VDL Dead load **11.7** kN/m at **0.000** m to **0.0** kN/m at **2.500** m

Load 5 Partial VDL Imposed load **24.5** kN/m at **0.000** m to **0.0** kN/m at **2.500** m

LOAD COMBINATIONS

Load combination 1 - uls

Span 1 1.4×Dead + 1.6×Imposed

Load combination 2 - sls

Span 1 1×Dead + 1×Imposed

CONTINUOUS BEAM ANALYSIS - RESULTS

Support Reactions - Combination Summary

Support A Max react = **-90.7** kN Min react = **-134.4** kN Max mom = **-105.9** kNm Min mom = **-155.3** kNm

Support B Max react = **0.0** kN Min react = **0.0** kN Max mom = **0.0** kNm Min mom = **0.0** kNm

Beam Max/Min results - Combination Summary

Maximum shear = **134.4** kN

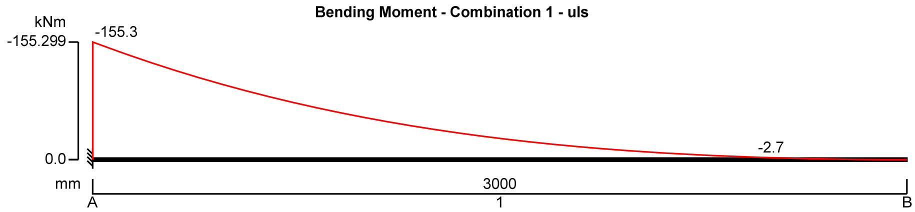
Minimum shearF_{min} = **0.0** kN

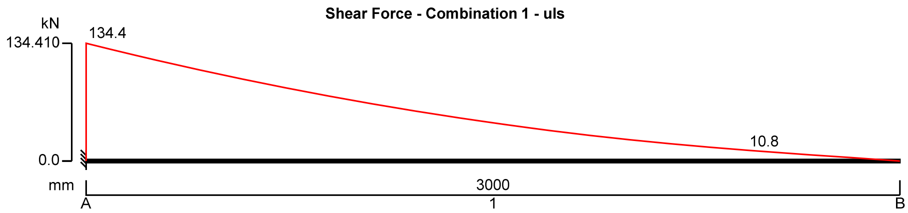
Maximum moment = **0.0** kNm

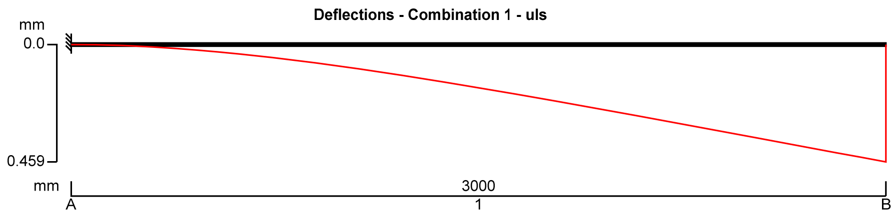
Minimum moment = **-155.3** kNm

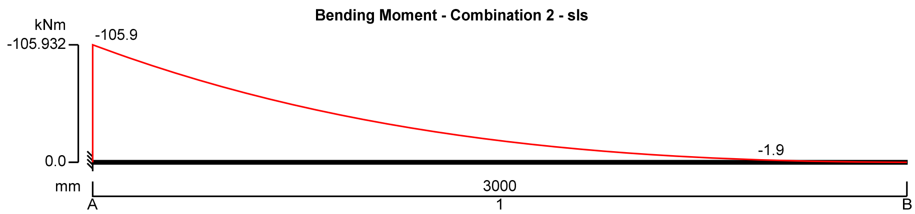
Maximum deflection = **0.5** mm

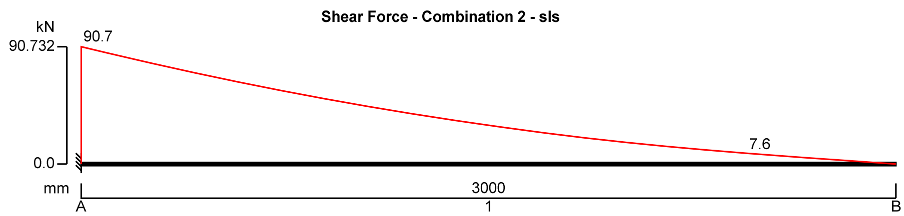
Minimum deflection = **0.0** mm











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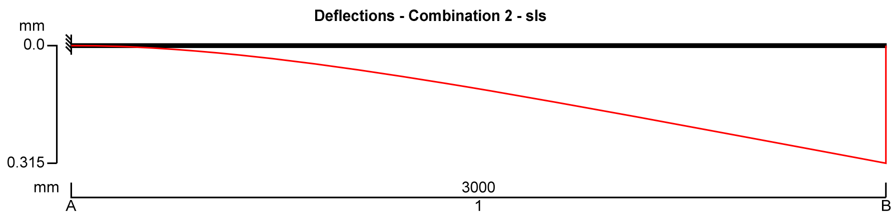
	Section Scheme Design Structural Calculations			Sheet no./rev. 28 1	
	Calc. by EP	Date 05/07/2016	Chk'd by PDH	Date	App'd by	Date



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Date Jun-16	Rev	Date	Description
By pdh			
Checked			
Job No 150122	Status		Rev

Ref

Movement of closest neighbouring property (No. 21 Ravenshaw Street)

Neighbouring building

Building width, L = 6000 mm

Distance to furthest point of building from excavation & installation, L_1 = 6000 mm

Height H= 10800 mm

L/H = 0.56

Excav'n depth H_b= 3.5 m

analysis depth, D = 3.5 m

Note: the height of the neighbouring building varies. Conservatively, the lowest height is used (height to eaves).

Movement Assessment CIRIA C580: Embedded retaining walls - guidance for economic design

Table A

distance from wall in mm (x)	movement due to wall installation	
	horizontal (δ_h) in mm	vertical (δ_v) in mm
0	0.0	0.0
2000	0.0	0.0
4000	0.0	0.0
6000	0.0	0.0
8000	0.0	0.0
10000	0.0	0.0
12000	0.0	0.0
14000	0.0	0.0
16000	0.0	0.0
18000	0.0	0.0
20000	0.0	0.0
22000	0.0	0.0
24000	0.0	0.0
26000	0.0	0.0
28000	0.0	0.0
30000	0.0	0.0
32000	0.0	0.0

Table B

distance from wall in mm (x)	movement due to wall excavation	
	horizontal (δ_h) in mm	vertical (δ_v) in mm
0	-5.3	-1.4
2000	-4.5	-2.7
4000	-3.8	-2.3
6000	-3.0	-1.6
8000	-2.3	-0.9
10000	-1.5	-0.4
12000	-0.8	-0.07
14000	0.0	0.0
16000	0.0	0.0
18000	0.0	0.0
20000	0.0	0.0

Table C

Distance from wall in m (x)	Total Movement		Total Movement	
	horizontal (δ_h) in mm	vertical (δ_v) in mm	heave (in mm)	combined (in mm)
0	-5.3	-1.4	6.4	5.0
2	-4.5	-2.7	3.5	0.8
4	-3.8	-2.3	1.2	-1.1
6	-3.0	-1.6	0.6	-1.0
8	-2.3	-0.9	0.0	-0.9
10	-1.5	-0.4	0.0	-0.4
12	-0.8	-0.1	0.0	-0.1
14	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0

Potential movement due to excavation of wall

using parameters from Table 2.4 of CIRIA C580

(high stiffness: excavation will be propped during construction)

Horizontal Surface Movement / excavation depth				=	-0.15%	
max δ_h =	-0.15%	x	3500	=	-5.25	mm
Distance behind wall to negligible movement (multiple of excav'n d				=	4	
L_0 =	3500	x	4	=	14000	mm

Vertical Surface Movements

Distance behind wall to negligible movement (multiple of excav'n d				=	3.5	
L_0 =	3500	x	3.5	=	12250	mm

Total differential movement - 21 Ravenshaw

(from Graph 1, Sheet GMA - 2)

Total Horizontal Movement	δ_h =	1.9	mm
Total Vertical Movement	Δ =	1.6	mm

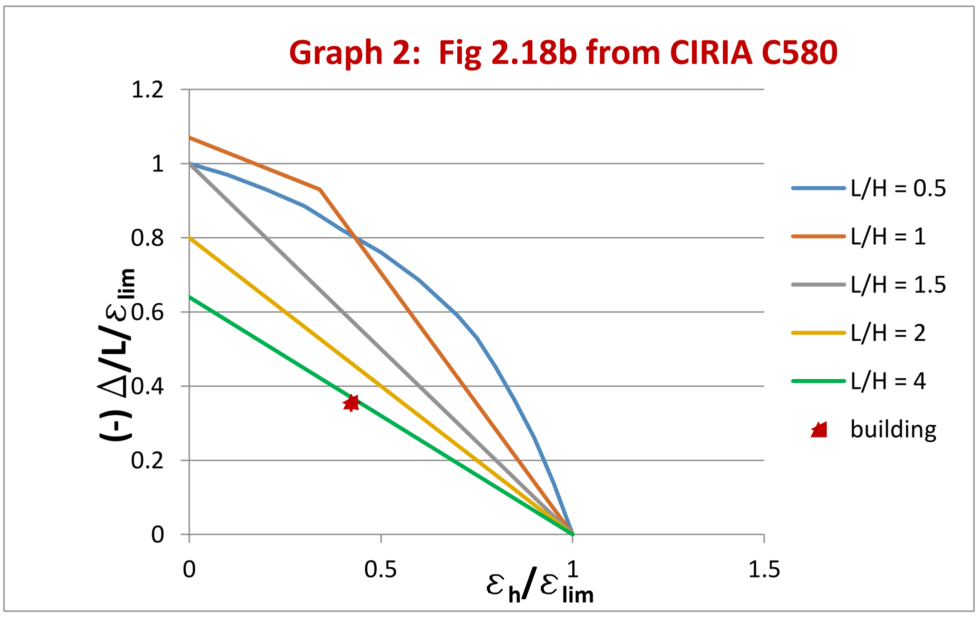
TOTAL STRAIN (EXCAVATION, INSTALLATION AND HEAVE) -

Table 2.5 CIRIA C580

Category of Damage	Normal Degree	Limiting Tensile Strain %		
0	Negligible	0.00%	-	0.05%
1	Very slight	0.05%	-	0.075%
2	Slight	0.075%	-	0.15%
3	Moderate	0.15%	-	0.30%
4 to 5	Severe to Very Severe		>	0.30%

Max Anticipated Damage may be categorised as **'Very Slight' ; Category 1**

ϵ_{lim}	=	**0.075%**			
ϵ_h	=	0.032%	$\epsilon_h/\epsilon_{lim}$	=	0.42
Δ/L	=	0.027%	$\Delta/L/\epsilon_{lim}$	=	0.36



By inspection, No. 25 will be similar

Total differential movement - 19 Ravenshaw

(from Graph 1, Sheet GMA - 2)

Total Horizontal Movement	δ_h =	1.9	mm
Total Vertical Movement	Δ =	0.6	mm

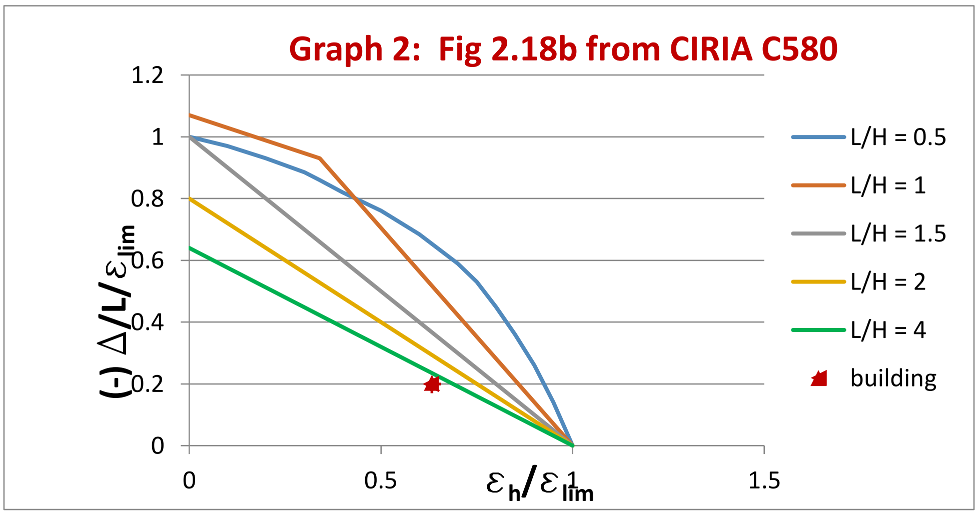
TOTAL STRAIN (EXCAVATION, INSTALLATION AND HEAVE) -

Table 2.5 CIRIA C580

Category of Damage	Normal Degree	Limiting Tensile Strain %		
0	Negligible	0.00%	-	0.05%
1	Very slight	0.05%	-	0.075%
2	Slight	0.075%	-	0.15%
3	Moderate	0.15%	-	0.30%
4 to 5	Severe to Very Severe		>	0.30%

Max Anticipated Damage may be categorised as **'Negligible' ; Category 0**

ϵ_{lim}	=	**0.050%**			
ϵ_h	=	0.032%	$\epsilon_h/\epsilon_{lim}$	=	0.63
Δ/L	=	0.010%	$\Delta/L/\epsilon_{lim}$	=	0.20



By inspection, No. 27 will be similar

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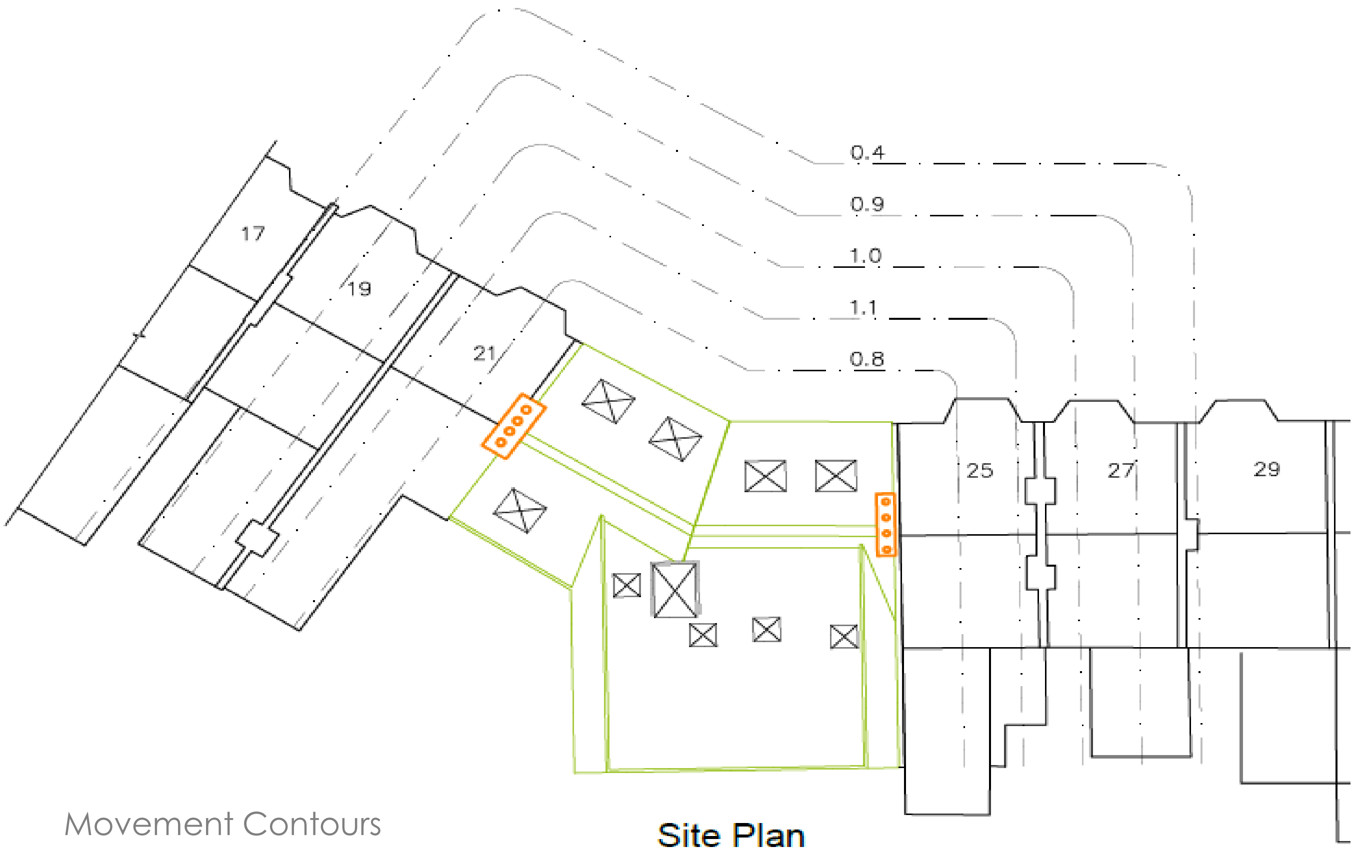
Movement of closest neighbouring property (No. 21 Ravenshaw Street)



Site Plan
(scale 1:200)