



PLANNING APPLICATION PACK

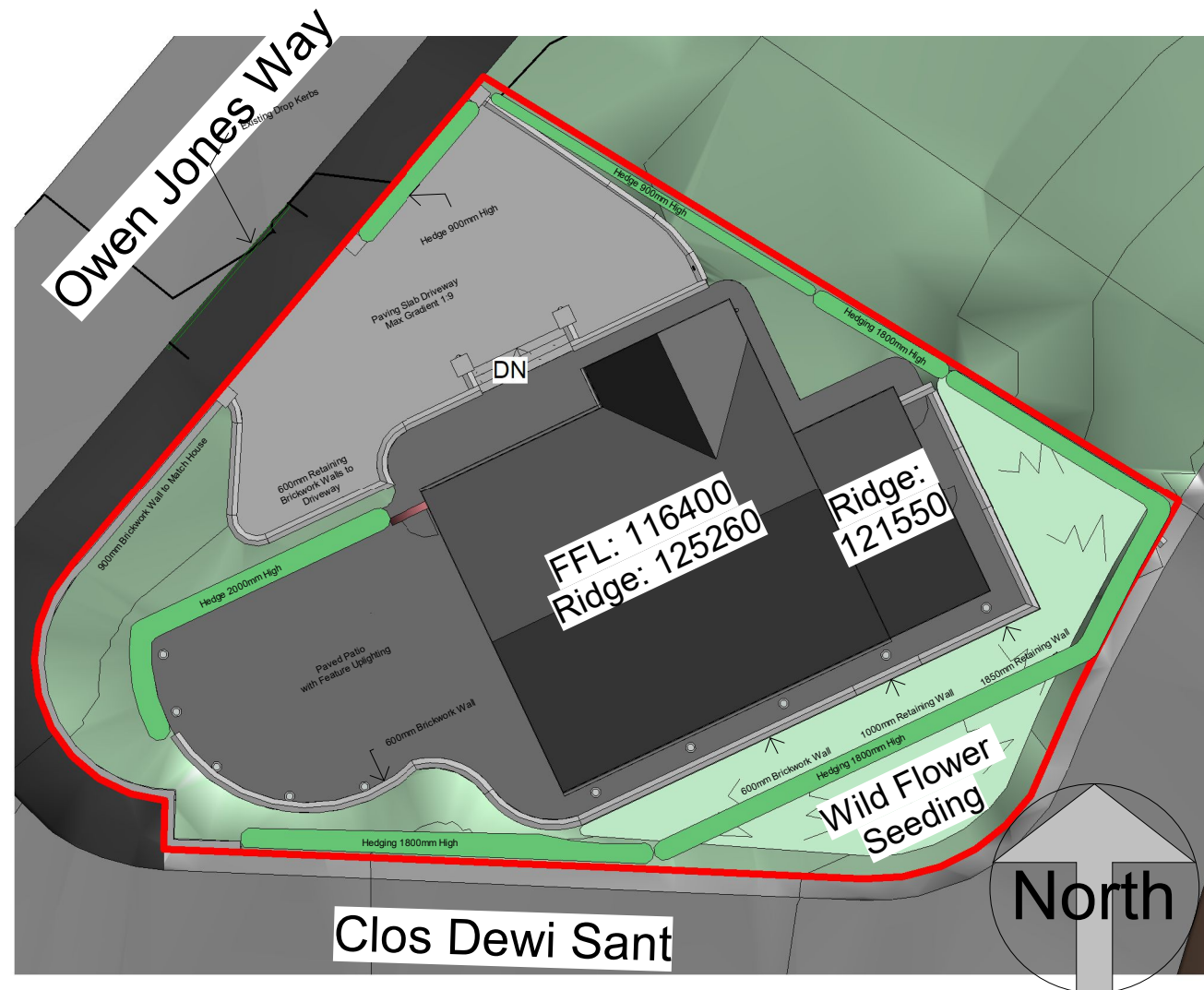
P2019/5078

DETAILS PURSUANT TO CONDITIONS

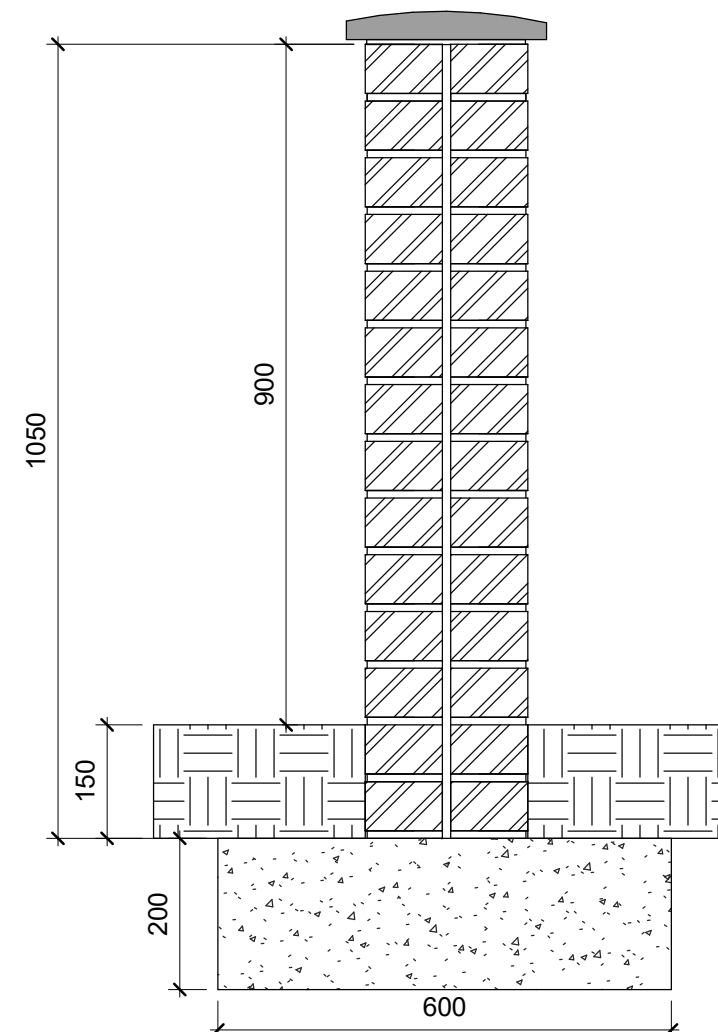
3, 4, 5 & 6

MR IAN MCKAY

**PLOT 29 OWEN JONES WAY
VARTEG FAWR
BRYN
SA13 2RF**



Evergreen Hedge



2 900mm Boundary Wall
1 : 10

NOTES:



DRAWING STATUS

PLANNING

PROJECT

Plot 29 Owen Jones Way, Varteg Fawr, Bryn

TITLE

Boundary Treatments

CLIENT

Mr & Mrs I McKay

DRAWN BY
Gareth Owen

DATE
30.08.19

SCALE (@A3)
As indicated

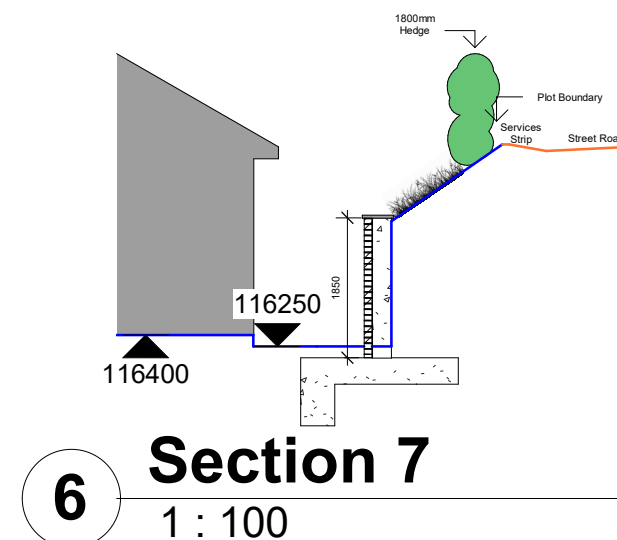
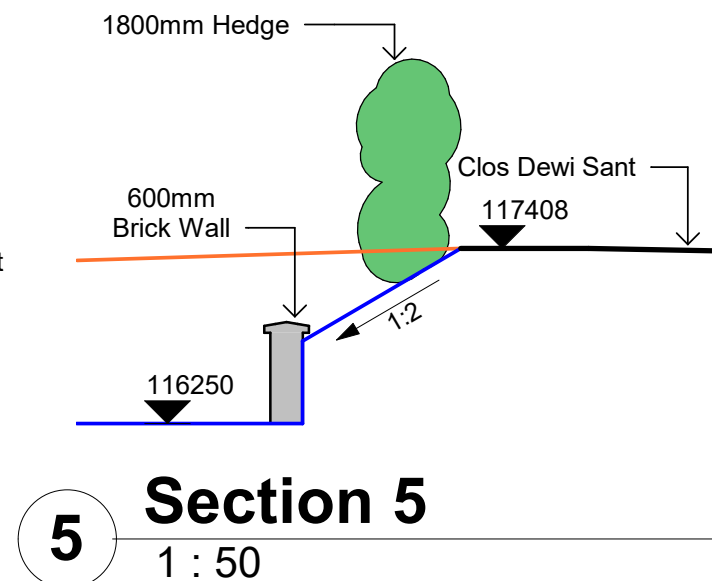
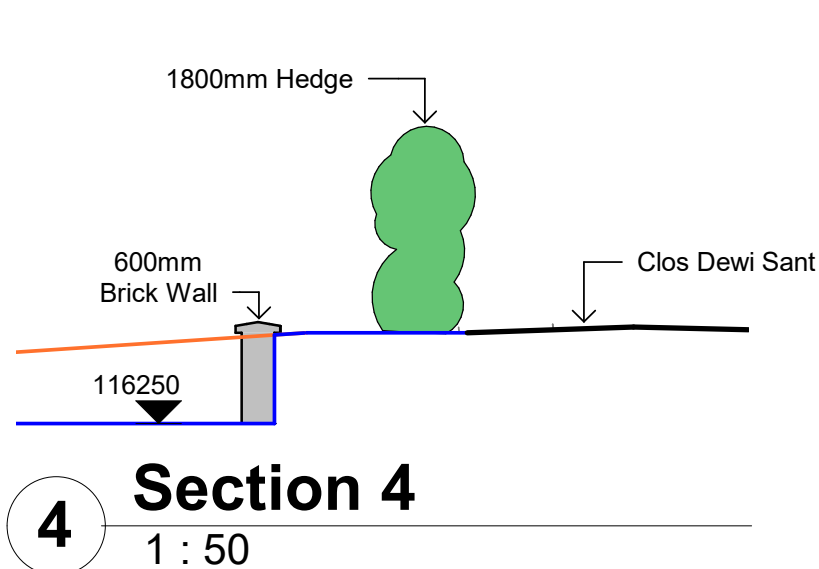
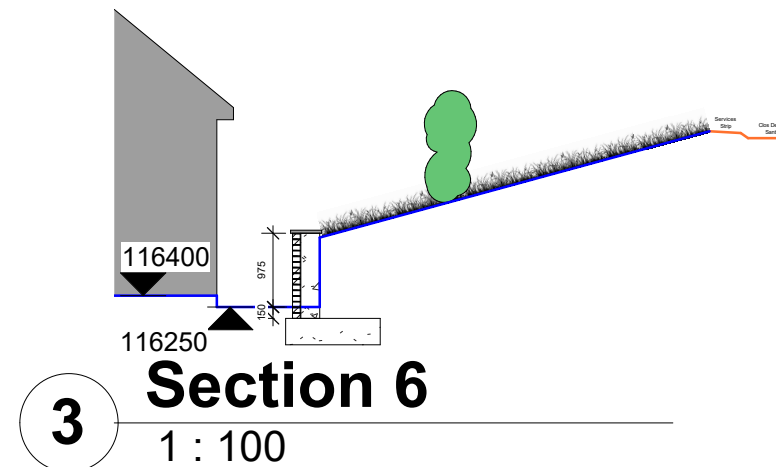
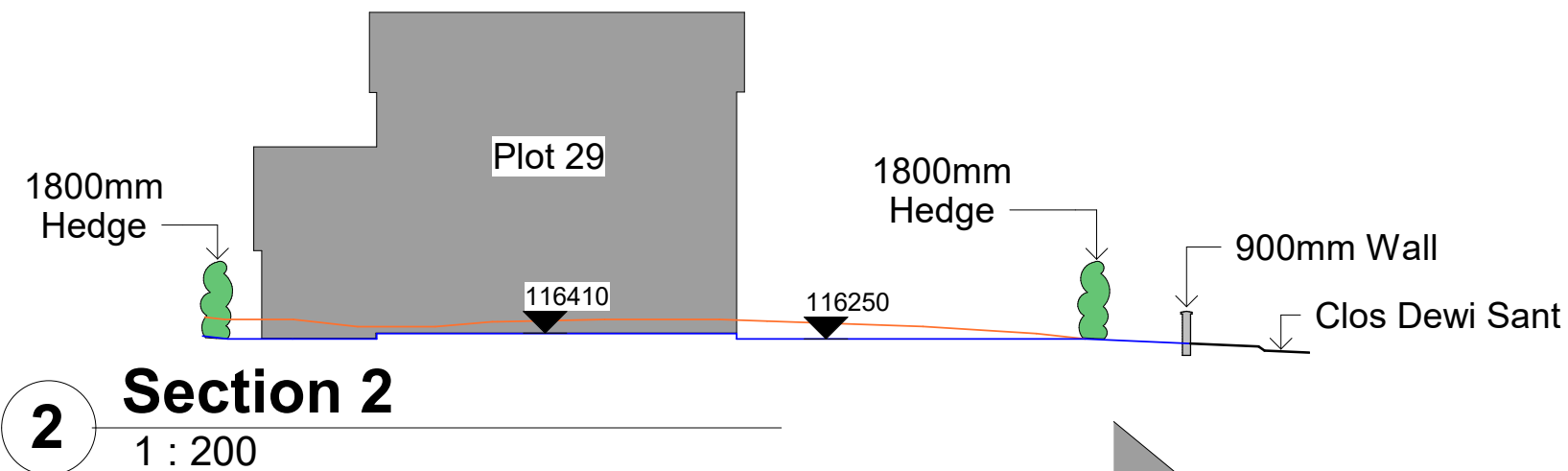
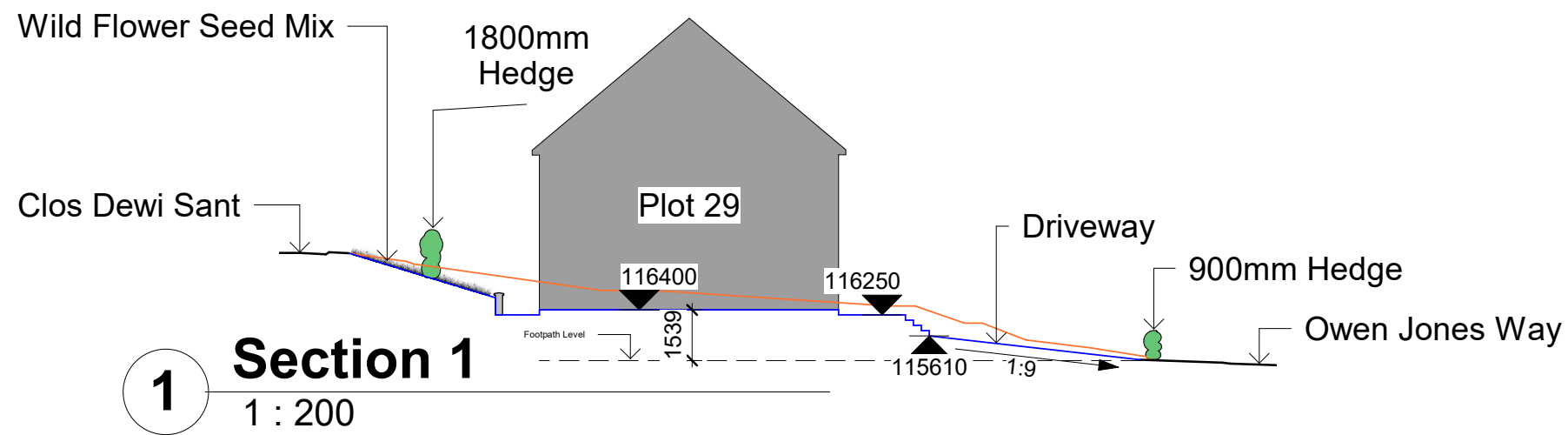
PROJECT NO.
GOCDD IM01

DRAWING NO.
A120 - SITE

REV
P1

GO CONCEPT DESIGNS, 9 DARWIN RD, PORT TALBOT, SA12 6BT
GOConceptDesigns@hotmail.com

1 Boundary Treatments 1 : 200



NOTES:



DRAWING STATUS

PLANNING

PROJECT

Plot 29 Owen Jones Way, Varteg Fawr, Bryn

TITLE

Site Sections

CLIENT

Mr & Mrs I McKay

DRAWN BY

Gareth Owen

DATE

30.08.19

SCALE (@A3)

As indicated

PROJECT NO.

GOC D IM01

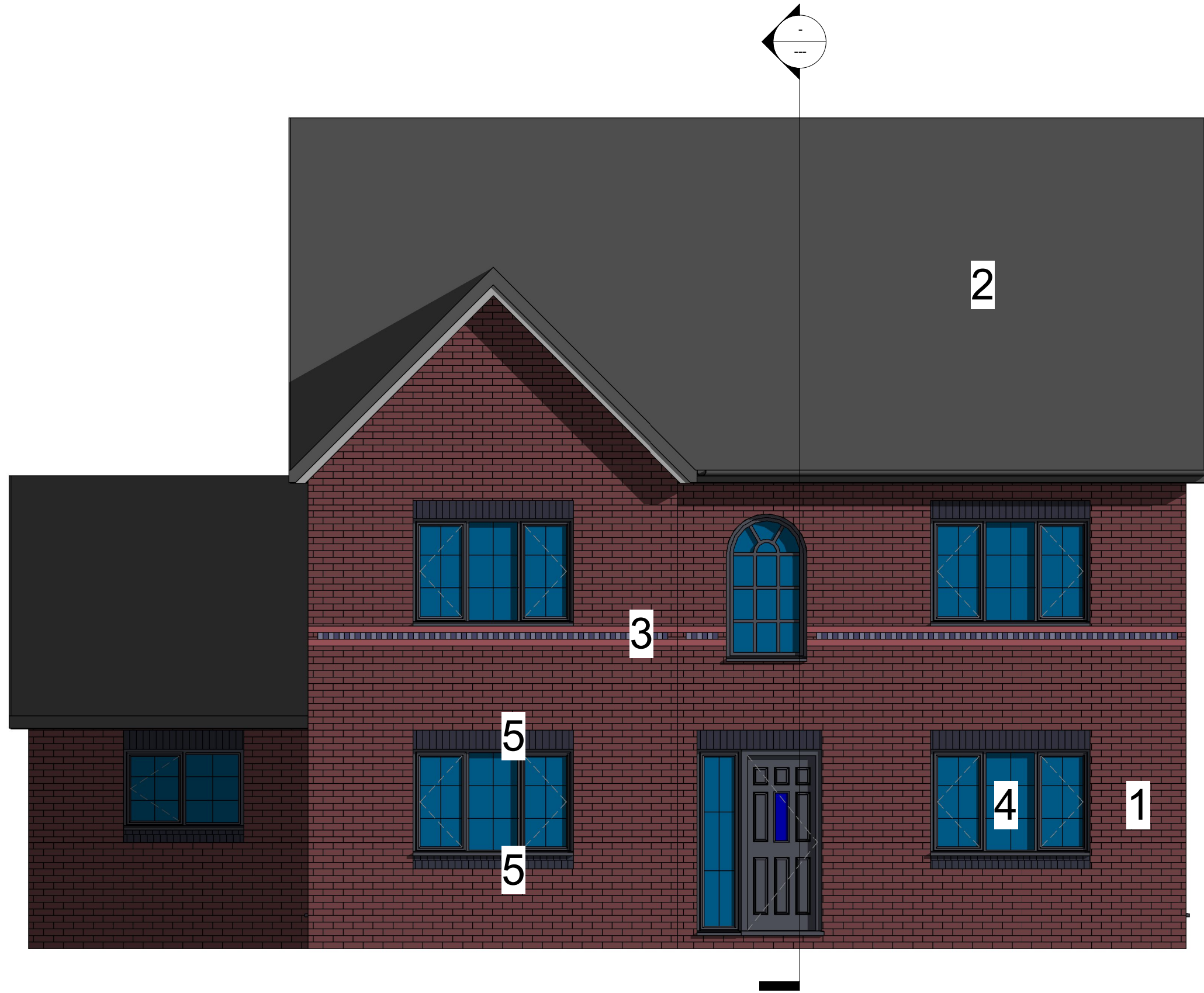
DRAWING NO.

A112 SITE

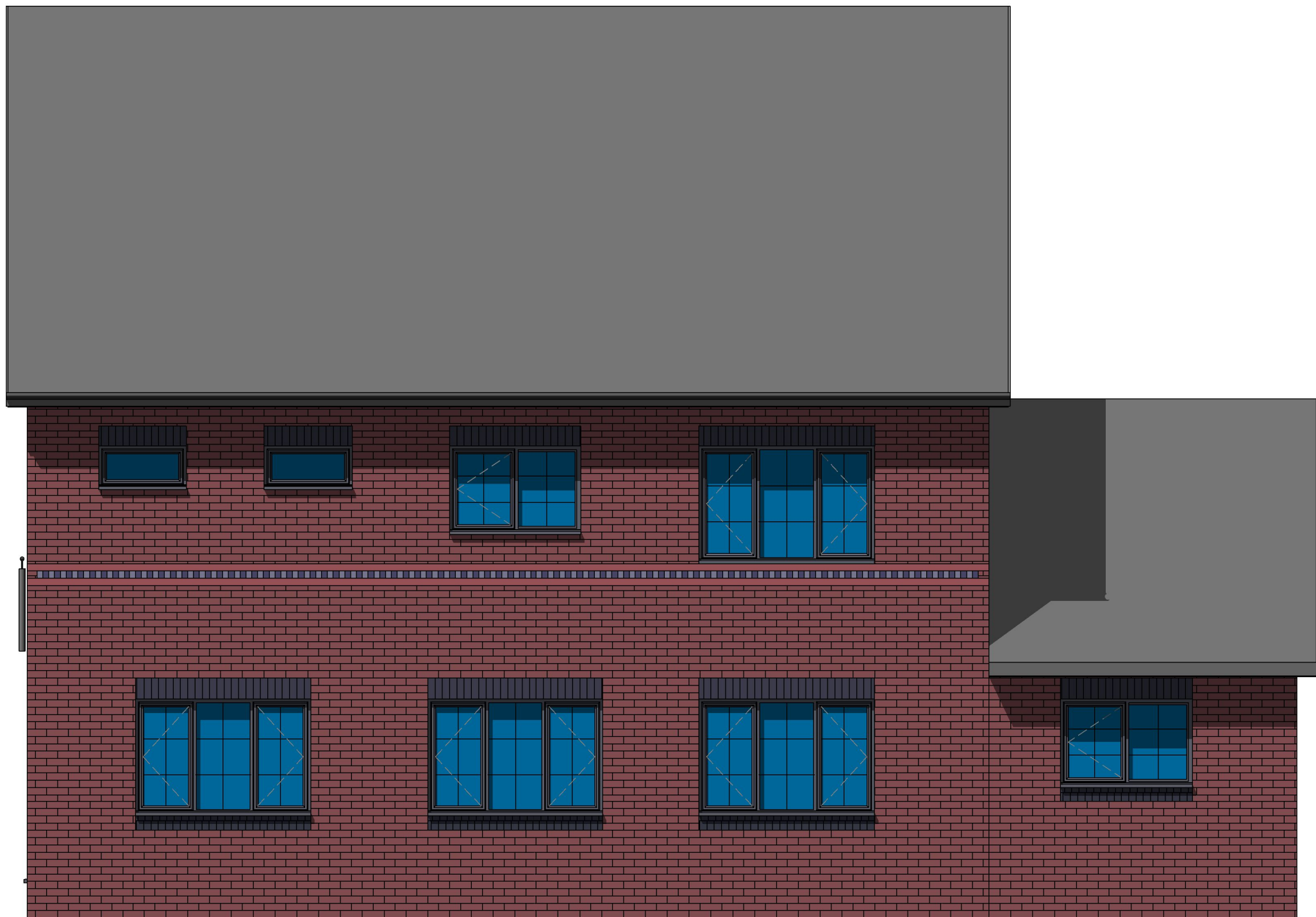
REV

C1

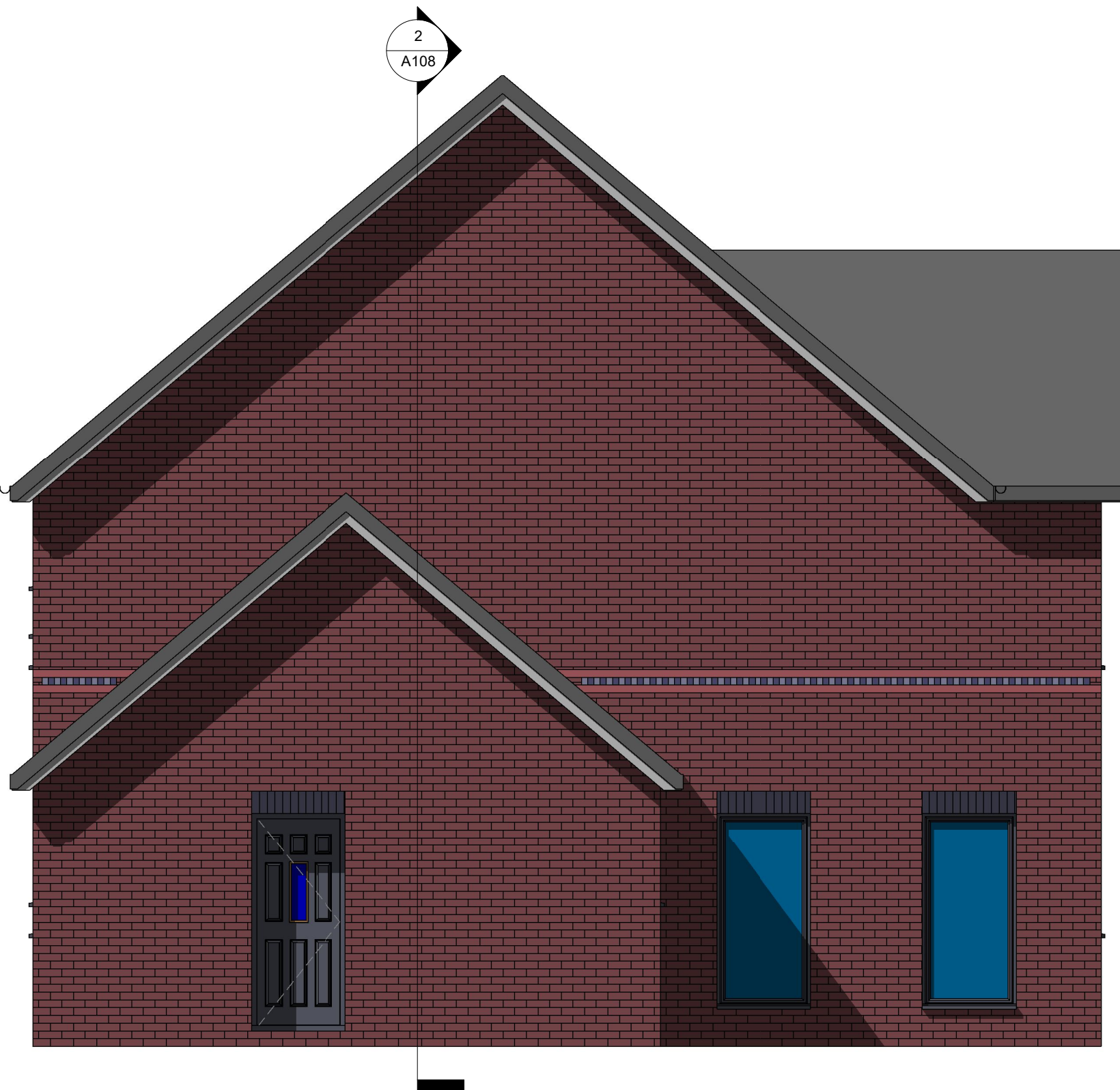
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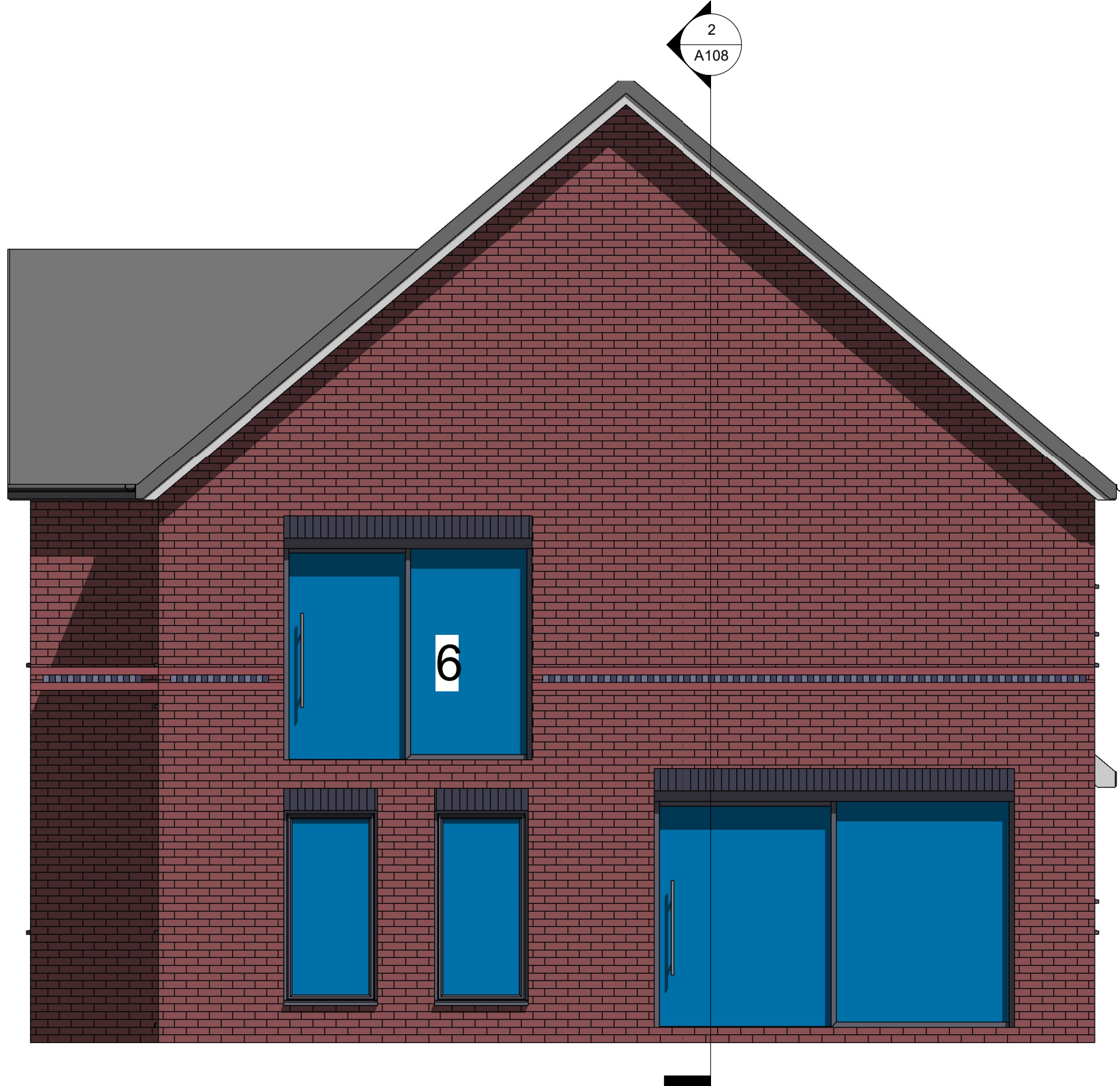
1 Front Brickwork Features
1 : 50



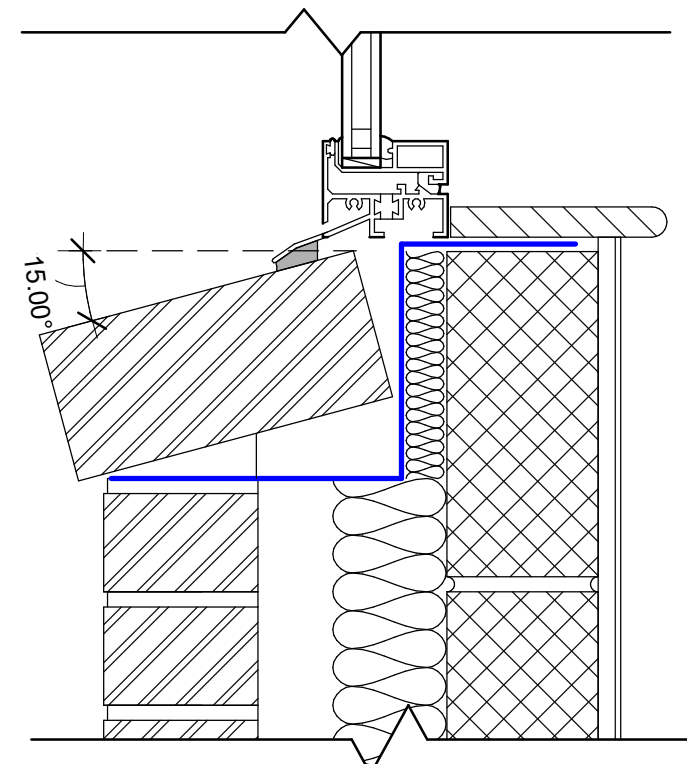
2 Rear Brickwork Features
1 : 50



3 Left Brickwork Features
1 : 50



4 Right Brickwork Features
1 : 50



5 Brick Sill Detail
1 : 5



Forterra Hampton Rural Blend Face Brick
(also used for external wall finishes)



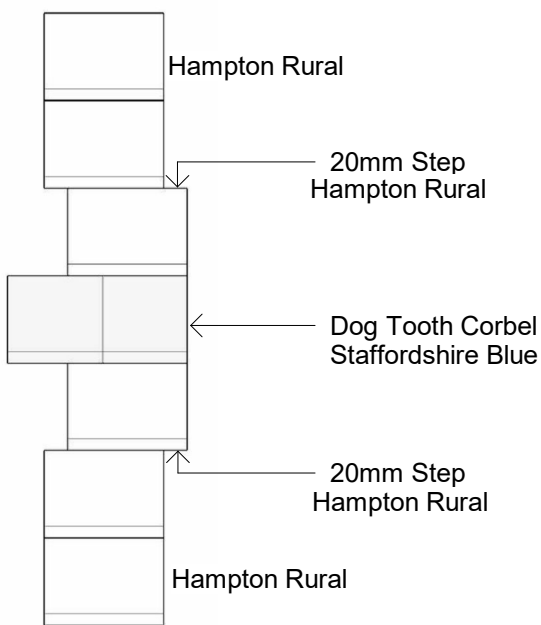
Eternit Thrutone Black/Blue Roof Slate



Staffordshire Blue Soldier Course - Dog Tooth, Soldier Course & Sills



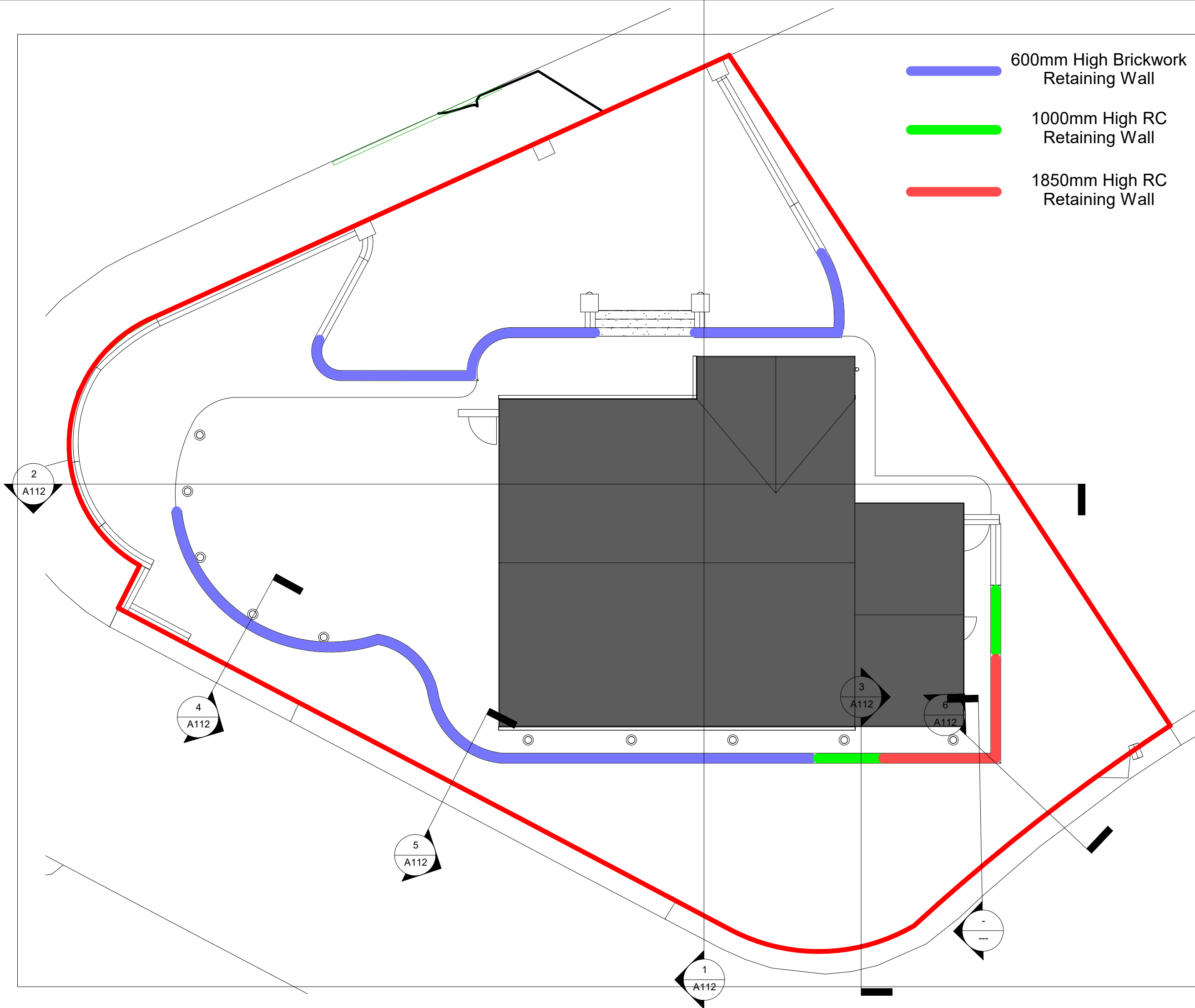
Grey Windows & Doors
Stainless Steel & Glass Juliette Balcony Railing



Dog Tooth Detail



DRAWING STATUS	
PLANNING	
PROJECT	
Plot 29 Owen Jones Way - New Build Detached Dwelling	
TITLE	
Brickwork Features	
CLIENT	
Mr & Mrs I McKay	
DRAWN BY	DATE
Gareth Owen	20.08.19
SCALE (@A1)	PROJECT NO.
As indicated	GOCD IM 01
DRAWING NO.	REV
A109 - Build	C1
GO CONCEPT DESIGNS, 8 DARWIN RD, PORT TALBOT, SA13 8BT	
gocconceptdesigns@gmail.com	



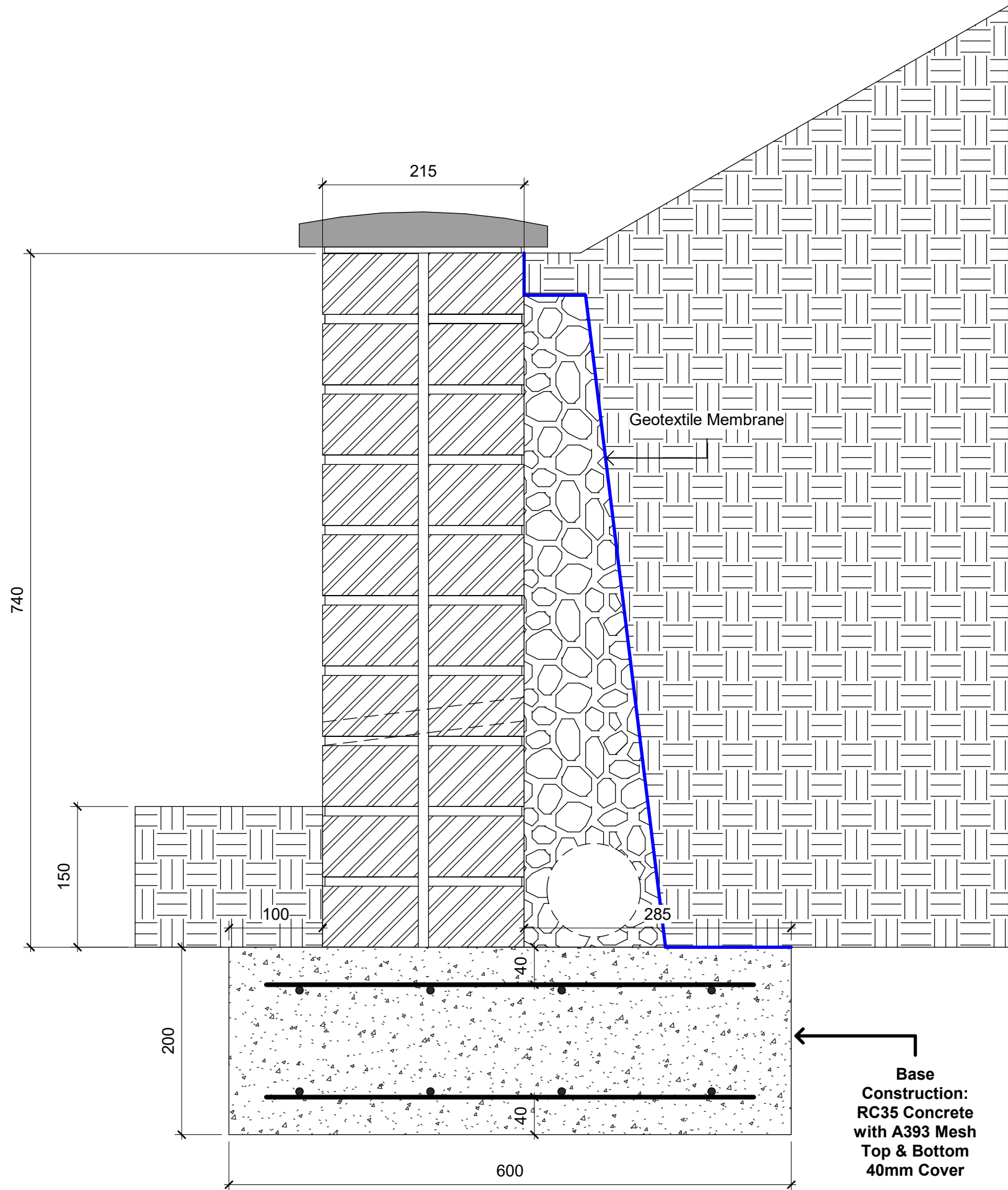
- 600mm High Brickwork Retaining Wall
- 1000mm High RC Retaining Wall
- 1850mm High RC Retaining Wall

NOTES:



GARETH OWEN
CONCEPT DESIGNS

DRAWING STATUS	
PLANNING	
PROJECT	
Plot 29 Owen Jones Way, Varteg Fawr, Bryn	
TITLE	
Retaining Walls Plan	
CLIENT	
Mr & Mrs I McKay	
DRAWN BY Gareth Owen	DATE 30.08.19
SCALE (@A3) 1 : 100	PROJECT NO. GOCD IM01
DRAWING NO. A124 - SITE	REV C1
GO CONCEPT DESIGNS, 9 DARWIN RD, PORT TALBOT, SA12 6BT GOConceptDesigns@hotmail.com	



1

600mm Retaining Wall Section

1 : 5

NOTES:



DRAWING STATUS

PLANNING

PROJECT

Plot 29 Owen Jones Way, Varteg
Fawr, Bryn

TITLE

600mm Retaining Wall Section

CLIENT

Mr & Mrs I McKay

DRAWN BY
Gareth Owen

DATE
30.08.19

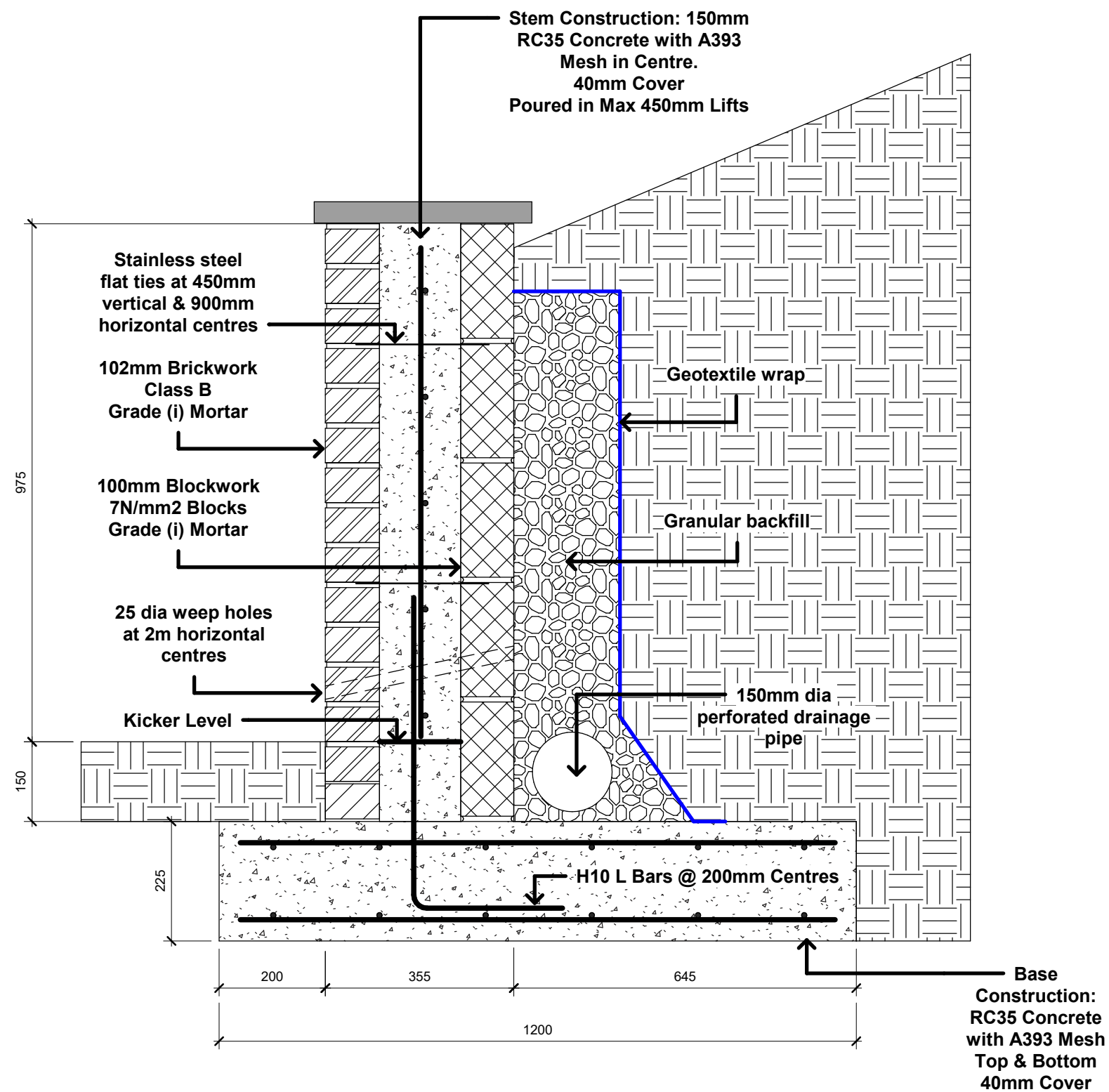
SCALE (@A3)
1 : 5

PROJECT NO.
GOCD IM01

DRAWING NO.
A119 - SITE

REV
C1

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GOConceptDesigns@hotmail.com



NOTES:



DRAWING STATUS

PLANNING

PROJECT

Plot 29 Owen Jones Way, Varteg Fawr, Bryn

TITLE

1125mm Cavity Fill RC Retaining Wall

CLIENT

Mr & Mrs I McKay

DRAWN BY
Gareth Owen

DATE
30.08.19

SCALE (@A3)
1 : 10

PROJECT NO.
GOC D IM01

DRAWING NO.
A121 - SITE

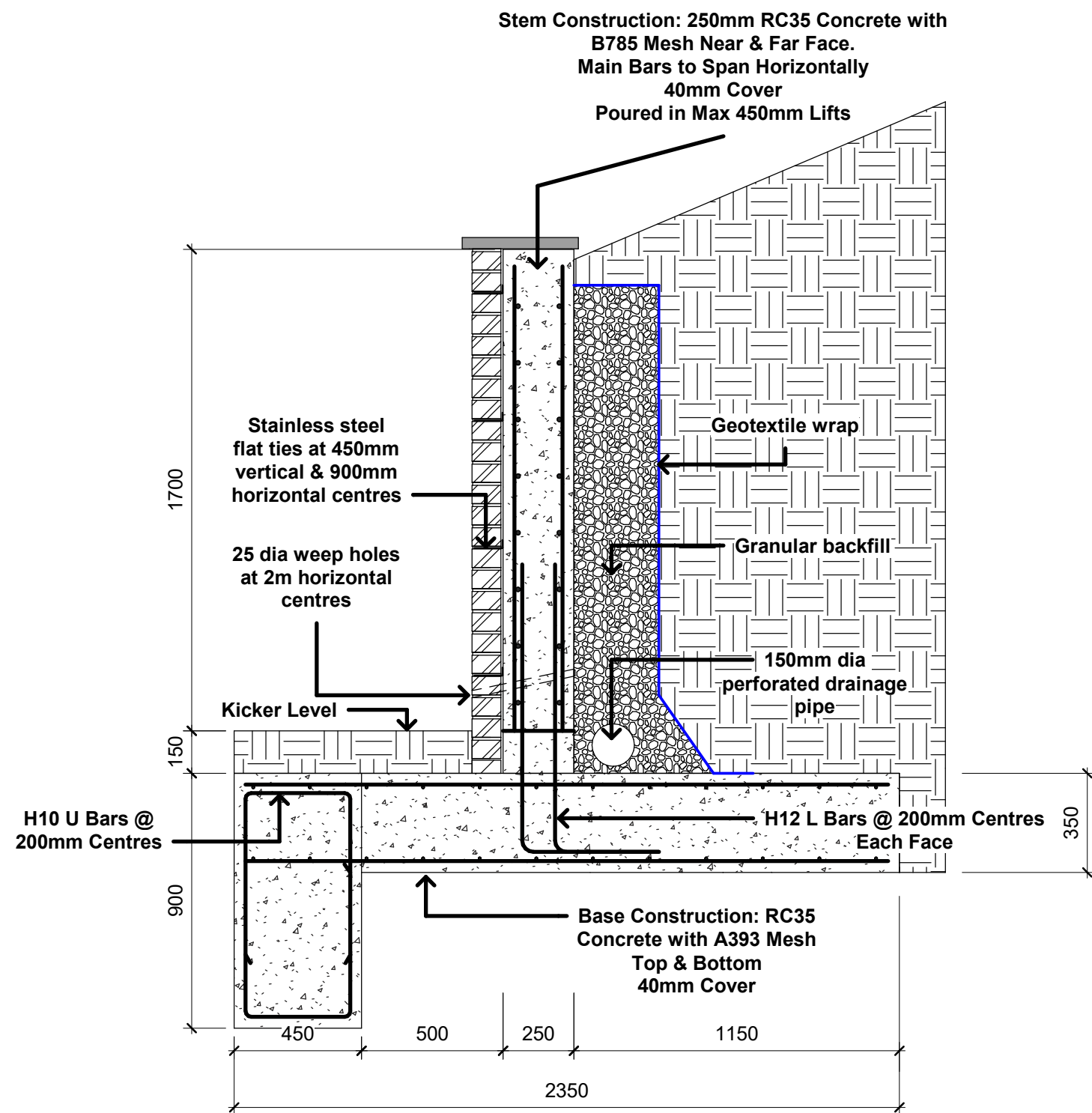
REV
C2

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GOConceptDesigns@hotmail.com

1

1000mm Cavity Fill RC Retaining Wall

1 : 10



NOTES:



DRAWING STATUS

PLANNING

PROJECT

Plot 29 Owen Jones Way, Varteg Fawr, Bryn

TITLE

1850mm In-Situ RC Retaining Wall

CLIENT

Mr & Mrs I McKay

DRAWN BY

Gareth Owen

DATE

30.08.19

SCALE (@A3)

1 : 20

PROJECT NO.

GOCD IM01

DRAWING NO.

A122 - SITE

REV

C2

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1

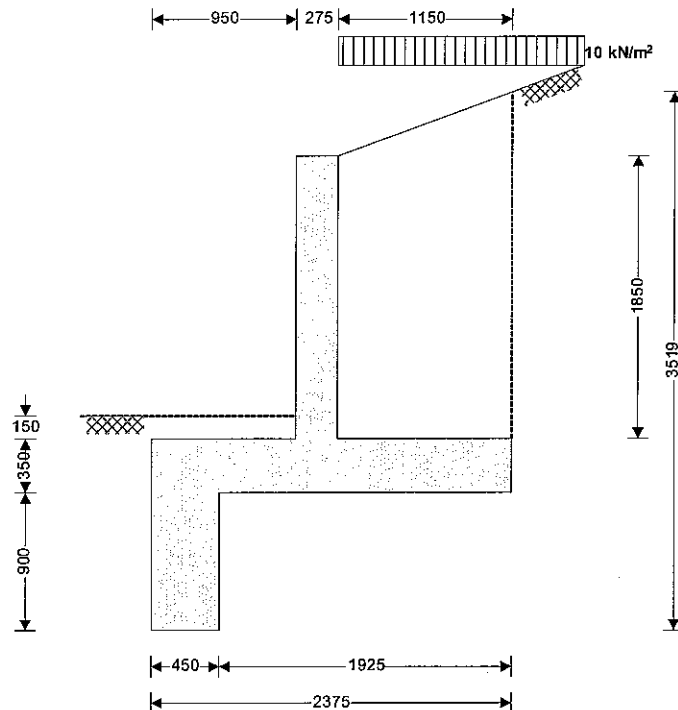
2000mm In-Situ RC Retaining Wall

1 : 20

Project <i>GARETH OWEN</i>				Job no.	
Calcs for <i>RETAINING ROAD</i>				Start page no./Revision 1	
Calcs by K	Calcs date 02/09/2019	Checked by	Checked date	Approved by	Approved date

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type
Height of retaining wall stem
Thickness of wall stem
Length of toe
Length of heel
Overall length of base
Thickness of base
Depth of downstand
Position of downstand
Thickness of downstand
Height of retaining wall
Depth of cover in front of wall
Depth of unplanned excavation
Height of ground water behind wall
Height of saturated fill above base
Density of wall construction
Density of base construction
Angle of rear face of wall
Angle of soil surface behind wall
Effective height at virtual back of wall

Unpropped cantilever

$h_{\text{stem}} = 1850 \text{ mm}$
 $t_{\text{wall}} = 275 \text{ mm}$
 $l_{\text{toe}} = 950 \text{ mm}$
 $l_{\text{heel}} = 1150 \text{ mm}$
 $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 2375 \text{ mm}$
 $t_{\text{base}} = 350 \text{ mm}$
 $d_{\text{ds}} = 900 \text{ mm}$
 $l_{\text{ds}} = 0 \text{ mm}$
 $t_{\text{ds}} = 450 \text{ mm}$
 $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 3100 \text{ mm}$
 $d_{\text{cover}} = 150 \text{ mm}$
 $d_{\text{exc}} = 0 \text{ mm}$
 $h_{\text{water}} = 0 \text{ mm}$
 $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$
 $\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$
 $\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$
 $\alpha = 90.0 \text{ deg}$
 $\beta = 20.0 \text{ deg}$
 $h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 3519 \text{ mm}$

Retained material details

Mobilisation factor
Moist density of retained material

$M = 1.5$
 $\gamma_m = 18.0 \text{ kN/m}^3$

Project				Job no.	
Calcs for				Start page no./Revision	
				2	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
K	02/09/2019				

Saturated density of retained material

$$\gamma_s = 21.0 \text{ kN/m}^3$$

Design shear strength

$$\phi' = 24.2 \text{ deg}$$

Angle of wall friction

$$\delta = 0.0 \text{ deg}$$

Base material details

Moist density

$$\gamma_{mb} = 18.0 \text{ kN/m}^3$$

Design shear strength

$$\phi'_b = 24.2 \text{ deg}$$

Design base friction

$$\delta_b = 18.6 \text{ deg}$$

Allowable bearing pressure

$$P_{\text{bearing}} = 150 \text{ kN/m}^2$$

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = 0.599$$

Passive pressure coefficient for base material

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

At-rest pressure

At-rest pressure for retained material

$$K_0 = 1 - \sin(\phi') = 0.590$$

Loading details

Surcharge load on plan

$$\text{Surcharge} = 10.0 \text{ kN/m}^2$$

Applied vertical dead load on wall

$$W_{\text{dead}} = 0.0 \text{ kN/m}$$

Applied vertical live load on wall

$$W_{\text{live}} = 0.0 \text{ kN/m}$$

Position of applied vertical load on wall

$$l_{\text{load}} = 0 \text{ mm}$$

Applied horizontal dead load on wall

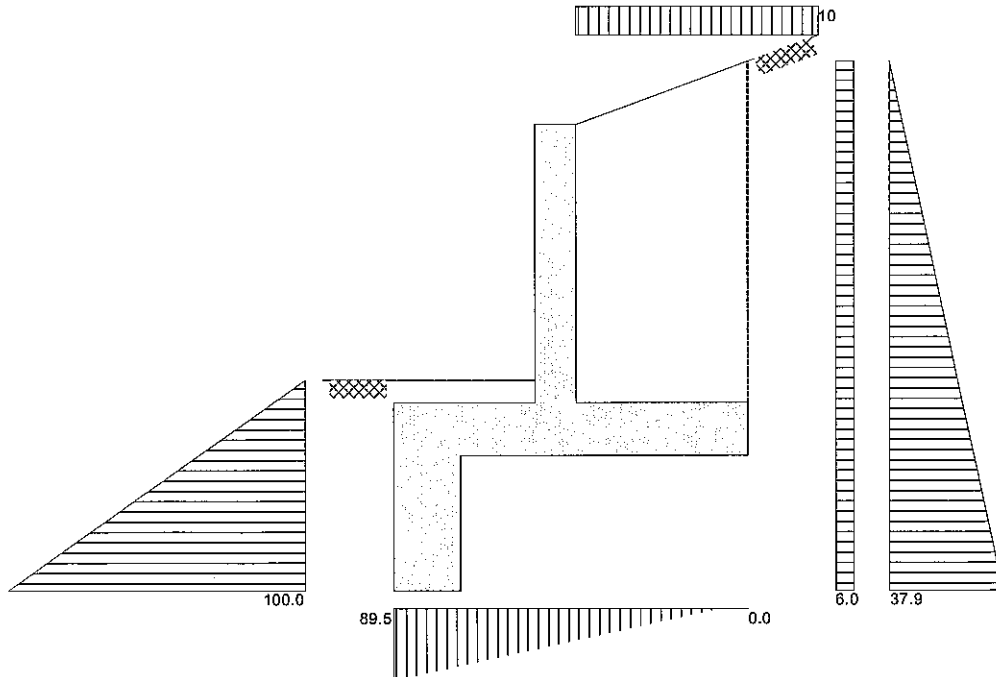
$$F_{\text{dead}} = 0.0 \text{ kN/m}$$

Applied horizontal live load on wall

$$F_{\text{live}} = 0.0 \text{ kN/m}$$

Height of applied horizontal load on wall

$$h_{\text{load}} = 0 \text{ mm}$$



Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem

$$W_{\text{wall}} = h_{\text{stem}} \times t_{\text{wall}} \times \gamma_{\text{wall}} = 12 \text{ kN/m}$$

Project				Job no.	
Calcs for				Start page no./Revision	
				3	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
K	02/09/2019				

Wall base $W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 19.6 \text{ kN/m}$
 Wall downstand $W_{ds} = d_{ds} \times t_{ds} \times \gamma_{base} = 9.6 \text{ kN/m}$
 Surcharge $W_{sur} = \text{Surcharge} \times l_{heel} = 11.5 \text{ kN/m}$
 Moist backfill to top of wall $W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 38.3 \text{ kN/m}$
 Moist backfill above top of wall $W_{m_s} = 0.5 \times l_{heel}^2 \times \tan(\beta) \times \gamma_m = 4.3 \text{ kN/m}$
 Soil in front of wall $W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 2.6 \text{ kN/m}$
 Total vertical load $W_{total} = W_{wall} + W_{base} + W_{ds} + W_{sur} + W_{m_w} + W_{m_s} + W_p = 97.9 \text{ kN/m}$

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 21.1 \text{ kN/m}$
 Moist backfill above water table $F_{m_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = 66.7 \text{ kN/m}$
 Total horizontal load $F_{total} = F_{sur} + F_{m_a} = 87.8 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 70 \text{ kN/m}$
 Resistance to sliding $F_{res} = F_p + (W_{total} - W_{sur} - W_p) \times \tan(\delta_b) = 98.2 \text{ kN/m}$
PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 18.1 \text{ kNm/m}$
 Moist backfill above water table $M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 18.2 \text{ kNm/m}$
 Soil in front of wall $M_{p_o} = F_p \times [2 \times d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 30.3 \text{ kNm/m}$
 Total overturning moment $M_{ot} = M_{sur} + M_{m_a} + M_{p_o} = 66.6 \text{ kNm/m}$

Restoring moments

Wall stem $M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 13.1 \text{ kNm/m}$
 Wall base $M_{base} = W_{base} \times l_{base} / 2 = 23.3 \text{ kNm/m}$
 Wall downstand $M_{ds} = W_{ds} \times (l_{ds} + t_{ds} / 2) = 2.2 \text{ kNm/m}$
 Moist backfill $M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 77.6 \text{ kNm/m}$
 Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{ds} + M_{m_r} = 116.1 \text{ kNm/m}$

Check stability against overturning

Total overturning moment $M_{ot} = 66.6 \text{ kNm/m}$
 Total restoring moment $M_{rest} = 116.1 \text{ kNm/m}$
PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge $M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 20.7 \text{ kNm/m}$
 Soil in front of wall $M_{p_r} = W_p \times l_{toe} / 2 = 1.2 \text{ kNm/m}$
 Total moment for bearing $M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 71.3 \text{ kNm/m}$
 Total vertical reaction $R = W_{total} = 97.9 \text{ kN/m}$
 Distance to reaction $x_{bar} = M_{total} / R = 729 \text{ mm}$
 Eccentricity of reaction $e = \text{abs}((l_{base} / 2) - x_{bar}) = 459 \text{ mm}$
Reaction acts outside middle third of base
 Bearing pressure at toe $p_{toe} = R / (1.5 \times x_{bar}) = 89.5 \text{ kN/m}^2$
 Bearing pressure at heel $p_{heel} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
PASS - Maximum bearing pressure is less than allowable bearing pressure

Project				Job no.	
Calcs for				Start page no./Revision	
				4	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
K	02/09/2019				

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	$\gamma_{f,d} = 1.4$
Live load factor	$\gamma_{f,l} = 1.6$
Earth and water pressure factor	$\gamma_{f,e} = 1.4$

Factored vertical forces on wall

Wall stem	$W_{wall,f} = \gamma_{f,d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 16.8 \text{ kN/m}$
Wall base	$W_{base,f} = \gamma_{f,d} \times l_{base} \times t_{base} \times \gamma_{base} = 27.5 \text{ kN/m}$
Wall downstand	$W_{ds,f} = \gamma_{f,d} \times d_{ds} \times t_{ds} \times \gamma_{base} = 13.4 \text{ kN/m}$
Surcharge	$W_{sur,f} = \gamma_{f,l} \times \text{Surcharge} \times l_{heel} = 18.4 \text{ kN/m}$
Moist backfill to top of wall	$W_{m,w,f} = \gamma_{f,d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 53.6 \text{ kN/m}$
Moist backfill above top of wall	$W_{m,s,f} = \gamma_{f,d} \times 0.5 \times l_{heel}^2 \times \tan(\beta) \times \gamma_m = 6.1 \text{ kN/m}$
Soil in front of wall	$W_{p,f} = \gamma_{f,d} \times l_{oe} \times d_{cover} \times \gamma_{mb} = 3.6 \text{ kN/m}$
Total vertical load kN/m	$W_{total,f} = W_{wall,f} + W_{base,f} + W_{ds,f} + W_{sur,f} + W_{m,w,f} + W_{m,s,f} + W_{p,f} = 139.3$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur,f} = \gamma_{f,l} \times K_0 \times \text{Surcharge} \times h_{eff} = 33.2 \text{ kN/m}$
Moist backfill above water table	$F_{m,a,f} = \gamma_{f,e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 92 \text{ kN/m}$
Total horizontal load	$F_{total,f} = F_{sur,f} + F_{m,a,f} = 125.3 \text{ kN/m}$
Passive resistance of soil in front of wall kN/m	$F_{p,f} = \gamma_{f,e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 98$

Factored overturning moments

Surcharge	$M_{sur,f} = F_{sur,f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 28.5 \text{ kNm/m}$
Moist backfill above water table	$M_{m,a,f} = F_{m,a,f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 25.1 \text{ kNm/m}$
Soil in front of wall	$M_{p_o,f} = F_{p,f} \times [2 \times d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 42.5 \text{ kNm/m}$
Total overturning moment	$M_{ot,f} = M_{sur,f} + M_{m,a,f} + M_{p_o,f} = 96.1 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall,f} = W_{wall,f} \times (l_{oe} + t_{wall} / 2) = 18.3 \text{ kNm/m}$
Wall base	$M_{base,f} = W_{base,f} \times l_{base} / 2 = 32.6 \text{ kNm/m}$
Wall downstand	$M_{ds,f} = W_{ds,f} \times (l_{ds} + t_{ds} / 2) = 3 \text{ kNm/m}$
Surcharge	$M_{sur_r,f} = W_{sur,f} \times (l_{base} - l_{heel} / 2) = 33.1 \text{ kNm/m}$
Moist backfill	$M_{m_r,f} = (W_{m,w,f} \times (l_{base} - l_{heel} / 2) + W_{m,s,f} \times (l_{base} - l_{heel} / 3)) = 108.6$
kNm/m	
Soil in front of wall	$M_{p_r,f} = W_{p,f} \times l_{oe} / 2 = 1.7 \text{ kNm/m}$
Total restoring moment	$M_{rest,f} = M_{wall,f} + M_{base,f} + M_{ds,f} + M_{sur_r,f} + M_{m_r,f} + M_{p_r,f} = 197.3 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total,f} = M_{rest,f} - M_{ot,f} = 101.2 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total,f} = 139.3 \text{ kN/m}$
Distance to reaction	$x_{bar,f} = M_{total,f} / R_f = 726 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar,f}) = 461 \text{ mm}$

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe,f} = R_f / (1.5 \times x_{bar,f}) = 127.9 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel,f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$

Project				Job no.	
Calcs for				Start page no./Revision	
				5	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
K	02/09/2019				

Rate of change of base reaction

$$\text{rate} = p_{\text{toe}_f} / (3 \times x_{\text{bar}_f}) = 58.69 \text{ kN/m}^2/\text{m}$$

Bearing pressure at stem / toe

$$p_{\text{stem_toe}_f} = \max(p_{\text{toe}_f} - (\text{rate} \times l_{\text{toe}}), 0 \text{ kN/m}^2) = 72.1 \text{ kN/m}^2$$

Bearing pressure at mid stem

$$p_{\text{stem_mid}_f} = \max(p_{\text{toe}_f} - (\text{rate} \times (l_{\text{toe}} + t_{\text{wall}} / 2)), 0 \text{ kN/m}^2) = 64.1 \text{ kN/m}^2$$

Bearing pressure at stem / heel

$$p_{\text{stem_heel}_f} = \max(p_{\text{toe}_f} - (\text{rate} \times (l_{\text{toe}} + t_{\text{wall}})), 0 \text{ kN/m}^2) = 56 \text{ kN/m}^2$$

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

Material properties

Characteristic strength of concrete

$$f_{\text{cu}} = 35 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

Base details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in toe

$$c_{\text{toe}} = 40 \text{ mm}$$

Calculate shear for toe design

Shear from bearing pressure

$$V_{\text{toe_bear}} = (p_{\text{toe}_f} + p_{\text{stem_toe}_f}) \times l_{\text{toe}} / 2 = 95 \text{ kN/m}$$

Shear from weight of base

$$V_{\text{toe_wt_base}} = \gamma_{\text{f}_d} \times \gamma_{\text{base}} \times l_{\text{toe}} \times t_{\text{base}} = 11 \text{ kN/m}$$

Shear from weight of downstand

$$V_{\text{toe_wt_ds}} = \gamma_{\text{f}_d} \times \gamma_{\text{base}} \times d_{\text{ds}} \times l_{\text{ds}} = 13.4 \text{ kN/m}$$

Shear from weight of soil

$$V_{\text{toe_wt_soil}} = W_{\text{p}_f} - (\gamma_{\text{f}_d} \times \gamma_{\text{m}} \times l_{\text{toe}} \times d_{\text{exc}}) = 3.6 \text{ kN/m}$$

Total shear for toe design

$$V_{\text{toe}} = V_{\text{toe_bear}} - V_{\text{toe_wt_base}} - V_{\text{toe_wt_ds}} - V_{\text{toe_wt_soil}} = 67 \text{ kN/m}$$

Calculate moment for toe design

Moment from bearing pressure

$$M_{\text{toe_bear}} = (2 \times p_{\text{toe}_f} + p_{\text{stem_mid}_f}) \times (l_{\text{toe}} + t_{\text{wall}} / 2)^2 / 6 = 63 \text{ kNm/m}$$

Moment from weight of base

$$M_{\text{toe_wt_base}} = (\gamma_{\text{f}_d} \times \gamma_{\text{base}} \times t_{\text{base}} \times (l_{\text{toe}} + t_{\text{wall}} / 2)^2 / 2) = 6.8 \text{ kNm/m}$$

Moment from weight of downstand

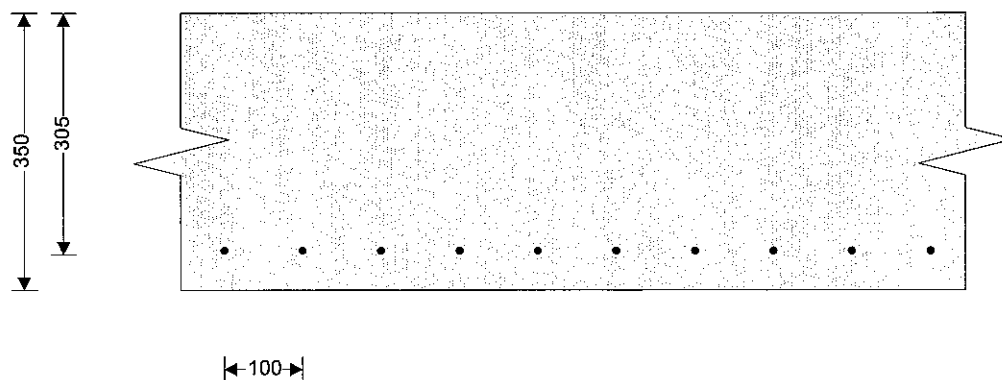
$$M_{\text{toe_wt_ds}} = \gamma_{\text{f}_d} \times \gamma_{\text{base}} \times d_{\text{ds}} \times t_{\text{ds}} \times (l_{\text{toe}} - l_{\text{ds}} + (t_{\text{wall}} - t_{\text{ds}}) / 2) = 11.5 \text{ kNm/m}$$

Moment from weight of soil

$$M_{\text{toe_wt_soil}} = (W_{\text{p}_f} - (\gamma_{\text{f}_d} \times \gamma_{\text{m}} \times l_{\text{toe}} \times d_{\text{exc}})) \times (l_{\text{toe}} + t_{\text{wall}}) / 2 = 2.2 \text{ kNm/m}$$

Total moment for toe design

$$M_{\text{toe}} = M_{\text{toe_bear}} - M_{\text{toe_wt_base}} - M_{\text{toe_wt_ds}} - M_{\text{toe_wt_soil}} = 42.5 \text{ kNm/m}$$



Check toe in bending

Width of toe

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{\text{toe}} = t_{\text{base}} - c_{\text{toe}} - (\phi_{\text{toe}} / 2) = 305.0 \text{ mm}$$

Constant

$$K_{\text{toe}} = M_{\text{toe}} / (b \times d_{\text{toe}}^2 \times f_{\text{cu}}) = 0.013$$

Compression reinforcement is not required

Lever arm

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

$$z_{\text{toe}} = 290 \text{ mm}$$

Area of tension reinforcement required

$$A_{\text{s_toe_des}} = M_{\text{toe}} / (0.87 \times f_y \times z_{\text{toe}}) = 337 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{\text{s_toe_min}} = k \times b \times t_{\text{base}} = 455 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{\text{s_toe_req}} = \text{Max}(A_{\text{s_toe_des}}, A_{\text{s_toe_min}}) = 455 \text{ mm}^2/\text{m}$$

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Reinforcement provided

B785 mesh

Area of reinforcement provided

$A_{s_toe_prov} = 785 \text{ mm}^2/\text{m}$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$V_{toe} = V_{toe} / (b \times d_{toe}) = 0.220 \text{ N/mm}^2$

Allowable shear stress

$V_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 4.733 \text{ N/mm}^2$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$V_{c_toe} = 0.481 \text{ N/mm}^2$

$V_{toe} < V_{c_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

$f_{cu} = 35 \text{ N/mm}^2$

Characteristic strength of reinforcement

$f_y = 500 \text{ N/mm}^2$

Base details

Minimum area of reinforcement

$k = 0.13 \%$

Cover to reinforcement in heel

$C_{heel} = 40 \text{ mm}$

Calculate shear for heel design

Shear from bearing pressure

$V_{heel_bear} = p_{stem_heel_f} \times ((3 \times x_{bar_f}) - l_{toe} - t_{wall}) / 2 = 26.7 \text{ kN/m}$

Shear from weight of base

$V_{heel_wt_base} = \gamma_{fd} \times \gamma_{base} \times l_{heel} \times t_{base} = 13.3 \text{ kN/m}$

Shear from weight of moist backfill

$V_{heel_wt_m} = W_{m_w_f} + W_{m_s_f} = 59.7 \text{ kN/m}$

Shear from surcharge

$V_{heel_sur} = W_{sur_f} = 18.4 \text{ kN/m}$

Total shear for heel design

$V_{heel} = -V_{heel_bear} + V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 64.7 \text{ kN/m}$

Calculate moment for heel design

Moment from bearing pressure

$M_{heel_bear} = p_{stem_mid_f} \times ((3 \times x_{bar_f}) - l_{toe} - t_{wall} / 2)^2 / 6 = 12.7 \text{ kNm/m}$

Moment from weight of base

$M_{heel_wt_base} = (\gamma_{fd} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 9.6 \text{ kNm/m}$

Moment from weight of moist backfill

$M_{heel_wt_m} = W_{m_w_f} \times (l_{heel} + t_{wall}) / 2 + W_{m_s_f} \times (2 \times l_{heel} / 3 + t_{wall} / 2) =$

43.7 kNm/m

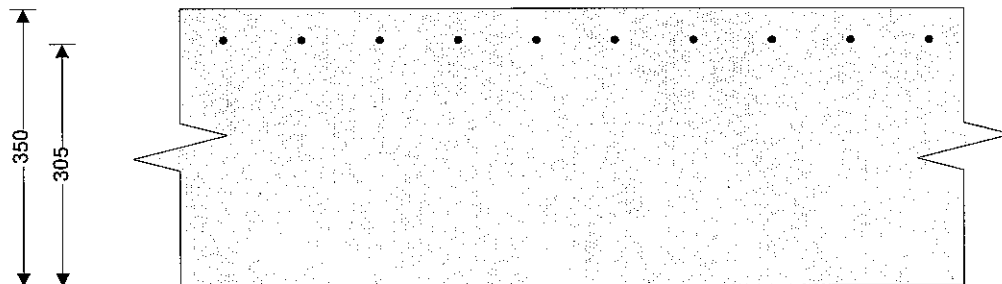
Moment from surcharge

$M_{heel_sur} = W_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 13.1 \text{ kNm/m}$

Total moment for heel design

$M_{heel} = -M_{heel_bear} + M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 53.7 \text{ kNm/m}$

← 100 →



Check heel in bending

Width of heel

$b = 1000 \text{ mm/m}$

Depth of reinforcement

$d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 305.0 \text{ mm}$

Constant

$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.016$

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Compression reinforcement is not required

Lever arm

$$Z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$$

$$Z_{heel} = 290 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = 426 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_heel_min} = k \times b \times t_{base} = 455 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = 455 \text{ mm}^2/\text{m}$$

Reinforcement provided

B785 mesh

Area of reinforcement provided

$$A_{s_heel_prov} = 785 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress

$$V_{heel} = V_{heel} / (b \times d_{heel}) = 0.212 \text{ N/mm}^2$$

Allowable shear stress

$$V_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 4.733 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = 0.481 \text{ N/mm}^2$$

$V_{heel} < V_{c_heel}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

$$f_{cu} = 35 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

Base details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in downstand

$$C_{ds} = 30 \text{ mm}$$

Calculate shear for downstand design

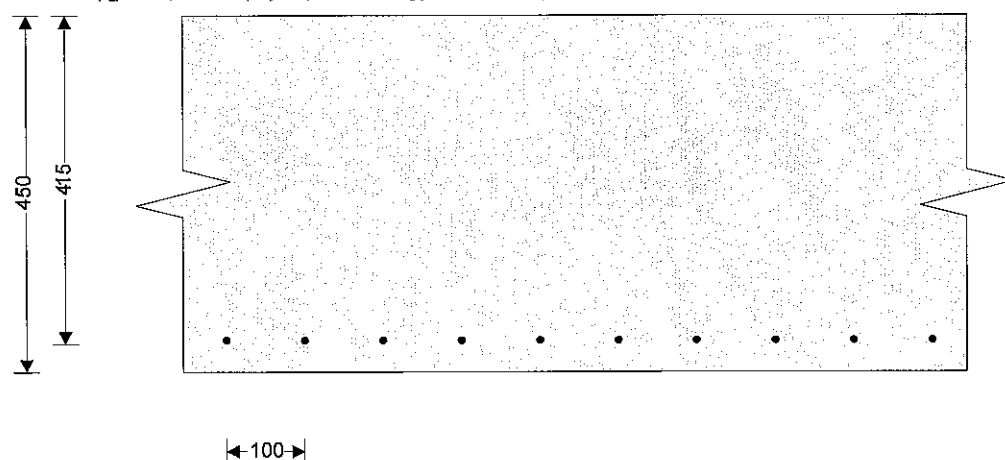
Total shear for downstand design

$$V_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times (d_{cover} + t_{base} + d_{ds} / 2) = 85.5 \text{ kN/m}$$

Calculate moment for downstand design

Total moment for downstand design

$$M_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times [(d_{cover} + t_{base}) \times (t_{base} + d_{ds}) + d_{ds} \times (t_{base} / 2 + 2 \times d_{ds} / 3)] / 2 = 59.5 \text{ kNm/m}$$



Check downstand in bending

Width of downstand

$$b = 1000 \text{ mm/m}$$

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Depth of reinforcement

$$d_{down} = t_{ds} - C_{ds} - (\phi_{down} / 2) = 415.0 \text{ mm}$$

Constant

$$K_{down} = M_{down} / (b \times d_{down}^2 \times f_{cu}) = 0.010$$

Compression reinforcement is not required

Lever arm

$$Z_{down} = \text{Min}(0.5 + \sqrt{(0.25 - (\min(K_{down}, 0.225) / 0.9))}, 0.95) \times d_{down}$$

$$Z_{down} = 394 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_down_des} = M_{down} / (0.87 \times f_y \times Z_{down}) = 347 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_down_min} = k \times b \times t_{ds} = 585 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_down_req} = \text{Max}(A_{s_down_des}, A_{s_down_min}) = 585 \text{ mm}^2/\text{m}$$

Reinforcement provided

B785 mesh

Area of reinforcement provided

$$A_{s_down_prov} = 785 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall downstand is adequate

Check shear resistance at downstand

Design shear stress

$$v_{down} = V_{down} / (b \times d_{down}) = 0.206 \text{ N/mm}^2$$

Allowable shear stress

$$v_{adm} = \min(0.8 \times \sqrt{f_{cu} / 1 \text{ N/mm}^2}, 5) \times 1 \text{ N/mm}^2 = 4.733 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_down} = 0.406 \text{ N/mm}^2$$

$v_{down} < v_{c_down}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

$$f_{cu} = 35 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

Wall details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in stem

$$C_{stem} = 30 \text{ mm}$$

Cover to reinforcement in wall

$$C_{wall} = 30 \text{ mm}$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{r1} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 21.4 \text{ kN/m}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{r,e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 38.3 \text{ kN/m}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = 59.7 \text{ kN/m}$$

Calculate moment for stem design

Surcharge

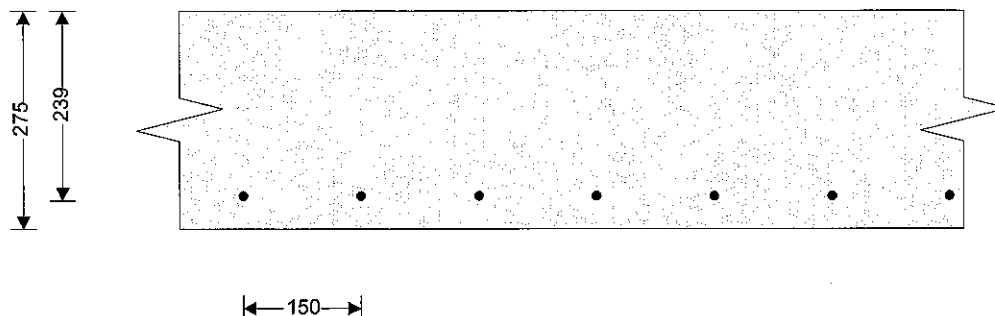
$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = 23.6 \text{ kNm/m}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 35.6 \text{ kNm/m}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = 59.2 \text{ kNm/m}$$



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Check wall stem in bending

Width of wall stem

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{\text{stem}} = t_{\text{wall}} - c_{\text{stem}} - (\phi_{\text{stem}} / 2) = 239.0 \text{ mm}$$

Constant

$$K_{\text{stem}} = M_{\text{stem}} / (b \times d_{\text{stem}}^2 \times f_{\text{cu}}) = 0.030$$

Compression reinforcement is not required

Lever arm

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

$$z_{\text{stem}} = 227 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_{\text{stem_des}}} = M_{\text{stem}} / (0.87 \times f_y \times z_{\text{stem}}) = 599 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_{\text{stem_min}}} = k \times b \times t_{\text{wall}} = 358 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_{\text{stem_req}}} = \text{Max}(A_{s_{\text{stem_des}}}, A_{s_{\text{stem_min}}}) = 599 \text{ mm}^2/\text{m}$$

Reinforcement provided

$$12 \text{ mm dia. bars @ } 150 \text{ mm centres}$$

Area of reinforcement provided

$$A_{s_{\text{stem_prov}}} = 754 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$v_{\text{stem}} = V_{\text{stem}} / (b \times d_{\text{stem}}) = 0.250 \text{ N/mm}^2$$

Allowable shear stress

$$v_{\text{adm}} = \min(0.8 \times \sqrt{f_{\text{cu}} / 1 \text{ N/mm}^2}, 5) \times 1 \text{ N/mm}^2 = 4.733 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_{\text{stem}}} = 0.547 \text{ N/mm}^2$$

$v_{\text{stem}} < v_{c_{\text{stem}}}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio

$$\text{ratio}_{\text{bas}} = 7$$

Design service stress

$$f_s = 2 \times f_y \times A_{s_{\text{stem_req}}} / (3 \times A_{s_{\text{stem_prov}}}) = 264.9 \text{ N/mm}^2$$

Modification factor

$$\text{factor}_{\text{tens}} = \min(0.55 + (477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + (M_{\text{stem}} / (b \times d_{\text{stem}}^2)))), 2) = 1.46$$

Maximum span/effective depth ratio

$$\text{ratio}_{\text{max}} = \text{ratio}_{\text{bas}} \times \text{factor}_{\text{tens}} = 10.24$$

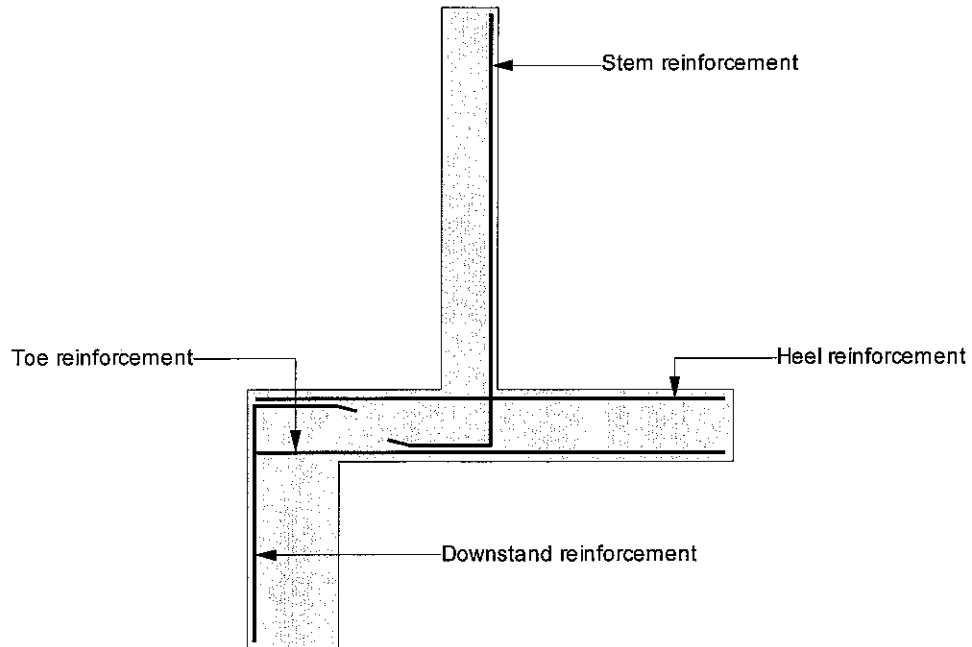
Actual span/effective depth ratio

$$\text{ratio}_{\text{act}} = h_{\text{stem}} / d_{\text{stem}} = 7.74$$

PASS - Span to depth ratio is acceptable

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Indicative retaining wall reinforcement diagram



Toe mesh - B785 - (785 mm²/m)

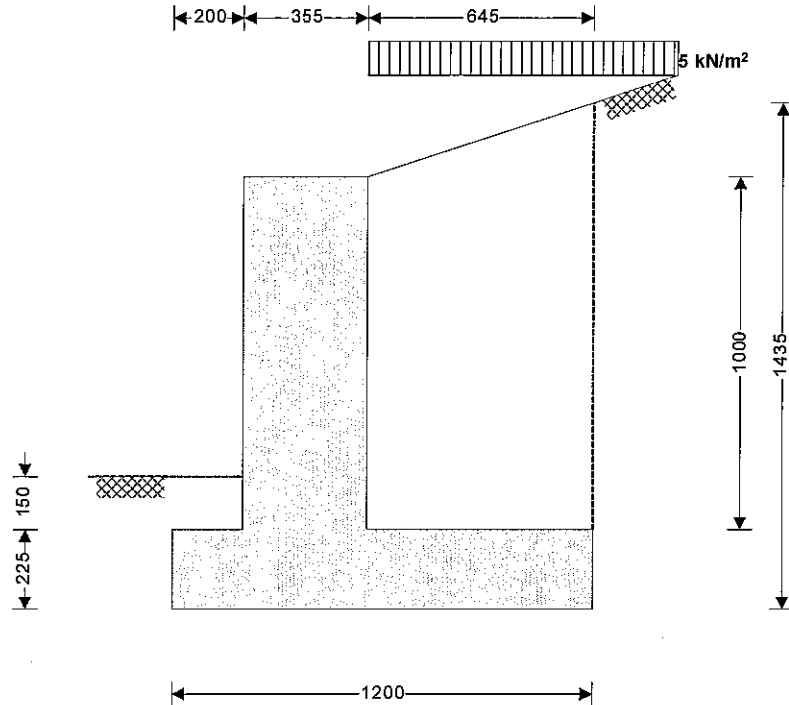
Heel mesh - B785 - (785 mm²/m)

Downstand mesh - B785 - (785 mm²/m)

Stem bars - 12 mm dia. @ 150 mm centres - (754 mm²/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type

Height of retaining wall stem

Thickness of wall stem

Length of toe

Length of heel

Overall length of base

Thickness of base

Depth of downstand

Position of downstand

Thickness of downstand

Height of retaining wall

Depth of cover in front of wall

Depth of unplanned excavation

Height of ground water behind wall

Height of saturated fill above base

Density of wall construction

Density of base construction

Angle of rear face of wall

Angle of soil surface behind wall

Effective height at virtual back of wall

Unpropped cantilever

$h_{\text{stem}} = 1000 \text{ mm}$

$t_{\text{wall}} = 355 \text{ mm}$

$l_{\text{toe}} = 200 \text{ mm}$

$l_{\text{heel}} = 645 \text{ mm}$

$l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 1200 \text{ mm}$

$t_{\text{base}} = 225 \text{ mm}$

$d_{\text{ds}} = 0 \text{ mm}$

$l_{\text{ds}} = 745 \text{ mm}$

$t_{\text{ds}} = 225 \text{ mm}$

$h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 1225 \text{ mm}$

$d_{\text{cover}} = 150 \text{ mm}$

$d_{\text{exc}} = 0 \text{ mm}$

$h_{\text{water}} = 0 \text{ mm}$

$h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$

$\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$

$\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$

$\alpha = 90.0 \text{ deg}$

$\beta = 18.0 \text{ deg}$

$h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 1435 \text{ mm}$

Retained material details

Mobilisation factor

$M = 1.5$

Moist density of retained material

$\gamma_m = 18.0 \text{ kN/m}^3$

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Saturated density of retained material

$$\gamma_s = 21.0 \text{ kN/m}^3$$

Design shear strength

$$\phi' = 24.2 \text{ deg}$$

Angle of wall friction

$$\delta = 18.6 \text{ deg}$$

Base material details

Moist density

$$\gamma_{mb} = 18.0 \text{ kN/m}^3$$

Design shear strength

$$\phi'_b = 24.2 \text{ deg}$$

Design base friction

$$\delta_b = 18.6 \text{ deg}$$

Allowable bearing pressure

$$P_{\text{bearing}} = 150 \text{ kN/m}^2$$

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))})^2] = 0.531$$

Passive pressure coefficient for base material

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

At-rest pressure

At-rest pressure for retained material

$$K_0 = 1 - \sin(\phi') = 0.590$$

Loading details

Surcharge load on plan

$$\text{Surcharge} = 5.0 \text{ kN/m}^2$$

Applied vertical dead load on wall

$$W_{\text{dead}} = 0.0 \text{ kN/m}$$

Applied vertical live load on wall

$$W_{\text{live}} = 0.0 \text{ kN/m}$$

Position of applied vertical load on wall

$$l_{\text{load}} = 0 \text{ mm}$$

Applied horizontal dead load on wall

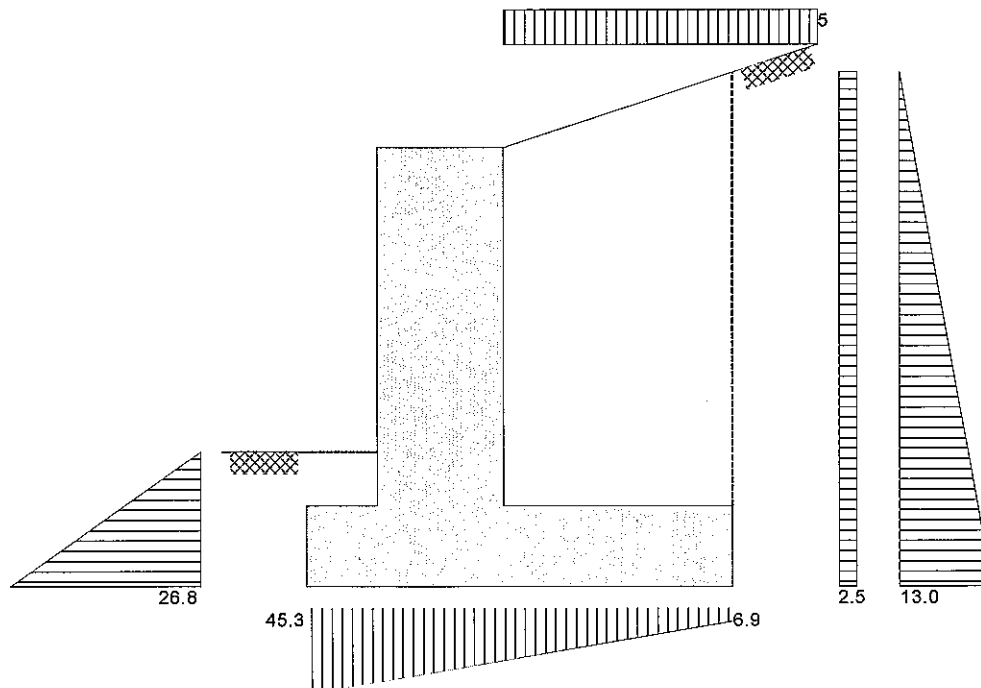
$$F_{\text{dead}} = 0.0 \text{ kN/m}$$

Applied horizontal live load on wall

$$F_{\text{live}} = 0.0 \text{ kN/m}$$

Height of applied horizontal load on wall

$$h_{\text{load}} = 0 \text{ mm}$$



Loads shown in kN/m, pressures shown in kN/m²

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Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 8.4 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 6.4 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} \times l_{heel} = 3.2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 11.6 \text{ kN/m}$
Moist backfill above top of wall	$W_{m_s} = 0.5 \times l_{heel}^2 \times \tan(\beta) \times \gamma_m = 1.2 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 0.5 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{sur} + W_{m_w} + W_{m_s} + W_p = 31.3 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = 3.6 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = 9.3 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 12.9 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 5 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p) \times \tan(\delta_b) = 14.3 \text{ kN/m}$

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 2.6 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 4.5 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} = 7.1 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 3.2 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 3.8 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 11.4 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m_r} = 18.4 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 7.1 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 18.4 \text{ kNm/m}$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 2.8 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p \times l_{toe} / 2 = 0.1 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 14.2 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 31.3 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 453 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 147 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 45.3 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 6.9 \text{ kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure

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RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	$\gamma_{f,d} = 1.4$
Live load factor	$\gamma_{f,l} = 1.6$
Earth and water pressure factor	$\gamma_{f,e} = 1.4$

Factored vertical forces on wall

Wall stem	$W_{wall,f} = \gamma_{f,d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 11.7 \text{ kN/m}$
Wall base	$W_{base,f} = \gamma_{f,d} \times l_{base} \times t_{base} \times \gamma_{base} = 8.9 \text{ kN/m}$
Surcharge	$W_{sur,f} = \gamma_{f,l} \times \text{Surcharge} \times l_{heel} = 5.2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m,w,f} = \gamma_{f,d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 16.3 \text{ kN/m}$
Moist backfill above top of wall	$W_{m,s,f} = \gamma_{f,d} \times 0.5 \times l_{heel}^2 \times \tan(\beta) \times \gamma_m = 1.7 \text{ kN/m}$
Soil in front of wall	$W_{p,f} = \gamma_{f,d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 0.8 \text{ kN/m}$
Total vertical load	$W_{total,f} = W_{wall,f} + W_{base,f} + W_{sur,f} + W_{m,w,f} + W_{m,s,f} + W_{p,f} = 44.5 \text{ kN/m}$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur,f} = \gamma_{f,l} \times K_0 \times \text{Surcharge} \times h_{eff} = 6.8 \text{ kN/m}$
Moist backfill above water table	$F_{m,a,f} = \gamma_{f,e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 15.3 \text{ kN/m}$
Total horizontal load	$F_{total,f} = F_{sur,f} + F_{m,a,f} = 22.1 \text{ kN/m}$
Passive resistance of soil in front of wall	$F_{p,f} = \gamma_{f,e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 7 \text{ kN/m}$

Factored overturning moments

Surcharge	$M_{sur,f} = F_{sur,f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 4.9 \text{ kNm/m}$
Moist backfill above water table	$M_{m,a,f} = F_{m,a,f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 7.3 \text{ kNm/m}$
Total overturning moment	$M_{ot,f} = M_{sur,f} + M_{m,a,f} = 12.2 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall,f} = W_{wall,f} \times (l_{toe} + t_{wall} / 2) = 4.4 \text{ kNm/m}$
Wall base	$M_{base,f} = W_{base,f} \times l_{base} / 2 = 5.4 \text{ kNm/m}$
Surcharge	$M_{sur,f} = W_{sur,f} \times (l_{base} - l_{heel} / 2) = 4.5 \text{ kNm/m}$
Moist backfill	$M_{m,r,f} = (W_{m,w,f} \times (l_{base} - l_{heel} / 2) + W_{m,s,f} \times (l_{base} - l_{heel} / 3)) = 15.9 \text{ kNm/m}$
Soil in front of wall	$M_{p,r,f} = W_{p,f} \times l_{toe} / 2 = 0.1 \text{ kNm/m}$
Total restoring moment	$M_{rest,f} = M_{wall,f} + M_{base,f} + M_{sur,f} + M_{m,r,f} + M_{p,r,f} = 30.3 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total,f} = M_{rest,f} - M_{ot,f} = 18.1 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total,f} = 44.5 \text{ kN/m}$
Distance to reaction	$X_{bar,f} = M_{total,f} / R_f = 408 \text{ mm}$
Eccentricity of reaction	$e_r = \text{abs}((l_{base} / 2) - X_{bar,f}) = 192 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe,f} = (R_f / l_{base}) + (6 \times R_f \times e_r / l_{base}^2) = 72.8 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel,f} = (R_f / l_{base}) - (6 \times R_f \times e_r / l_{base}^2) = 1.4 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = (p_{toe,f} - p_{heel,f}) / l_{base} = 59.47 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe,f} = \text{max}(p_{toe,f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 60.9 \text{ kN/m}^2$
Bearing pressure at mid stem	$p_{stem_mid,f} = \text{max}(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 50.3 \text{ kN/m}^2$
Bearing pressure at stem / heel	$p_{stem_heel,f} = \text{max}(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 39.8 \text{ kN/m}^2$

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

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Material properties

Characteristic strength of concrete

$$f_{cu} = 40 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

Base details

Minimum area of reinforcement

$$k = 0.00 \%$$

Cover to reinforcement in toe

$$C_{toe} = 30 \text{ mm}$$

Calculate shear for toe design

Shear from bearing pressure

$$V_{toe_bear} = (p_{toe_f} + p_{stem_toe_f}) \times l_{toe} / 2 = 13.4 \text{ kN/m}$$

Shear from weight of base

$$V_{toe_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 1.5 \text{ kN/m}$$

Shear from weight of soil

$$V_{toe_wt_soil} = w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc}) = 0.8 \text{ kN/m}$$

Total shear for toe design

$$V_{toe} = V_{toe_bear} - V_{toe_wt_base} - V_{toe_wt_soil} = 11.1 \text{ kN/m}$$

Calculate moment for toe design

Moment from bearing pressure

$$M_{toe_bear} = (2 \times p_{toe_f} + p_{stem_mid_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 4.7 \text{ kNm/m}$$

Moment from weight of base

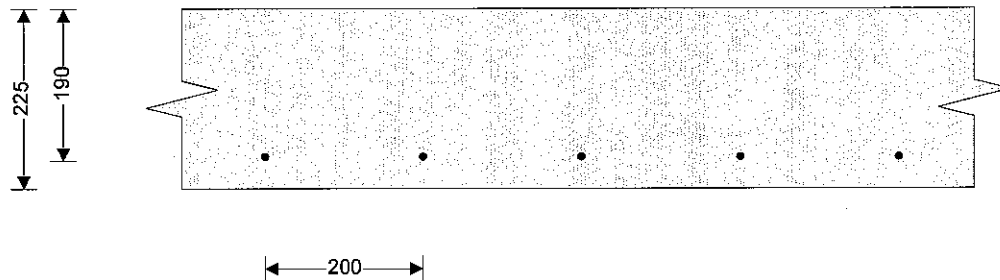
$$M_{toe_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 0.5 \text{ kNm/m}$$

Moment from weight of soil

$$M_{toe_wt_soil} = (w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall}) / 2 = 0.2 \text{ kNm/m}$$

Total moment for toe design

$$M_{toe} = M_{toe_bear} - M_{toe_wt_base} - M_{toe_wt_soil} = 3.9 \text{ kNm/m}$$



Check toe in bending

Width of toe

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{toe} = t_{base} - C_{toe} - (\phi_{toe} / 2) = 190.0 \text{ mm}$$

Constant

$$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.003$$

Compression reinforcement is not required

Lever arm

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

$$Z_{toe} = 181 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times Z_{toe}) = 50 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_toe_min} = k \times b \times t_{base} = 0 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = 50 \text{ mm}^2/\text{m}$$

Reinforcement provided

A393 mesh

Area of reinforcement provided

$$A_{s_toe_prov} = 393 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$$v_{toe} = V_{toe} / (b \times d_{toe}) = 0.059 \text{ N/mm}^2$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_toe} = 0.526 \text{ N/mm}^2$$

$v_{toe} < v_{c_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete $f_{cu} = 40 \text{ N/mm}^2$
 Characteristic strength of reinforcement $f_y = 500 \text{ N/mm}^2$

Base details

Minimum area of reinforcement $k = 0.00 \%$
 Cover to reinforcement in heel $C_{heel} = 30 \text{ mm}$

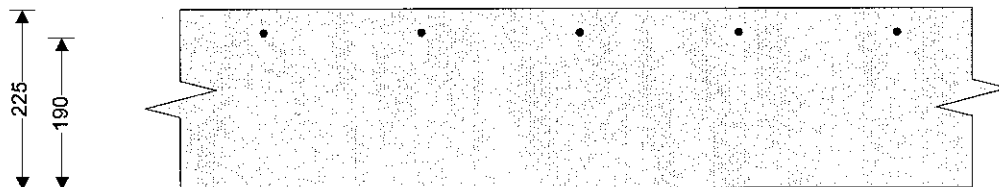
Calculate shear for heel design

Shear from bearing pressure $V_{heel_bear} = (p_{heel_f} + p_{stem_heel_f}) \times l_{heel} / 2 = 13.3 \text{ kN/m}$
 Shear from weight of base $V_{heel_wt_base} = \gamma_{fd} \times \gamma_{base} \times l_{heel} \times t_{base} = 4.8 \text{ kN/m}$
 Shear from weight of moist backfill $V_{heel_wt_m} = W_{m_w_f} + W_{m_s_f} = 18 \text{ kN/m}$
 Shear from surcharge $V_{heel_sur} = W_{sur_f} = 5.2 \text{ kN/m}$
 Total shear for heel design $V_{heel} = -V_{heel_bear} + V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 14.6 \text{ kN/m}$

Calculate moment for heel design

Moment from bearing pressure $M_{heel_bear} = (2 \times p_{heel_f} + p_{stem_mid_f}) \times (l_{heel} + t_{wall} / 2)^2 / 6 = 6 \text{ kNm/m}$
 Moment from weight of base $M_{heel_wt_base} = (\gamma_{fd} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 2.5 \text{ kNm/m}$
 Moment from weight of moist backfill $M_{heel_wt_m} = W_{m_w_f} \times (l_{heel} + t_{wall}) / 2 + W_{m_s_f} \times (2 \times l_{heel} / 3 + t_{wall} / 2) = 9.2 \text{ kNm/m}$
 Moment from surcharge $M_{heel_sur} = W_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 2.6 \text{ kNm/m}$
 Total moment for heel design $M_{heel} = -M_{heel_bear} + M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 8.3 \text{ kNm/m}$

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Check heel in bending

Width of heel $b = 1000 \text{ mm/m}$
 Depth of reinforcement $d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 190.0 \text{ mm}$
 Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.006$

Compression reinforcement is not required

Lever arm $Z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$
 $Z_{heel} = 181 \text{ mm}$

Area of tension reinforcement required $A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = 105 \text{ mm}^2/\text{m}$
 Minimum area of tension reinforcement $A_{s_heel_min} = k \times b \times t_{base} = 0 \text{ mm}^2/\text{m}$
 Area of tension reinforcement required $A_{s_heel_req} = \max(A_{s_heel_des}, A_{s_heel_min}) = 105 \text{ mm}^2/\text{m}$
 Reinforcement provided **A393 mesh**
 Area of reinforcement provided $A_{s_heel_prov} = 393 \text{ mm}^2/\text{m}$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel}) = 0.077 \text{ N/mm}^2$
 Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 5.000 \text{ N/mm}^2$

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PASS - Design shear stress is less than maximum shear stress

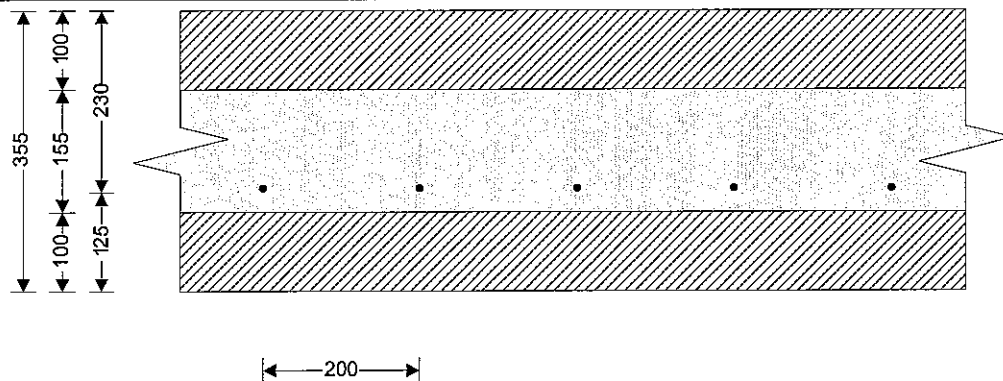
From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = 0.526 \text{ N/mm}^2$$

$V_{heel} < V_{c_heel}$ - No shear reinforcement required

Design of cavity reinforced masonry retaining wall stem - BS5628-2:2000



Wall details

Thickness of outer leaf of wall

$$t_{outer} = 100 \text{ mm}$$

Thickness of inner leaf of wall

$$t_{inner} = 100 \text{ mm}$$

Thickness of reinforced cavity

$$t_{cavity} = t_{wall} - t_{outer} - t_{inner} = 155 \text{ mm}$$

Depth of stem reinforcement

$$d_{stem} = 230 \text{ mm}$$

Masonry details

Masonry type

Standard format bricks

Compressive strength of units

$$p_{unit} = 10.0 \text{ N/mm}^2$$

Mortar designation

(ii)

Category of manufacturing control of units

Category I

Partial safety factor for material strength

$$\gamma_{mm} = 2.0$$

Characteristic compressive strength of masonry

From BS5628:2 Table 3a, mortar ii

Characteristic compressive strength

$$f_k = 3.8 \text{ N/mm}^2$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{f1} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 5.7 \text{ kN/m}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{f2} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 10.9 \text{ kN/m}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = 16.6 \text{ kN/m}$$

Calculate moment for stem design

Surcharge

$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = 3.5 \text{ kNm/m}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 5.6 \text{ kNm/m}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = 9.1 \text{ kNm/m}$$

Check maximum design moment for wall stem

Width of wall

$$b = 1000 \text{ mm/m}$$

Maximum design moment

$$M_{d_stem} = 0.4 \times f_k \times b \times d_{stem}^2 / \gamma_{mm} = 40.2 \text{ kNm/m}$$

PASS - Applied moment is less than maximum design moment

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Check wall stem in bending

Moment of resistance factor

$$Q = M_{stem} / d_{stem}^2 = 0.172 \text{ N/mm}^2$$

$$Q = 2 \times c \times (1 - c) \times f_k / \gamma_{mm}$$

Lever arm factor

$$c = 0.952$$

Lever arm

$$z_{stem} = \min(0.95, c) \times d_{stem} = 218.5 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{stem} \times \gamma_{ms} / (f_y \times z_{stem}) = 96 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{wall} = 0 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = 96 \text{ mm}^2/\text{m}$$

Reinforcement provided

$$10 \text{ mm dia. bars @ } 200 \text{ mm centres}$$

Area of reinforcement provided

$$A_{s_stem_prov} = \pi \times \phi_{stem}^2 / (4 \times s_{stem}) = 393 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$v_{stem} = V_{stem} / (b \times d_{stem}) = 0.072 \text{ N/mm}^2$$

Basic characteristic shear strength of masonry

$$f_{vbas} = \min[0.35 + (17.5 \times A_{s_stem_prov} / (b \times d_{stem})), 0.7] \times 1 \text{ N/mm}^2$$

$$f_{vbas} = 0.380 \text{ N/mm}^2$$

Shear span

$$a = M_{stem} / V_{stem} = 549.0 \text{ mm}$$

Characteristic shear strength of masonry

$$f_v = \text{Min}(f_{vbas} \times \max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75 \text{ N/mm}^2)$$

$$f_v = 0.723 \text{ N/mm}^2$$

Allowable shear stress

$$v_{adm} = f_v / \gamma_{mv} = 0.362 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio

$$\text{ratio}_{max} = 18.00$$

Actual span/effective depth ratio

$$\text{ratio}_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = 4.85$$

PASS - Span to depth ratio is acceptable

Axial load check

Factored axial load on wall

$$N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f_d}) + (W_{live} \times \gamma_{f_l}) = 11.7 \text{ kN/m}$$

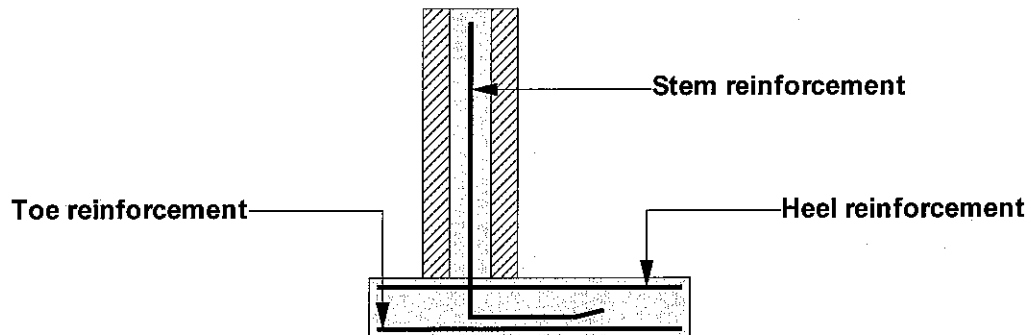
Limiting axial load

$$N_{limit} = 0.1 \times f_k \times t_{wall} = 134.9 \text{ kN/m}$$

Applied axial load may be ignored - calculations valid

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Indicative retaining wall reinforcement diagram



Toe mesh - A393 - (393 mm²/m)

Heel mesh - A393 - (393 mm²/m)

Stem bars - 10 mm dia. @ 200 mm centres - (393 mm²/m)

 Rodgers Leask Ltd	Project Standard Retaining Walls				Job no.	
	Calcs for Retaining Wall A - 600mm				Start page no./Revision 1	
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RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.6.05

Retaining wall details

Stem type	Cantilever with stepped rear face
Stem height	$h_{\text{stem}} = 750 \text{ mm}$
Number of steps	$N_{\text{steps}} = 1$
Height of step 1	$h_{s1} = 750 \text{ mm}$
Thickness of step 1	$t_{s1} = 215 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 100 \text{ mm}$
Heel length	$l_{\text{heel}} = 285 \text{ mm}$
Base thickness	$t_{\text{base}} = 200 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 600 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 150 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 150 \text{ mm}$

Retained soil properties

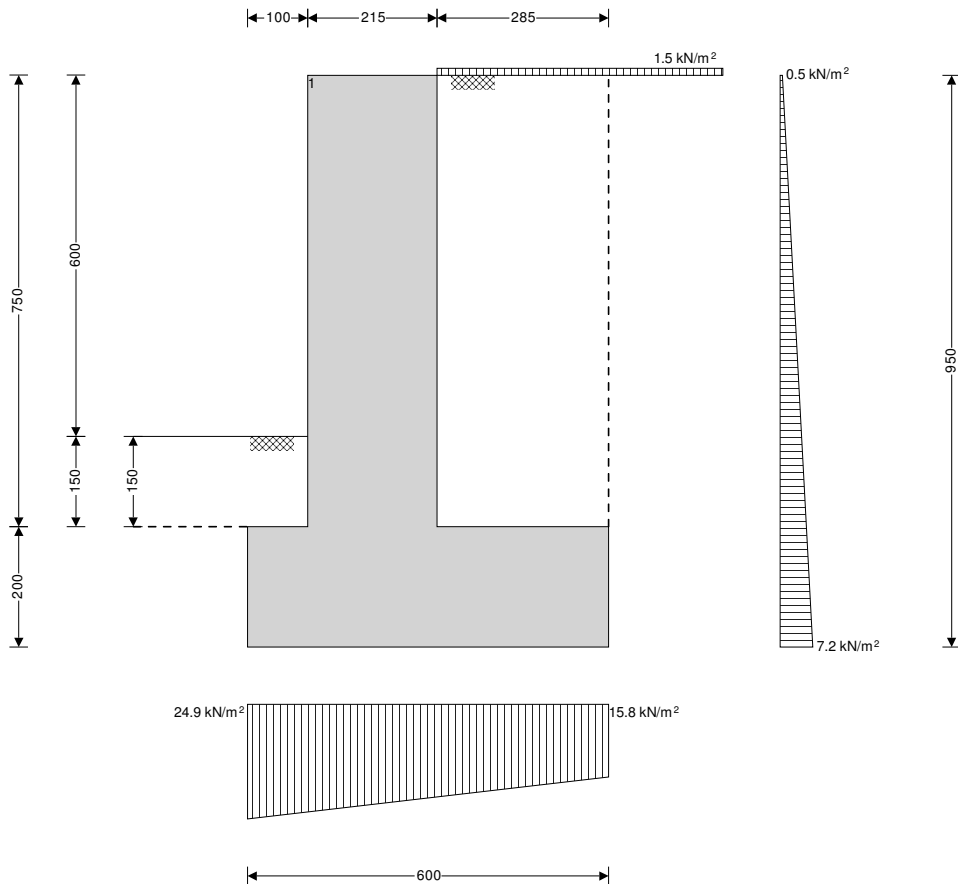
Soil type	Medium dense well graded sand
Moist density	$\gamma_{\text{mr}} = 21 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 23 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{r,k} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{r,k} = 0 \text{ deg}$

Base soil properties

Soil type	Medium dense well graded sand
Soil density	$\gamma_b = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{b,k} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{b,k} = 15 \text{ deg}$
Characteristic base friction angle	$\delta_{bb,k} = 30 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 75 \text{ kN/m}^2$

Loading details

Variable surcharge load	Surcharge _Q = 1.5 kN/m²
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Calculate retaining wall geometry

Base length

Moist soil height

Length of surcharge load

- Distance to vertical component

Effective height of wall

- Distance to horizontal component

Area of wall stem

- Distance to vertical component

Area of wall base

- Distance to vertical component

Area of moist soil

- Distance to vertical component

- Distance to horizontal component

Area of base soil

- Distance to vertical component

- Distance to horizontal component

Using Coulomb theory

Active pressure coefficient

$$l_{base} = l_{toe} + t_{s1} + l_{heel} = 600 \text{ mm}$$

$$h_{moist} = h_{soil} = 750 \text{ mm}$$

$$l_{sur} = (l_{heel} + t_{s1} - t_{s1}) = 285 \text{ mm}$$

$$x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s1}) / 2 = 458 \text{ mm}$$

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 950 \text{ mm}$$

$$x_{sur_h} = h_{eff} / 2 = 475 \text{ mm}$$

$$A_{stem} = h_{s1} \times t_{s1} = 0.161 \text{ m}^2$$

$$x_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2)) / A_{stem} = 208 \text{ mm}$$

$$A_{base} = l_{base} \times t_{base} = 0.12 \text{ m}^2$$

$$x_{base} = l_{base} / 2 = 300 \text{ mm}$$

$$A_{moist} = l_{heel} \times h_{s1} = 0.214 \text{ m}^2$$

$$x_{moist_v} = l_{base} - (l_{heel} \times h_{s1} \times l_{heel} / 2) / A_{moist} = 458 \text{ mm}$$

$$x_{moist_h} = h_{eff} / 3 = 317 \text{ mm}$$

$$A_{pass} = d_{cover} \times l_{toe} = 0.015 \text{ m}^2$$

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 50 \text{ mm}$$

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 117 \text{ mm}$$

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))]}]^2) = 0.333$$

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Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))]}]^2) = \mathbf{4.977}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{4 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = \mathbf{3 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = \text{Surcharge}_Q \times (l_{heel} + t_{s1} - t_{s1}) = \mathbf{0.4 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr}' = \mathbf{4.5 \text{ kN/m}}$$

Base soil

$$F_{pass_v} = A_{pass} \times \gamma_b' = \mathbf{0.3 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{pass_v} + F_{sur_v} = \mathbf{12.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \text{Surcharge}_Q \times h_{eff} = \mathbf{0.5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{3.2 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = -K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-5.3 \text{ kN/m}}$$

Total

$$F_{total_h} = \max(F_{moist_h} + F_{pass_h} + F_{sur_h} - F_{total_v} \times \tan(\delta_{bb,d}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{0.8 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{0.9 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{0 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{1.1 \text{ kNm/m}}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} - F_{pass_h} \times X_{pass_h} = \mathbf{0.6 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_{sur} = \mathbf{3.4 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{278 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-22 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{600 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{24.9 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{15.8 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{3.009}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 1

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.00}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.00}$$

Weight density

$$\gamma_{\gamma} = \mathbf{1.00}$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = \mathbf{21 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = \mathbf{23 \text{ kN/m}^3}$$

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Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi}) = \mathbf{30 \text{ deg}}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi}) = \mathbf{0 \text{ deg}}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_r = \mathbf{18 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi}) = \mathbf{30 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi}) = \mathbf{15 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi}) = \mathbf{30 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_c = \mathbf{0 \text{ kN/m}^2}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.333}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = \mathbf{4.977}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{4 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{4.5 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} = \mathbf{11.5 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{0.7 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = \mathbf{4.3 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = \mathbf{5 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{1.7 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{6.7 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{8.4 \text{ kN/m}}$$

Factor of safety

$$FoS_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.684}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{4 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{4.5 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} = \mathbf{11.5 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{0.7 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = \mathbf{4.3 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-1.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = \mathbf{3.2 \text{ kN/m}}$$

Overtuning moments on wall

Surcharge load

$$M_{\text{sur}_\text{OT}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{0.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_\text{OT}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{1.4 \text{ kNm/m}}$$

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Total

$$M_{\text{total_OT}} = M_{\text{moist_OT}} + M_{\text{sur_OT}} = 1.7 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem_R}} = F_{\text{stem}} \times X_{\text{stem}} = 0.8 \text{ kNm/m}$$

Wall base

$$M_{\text{base_R}} = F_{\text{base}} \times X_{\text{base}} = 0.9 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist_R}} = F_{\text{moist_v}} \times X_{\text{moist_v}} = 2.1 \text{ kNm/m}$$

Base soil

$$M_{\text{exc_R}} = -F_{\text{exc_h}} \times X_{\text{exc_h}} = 0.1 \text{ kNm/m}$$

Total

$$M_{\text{total_R}} = M_{\text{stem_R}} + M_{\text{base_R}} + M_{\text{moist_R}} + M_{\text{exc_R}} = 3.9 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$FoS_{\text{ot}} = M_{\text{total_R}} / M_{\text{total_OT}} = 2.313$$

PASS - Maximum restoring moment is greater than overturning moment

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action

$$\gamma_G = 1.00$$

Permanent favourable action

$$\gamma_{Gf} = 1.00$$

Variable unfavourable action

$$\gamma_Q = 1.30$$

Variable favourable action

$$\gamma_{Qf} = 0.00$$

Partial factors for soil parameters – Table A.4 - Combination 2

Angle of shearing resistance

$$\gamma_{\phi'} = 1.25$$

Effective cohesion

$$\gamma_{c'} = 1.25$$

Weight density

$$\gamma_{\gamma} = 1.00$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 23 \text{ kN/m}^3$$

Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 24.8 \text{ deg}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 0 \text{ deg}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_{\gamma} = 18 \text{ kN/m}^3$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 24.8 \text{ deg}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 12.1 \text{ deg}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 24.8 \text{ deg}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = 0.409$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = 3.473$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 4 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 3 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist_v}} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 4.5 \text{ kN/m}$$

Total

$$F_{\text{total_v}} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist_v}} = 11.5 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur_h}} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 0.8 \text{ kN/m}$$

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Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 3.9 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = 4.6 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \cos(\delta_{\text{b.d}}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 1.2 \text{ kN/m}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{\text{bb.d}}) = 5.3 \text{ kN/m}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 6.5 \text{ kN/m}$$

Factor of safety

$$\text{FoS}_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.412$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 4 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = 3 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = 4.5 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} = 11.5 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 0.8 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 3.9 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{\text{b.d}}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = -1.2 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = 3.4 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_{\text{OT}}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = 0.4 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_{\text{OT}}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = 1.2 \text{ kNm/m}$$

Total

$$M_{\text{total}_{\text{OT}}} = M_{\text{moist}_{\text{OT}}} + M_{\text{sur}_{\text{OT}}} = 1.6 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = 0.8 \text{ kNm/m}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = 0.9 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = 2.1 \text{ kNm/m}$$

Base soil

$$M_{\text{exc}_R} = -F_{\text{exc}_h} \times X_{\text{exc}_h} = 0.1 \text{ kNm/m}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = 3.9 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$\text{FoS}_{\text{ot}} = M_{\text{total}_R} / M_{\text{total}_{\text{OT}}} = 2.438$$

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1 and EN1996-1-1:2005 incorporating Corrigenda dated February 2006 and July 2009 and the UK National Annex

Tedds calculation version 2.6.05

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class

C28/35

Characteristic compressive cylinder strength

$$f_{\text{ck}} = 28 \text{ N/mm}^2$$

Characteristic compressive cube strength

$$f_{\text{ck,cube}} = 35 \text{ N/mm}^2$$

Mean value of compressive cylinder strength

$$f_{\text{cm}} = f_{\text{ck}} + 8 \text{ N/mm}^2 = 36 \text{ N/mm}^2$$

Mean value of axial tensile strength

$$f_{\text{ctm}} = 0.3 \text{ N/mm}^2 \times (f_{\text{ck}} / 1 \text{ N/mm}^2)^{2/3} = 2.8 \text{ N/mm}^2$$

5% fractile of axial tensile strength

$$f_{\text{ctk},0.05} = 0.7 \times f_{\text{ctm}} = 1.9 \text{ N/mm}^2$$

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Secant modulus of elasticity of concrete $E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = \mathbf{32308 \text{ N/mm}^2}$
Partial factor for concrete - Table 2.1N $\gamma_C = \mathbf{1.50}$
Compressive strength coefficient - cl.3.1.6(1) $\alpha_{cc} = \mathbf{0.85}$
Design compressive concrete strength - exp.3.15 $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{15.9 \text{ N/mm}^2}$
Maximum aggregate size $h_{agg} = \mathbf{20 \text{ mm}}$

Reinforcement details

Characteristic yield strength of reinforcement $f_{yk} = \mathbf{500 \text{ N/mm}^2}$
Modulus of elasticity of reinforcement $E_s = \mathbf{200000 \text{ N/mm}^2}$
Partial factor for reinforcing steel - Table 2.1N $\gamma_S = \mathbf{1.15}$
Design yield strength of reinforcement $f_{yd} = f_{yk} / \gamma_S = \mathbf{435 \text{ N/mm}^2}$

Cover to reinforcement

Top face of base $c_{bt} = \mathbf{40 \text{ mm}}$
Bottom face of base $c_{bb} = \mathbf{40 \text{ mm}}$

Masonry details - Section 3.1

Masonry type Clay with water absorption of < 7% - Group 1
Normalised mean compressive strength $f_b = \mathbf{50 \text{ N/mm}^2}$
Characteristic flexural strength - Table NA.6 $f_{xk} = \mathbf{0.7 \text{ N/mm}^2}$
Initial shear strength - Table NA.5 $f_{vko} = \mathbf{0.3 \text{ N/mm}^2}$

Mortar details - Section 3.2

Mortar type General purpose - M12, prescribed mix
Compressive strength of mortar $f_m = \mathbf{12 \text{ N/mm}^2}$

Ultimate limit states - Table NA.1

Class of execution control 2
Category of manufacture control 1
Partial factor for direct or flexural compression $\gamma_{Mc} = \mathbf{2.7}$
Partial factor for flexural tension $\gamma_{Mt} = \mathbf{2.7}$
Partial factor for shear $\gamma_{Mv} = \mathbf{2.5}$

Check stem design at base of stem

Depth of section $t = \mathbf{215 \text{ mm}}$

Masonry characteristics

Compressive strength constants - Table NA.4 $K = \mathbf{0.5}$
Characteristic compressive strength - cl.3.6.1.2(1) $f_k = K \times f_b^{0.7} \times f_m^{0.3} = \mathbf{16.293 \text{ N/mm}^2}$
Design compressive strength $f_d = f_k / \gamma_{Mc} = \mathbf{6.034 \text{ N/mm}^2}$
Design flexural strength $f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0.259 \text{ N/mm}^2}$
Height of masonry $h_{wt} = h_{stem} = \mathbf{750 \text{ mm}}$
Compressive axial force combination 1 $F_x = \gamma_{Gf} \times \gamma_{stem} \times h_{s1} \times t_{s1} = \mathbf{4 \text{ kN/m}}$
Moment combination 1 $M_x = \gamma_{Gf} \times \gamma_{stem} \times h_{s1} \times t_{s1} \times t_{s1} / 2 = \mathbf{0.4 \text{ kNm/m}}$
Eccentricity of axial load $e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{10.8 \text{ mm}}$
Capacity reduction factor - exp.6.4 $\Phi = 1 - 2 \times e / t = \mathbf{0.9}$
Design vertical resistance - exp.6.2 $N_{Rd} = \Phi \times t \times f_d = \mathbf{1167.7 \text{ kN/m}}$
Design vertical compressive stress $\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.019 \text{ N/mm}^2}$
Apparent design flexural strength - exp.6.16 $f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.278 \text{ N/mm}^2}$
Characteristic shear strength - exp.3.5 $f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, 0.065 \times f_b) = \mathbf{0.308 \text{ N/mm}^2}$
Design shear strength $f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.123 \text{ N/mm}^2}$

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Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 1 $M = 0.875$ kNm/m
Elastic section modulus of wall $Z = t^2 / 6 = 7704167$ mm³/m
Moment of resistance of masonry - exp.6.15 $M_{Rd} = f_{xd,app} \times Z = 2.142$ kNm/m
 $M / M_{Rd} = 0.409$

PASS - Moment of resistance exceeds applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force $V = 3.22$ kN/m
Maximum compressive stress $\sigma_{max} = F_x / t + M / Z = 0.132$ N/mm²
Minimum compressive stress $\sigma_{min} = F_x / t - M / Z = -0.095$ N/mm²
Thickness of wall in compression $t_c = t \times \sigma_{max} / (\sigma_{max} - \sigma_{min}) = 125$ mm
Design shear resistance - exp.6.13 $V_{Rd} = f_{vd} \times t_c = 15.404$ kN/m
 $V / V_{Rd} = 0.209$

PASS - Design shear resistance exceeds applied design shear force

Check base design at toe

Depth of section $h = 200$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 $M = 0.1$ kNm/m
Depth to tension reinforcement $d = h - C_{bb} - \phi_{bb} / 2 = 155$ mm
 $K = M / (d^2 \times f_{ck}) = 0.000$
 $K' = 0.207$

$K' > K$ - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 147$ mm
Depth of neutral axis $x = 2.5 \times (d - z) = 19$ mm
Area of tension reinforcement required $A_{bb,req} = M / (f_{yd} \times z) = 2$ mm²/m
Tension reinforcement provided 10 dia.bars @ 200 c/c
Area of tension reinforcement provided $A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times S_{bb}) = 393$ mm²/m
Minimum area of reinforcement - exp.9.1N $A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 223$ mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb,max} = 0.04 \times h = 8000$ mm²/m
 $\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = 0.568$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Limiting crack width $w_{max} = 0.3$ mm
Variable load factor - EN1990 – Table A1.1 $\psi_2 = 0.6$
Serviceability bending moment $M_{sls} = 0.1$ kNm/m
Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb,prov} \times z) = 1.4$ N/mm²
Load duration Long term
Load duration factor $k_t = 0.4$
Effective area of concrete in tension $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = 60208$ mm²/m
Mean value of concrete tensile strength $f_{ct,eff} = f_{ctm} = 2.8$ N/mm²
Reinforcement ratio $\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.007$
Modular ratio $\alpha_e = E_s / E_{cm} = 6.19$
Bond property coefficient $k_1 = 0.8$
Strain distribution coefficient $k_2 = 0.5$
 $k_3 = 3.4$

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Maximum crack spacing - exp.7.11

Maximum crack width - exp.7.8

$$k_4 = 0.425$$

$$s_{r,max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 397 \text{ mm}$$

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = 0.002 \text{ mm}$$

$$w_k / w_{max} = 0.006$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 2.6 \text{ kN/m}$$

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 2.000$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = 0.003$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.524 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = 81.2 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.032$$

PASS - Design shear resistance exceeds design shear force

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$$M = 0.5 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = 155 \text{ mm}$$

$$K = M / (d^2 \times f_{ck}) = 0.001$$

$$K' = 0.207$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 147 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = 19 \text{ mm}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = 7 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$10 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = 393 \text{ mm}^2/\text{m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 223 \text{ mm}^2/\text{m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = 8000 \text{ mm}^2/\text{m}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = 0.568$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Limiting crack width

$$w_{max} = 0.3 \text{ mm}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sls} = 0.2 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = 3.1 \text{ N/mm}^2$$

Load duration

Long term

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = 60208 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = 2.8 \text{ N/mm}^2$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = 0.007$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = 6.19$$

Bond property coefficient

$$k_1 = 0.8$$

Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

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Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p,eff} = \mathbf{397 \text{ mm}}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = \mathbf{0.004 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.012}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{2.6 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{2.000}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = \mathbf{0.003}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.524 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{81.2 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.032}$$

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)

$$A_{bx,req} = 0.2 \times A_{bb,prov} = \mathbf{79 \text{ mm}^2/\text{m}}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{bx,max} = \mathbf{450 \text{ mm}}$$

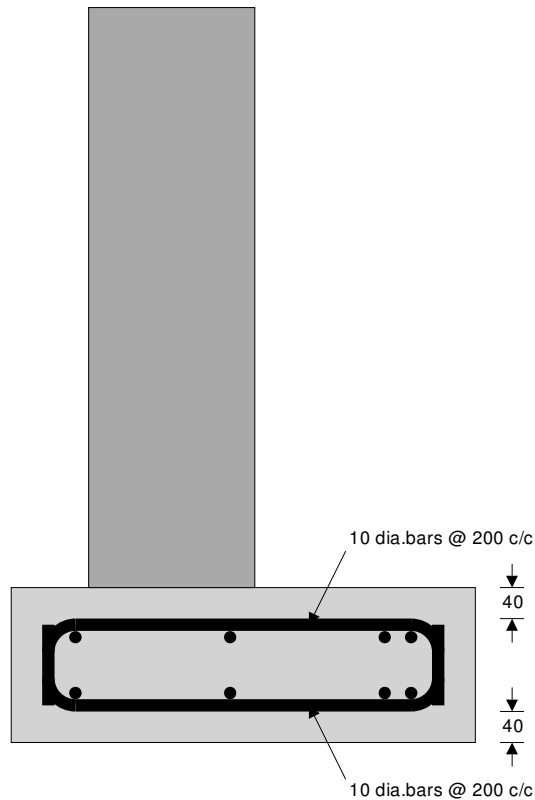
Transverse reinforcement provided

$$\mathbf{10 \text{ dia.bars @ } 200 \text{ c/c}}$$

Area of transverse reinforcement provided

$$A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = \mathbf{393 \text{ mm}^2/\text{m}}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required



10 dia.bars @ 200 c/c
transverse reinforcement
in base