



Job Title	Canada Road, Arundel	Date	June 2021
Item	DESIGN DATA	Job No.	WG1365
		Sheet No.	01
Prepared by	G Waller	Checked by	LG

Client		Bright Plans Civils				
Architect						
Q.S.						
Others						
Design Codes, British Standards & References (Current editions & Parts will be used as appropriate at the time of this design)		BS6399: Dead, Imposed and Wind Loading for Buildings BS449: The Use of Structural Steel in Buildings BS648: Schedule of Weights of Building Materials BS5268: Structural Use of Timber BS5628: Structural Use of Masonry BS5950: Structural Steelwork		BS8004: Code of Practice for Foundations BS8110: Structural Use of Concrete The Building Regulations Others:		
Building Structure Description		Highway retaining wall design. Wall retains footpath at a maximum height of 840mm.				
Fire Resistance						
Subsoil Foundation Data		/ Soil Investigation carried out by Geo-Environmental Ref :GE16975 – GARv1WH181026 : 26 th October 2018. Made ground over the Lambeth Group & White Chalk Subgroup at depth. Allowable bearing capacity of 100kPa at 1.5m bgl. DS-1 / AC-1 (C20) WS1 closest trial pit shows Lambeth Group at 1.3m bgl.				
Material Data		Blinding Concrete R.C. Foundations M.C. Foundations Superstructure	Works Cube Strength	Aggregate Size	Cement Content	Max. Free Water/ Cement Ratio
1. Concrete						
	C20		20	220	0.80	
2. Reinforcement		A) T High Tensile				

Job Title Canada Road, Arundel		Date June 2021
Item STANDARD NOTES	Job No. WG1365	Sheet No. 02
Prepared by GW		Checked by LG

MATERIALS & WOKMANSHIP: These calculations are based on the assumption that the work on site is directed and undertaken by an experienced, competent building contractor whose workmanship and materials comply with the latest edition of the Building Regulations. The building contractor is entirely responsible for the quality of the materials and workmanship used in carrying out the building work. All proprietary products are to be installed in accordance with the manufacturers' instructions.

All roof rafters, walls, floors and ceilings shall be tied together using wall / floor / ceiling and wall / wallplate / rafter ties of galvanised mild steel complying in size, thickness, fixing and spacing etc. with the latest edition of the Building Regulations.

Dimensions in these calculations are only approximate and the builder must check the latest architectural drawings and measure up on site before ordering any materials.

CDM REGULATIONS 2015: The client must notify the HSE of projects where construction work is intended to or likely to last more than 30 working days and has more than 20 workers on site together at any point or if the project exceeds 500 person days. Wherever there is more than one contractor, the client must appoint a Principal Contractor who must ensure a construction phase plan is completed prior to commencement of construction. The client or a Principal Designer appointed by the client is responsible for the co-ordination of health & safety during the pre-construction and construction phase of the project.

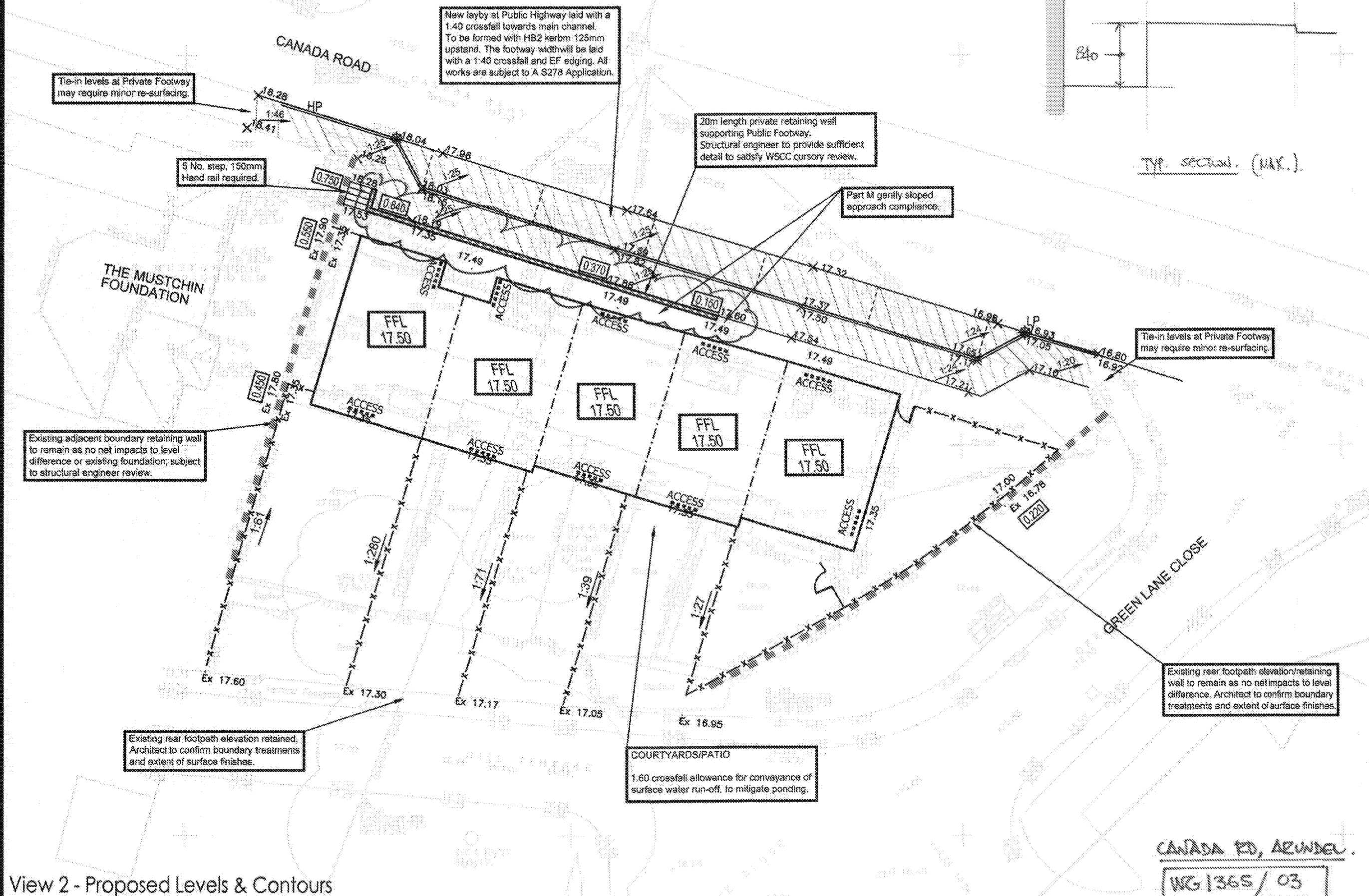
TEMPORARY WORKS: For alteration work requiring new openings in walls or the removal of existing walls, the builder is to follow the guidance in the BRE Good Building Guides Nos. 15 and 20 - "Providing temporary support during work on openings in external walls" and "Removing internal load-bearing walls in older dwellings". We advise against the use of "Strong-Boy" Acrow props where heavy loads are to be supported.

PARTY WALL ETC. ACT 1996: If the building work involves:

- work on an existing wall shared with another property or
- building on the boundary with a neighbouring property or
- excavating near a neighbouring building,

then the client must find out whether the work falls within the Act. If it does, the Act requires the client to notify all affected neighbours. We can if requested by our client, provide additional advice on these matters and if necessary act as **Party Wall Surveyor** for which an additional charge would be made.

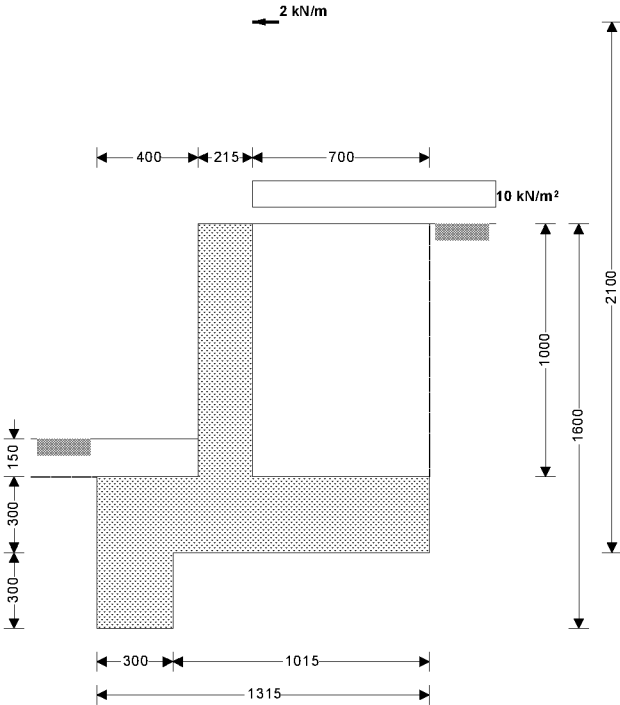
EXTENT OF RESPONSIBILITY: Waller Gray Consulting Ltd's responsibility extends only to the supply of structural calculations and does not include inspection of workmanship or materials on site. The builder is entirely responsible for all temporary works and for maintaining the stability of the new and existing structures during the work on site. We will if requested by our client, additionally provide advice regarding these matters and/or inspection of work on site, for which an additional charge will be made



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	Canada Road, Arundel				WG1365	
	Calcs for				Start page no./Revision	
	Highway Retaining Aall				04	
	Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
	GW	23/06/2021	LG		LG	

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.08



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
 $h_{stem} = 1000 \text{ mm}$
 $t_{wall} = 215 \text{ mm}$
 $l_{toe} = 400 \text{ mm}$
 $l_{heel} = 700 \text{ mm}$
 $l_{base} = l_{toe} + l_{heel} + t_{wall} = 1315 \text{ mm}$
 $t_{base} = 300 \text{ mm}$
 $d_{ds} = 300 \text{ mm}$
 $l_{ds} = 0 \text{ mm}$
 $t_{ds} = 300 \text{ mm}$
 $h_{wall} = h_{stem} + t_{base} + d_{ds} = 1600 \text{ mm}$
 $d_{cover} = 150 \text{ mm}$
 $d_{exc} = 150 \text{ mm}$
 $h_{water} = 0 \text{ mm}$
 $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 0 \text{ mm}$
 $\gamma_{wall} = 23.6 \text{ kN/m}^3$
 $\gamma_{base} = 23.6 \text{ kN/m}^3$
 $\alpha = 90.0 \text{ deg}$
 $\beta = 0.0 \text{ deg}$
 $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 1600 \text{ mm}$

Retained material details

Mobilisation factor
Moist density of retained material

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

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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 $\delta = 0.0 \text{ deg}$

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 $P_{\text{bearing}} = 100 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient for retained material

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

Passive pressure coefficient for base material

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

At-rest pressure

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

Loading details

Surcharge load on plan Surcharge = **10.0 kN/m²**

Applied vertical dead load on wall $W_{\text{dead}} = 0.0 \text{ kN/m}$

Applied vertical live load on wall $W_{\text{live}} = 0.0 \text{ kN/m}$

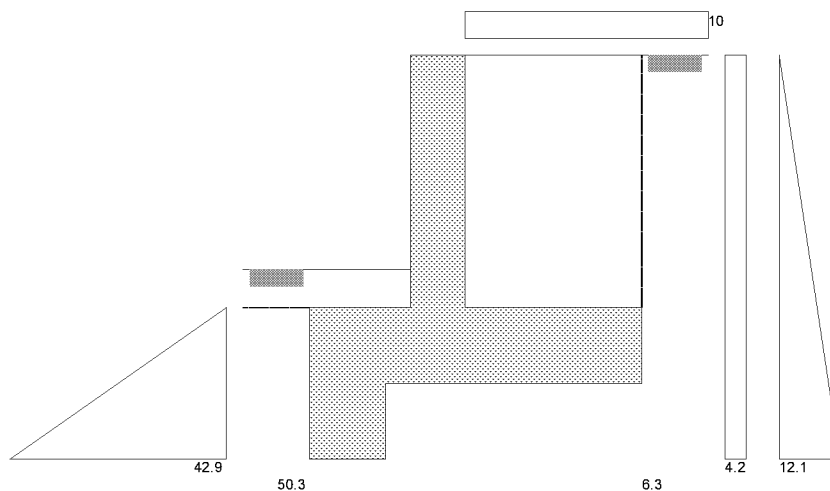
Position of applied vertical load on wall $l_{\text{load}} = 0 \text{ mm}$

Applied horizontal dead load on wall $F_{\text{dead}} = 0.0 \text{ kN/m}$

Applied horizontal live load on wall $F_{\text{live}} = 1.5 \text{ kN/m}$

Height of applied horizontal load on wall $h_{\text{load}} = 2100 \text{ mm}$

←²



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

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Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} * t_{wall} * \gamma_{wall} = 5.1 \text{ kN/m}$
Wall base	$W_{base} = l_{base} * t_{base} * \gamma_{base} = 9.3 \text{ kN/m}$
Wall downstand	$W_{ds} = d_{ds} * t_{ds} * \gamma_{base} = 2.1 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} * l_{heel} = 7 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} * (h_{stem} - h_{sat}) * \gamma_m = 12.6 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} * d_{cover} * \gamma_{mb} = 1.1 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{ds} + W_{sur} + W_{m_w} + W_p = 37.2 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a * \text{Surcharge} * h_{eff} = 6.7 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 * K_a * \gamma_m * (h_{eff} - h_{water})^2 = 9.6 \text{ kN/m}$
Applied horizontal load	$F_h = F_{dead} + F_{live} = 1.5 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} + F_h = 17.8 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 * K_p * \cos(\delta_b) * (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 * \gamma_{mb} = 12.9 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p) * \tan(\delta_b) = 22.7 \text{ kN/m}$

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge	$M_{sur} = F_{sur} * (h_{eff} - 2 * d_{ds}) / 2 = 3.3 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} * (h_{eff} + 2 * h_{water} - 3 * d_{ds}) / 3 = 2.2 \text{ kNm/m}$
Applied horizontal load	$M_{hor} = F_h * h_{load} = 3.2 \text{ kNm/m}$
Soil in front of wall	$M_{p_o} = F_p * [2 * d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 1.3 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} + M_{hor} + M_{p_o} = 10 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} * (l_{toe} + t_{wall} / 2) = 2.6 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} * l_{base} / 2 = 6.1 \text{ kNm/m}$
Wall downstand	$M_{ds} = W_{ds} * (l_{ds} + t_{ds} / 2) = 0.3 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} * (l_{base} - l_{heel} / 2) + W_{m_s} * (l_{base} - l_{heel} / 3)) = 12.2 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{ds} + M_{m_r} = 21.2 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 10.0 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 21.2 \text{ kNm/m}$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} * (l_{base} - l_{heel} / 2) = 6.8 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p * l_{toe} / 2 = 0.2 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 18.1 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 37.2 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 487 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 170 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 * R * e / l_{base}^2) = 50.3 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 * R * e / l_{base}^2) = 6.3 \text{ kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure

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RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.08

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	$W_{wall_f} = \gamma_{f_d} * h_{stem} * t_{wall} * \gamma_{wall} = 7.1 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} * l_{base} * t_{base} * \gamma_{base} = 13 \text{ kN/m}$
Wall downstand	$W_{ds_f} = \gamma_{f_d} * d_{ds} * t_{ds} * \gamma_{base} = 3 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} * \text{Surcharge} * l_{heel} = 11.2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} * l_{heel} * (h_{stem} - h_{sat}) * \gamma_m = 17.6 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} * l_{toe} * d_{cover} * \gamma_{mb} = 1.5 \text{ kN/m}$
Total vertical load	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{ds_f} + W_{sur_f} + W_{m_w_f} + W_{p_f} = 53.5 \text{ kN/m}$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} * K_0 * \text{Surcharge} * h_{eff} = 15.1 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} * 0.5 * K_0 * \gamma_m * (h_{eff} - h_{water})^2 = 19 \text{ kN/m}$
Applied horizontal load	$F_{h_f} = \gamma_{f_e} * F_{dead} + \gamma_{f_l} * F_{live} = 2.4 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} + F_{h_f} = 36.5 \text{ kN/m}$
Passive resistance of soil in front of wall	$F_{p_f} = \gamma_{f_e} * 0.5 * K_p * \cos(\delta_b) * (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 * \gamma_{mb} = 18 \text{ kN/m}$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} * (h_{eff} - 2 * d_{ds}) / 2 = 7.6 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} * (h_{eff} + 2 * h_{water} - 3 * d_{ds}) / 3 = 4.4 \text{ kNm/m}$
Applied horizontal load	$M_{hor_f} = F_{h_f} * h_{load} = 5 \text{ kNm/m}$
Soil in front of wall	$M_{p_o_f} = F_{p_f} * [2 * d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 1.8 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} + M_{hor_f} + M_{p_o_f} = 18.8 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} * (l_{toe} + t_{wall} / 2) = 3.6 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} * l_{base} / 2 = 8.6 \text{ kNm/m}$
Wall downstand	$M_{ds_f} = W_{ds_f} * (l_{ds} + t_{ds} / 2) = 0.4 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} * (l_{base} - l_{heel} / 2) = 10.8 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} * (l_{base} - l_{heel} / 2) + W_{m_s_f} * (l_{base} - l_{heel} / 3)) = 17 \text{ kNm/m}$
Soil in front of wall	$M_{p_r_f} = W_{p_f} * l_{toe} / 2 = 0.3 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{ds_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} = 40.8 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 21.9 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 53.5 \text{ kN/m}$
Distance to reaction	$x_{bar_f} = M_{total_f} / R_f = 410 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar_f}) = 247 \text{ mm}$

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 * x_{bar_f}) = 86.9 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = p_{toe_f} / (3 * x_{bar_f}) = 70.68 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \text{max}(p_{toe_f} - (\text{rate} * l_{toe}), 0 \text{ kN/m}^2) = 58.7 \text{ kN/m}^2$
Bearing pressure at mid stem	$p_{stem_mid_f} = \text{max}(p_{toe_f} - (\text{rate} * (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 51.1 \text{ kN/m}^2$

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Bearing pressure at stem / heel

$$p_{\text{stem_heel}_f} = \max(p_{\text{toe}_f} - (\text{rate} * (l_{\text{toe}} + t_{\text{wall}})), 0 \text{ kN/m}^2) = 43.5 \text{ kN/m}^2$$

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

Material properties

Characteristic strength of concrete

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

Characteristic strength of reinforcement

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

Base details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in toe

$$c_{\text{toe}} = 50 \text{ mm}$$

Calculate shear for toe design

Shear from bearing pressure

$$V_{\text{toe_bear}} = (p_{\text{toe}_f} + p_{\text{stem_toe}_f}) * l_{\text{toe}} / 2 = 29.1 \text{ kN/m}$$

Shear from weight of base

$$V_{\text{toe_wt_base}} = \gamma_{\text{f}_d} * \gamma_{\text{base}} * l_{\text{toe}} * t_{\text{base}} = 4 \text{ kN/m}$$

Shear from weight of downstand

$$V_{\text{toe_wt_ds}} = \gamma_{\text{f}_d} * \gamma_{\text{base}} * d_{\text{ds}} * t_{\text{ds}} = 3 \text{ kN/m}$$

Total shear for toe design

$$V_{\text{toe}} = V_{\text{toe_bear}} - V_{\text{toe_wt_base}} - V_{\text{toe_wt_ds}} = 22.2 \text{ kN/m}$$

Calculate moment for toe design

Moment from bearing pressure

$$M_{\text{toe_bear}} = (2 * p_{\text{toe}_f} + p_{\text{stem_mid}_f}) * (l_{\text{toe}} + t_{\text{wall}} / 2)^2 / 6 = 9.7 \text{ kNm/m}$$

Moment from weight of base

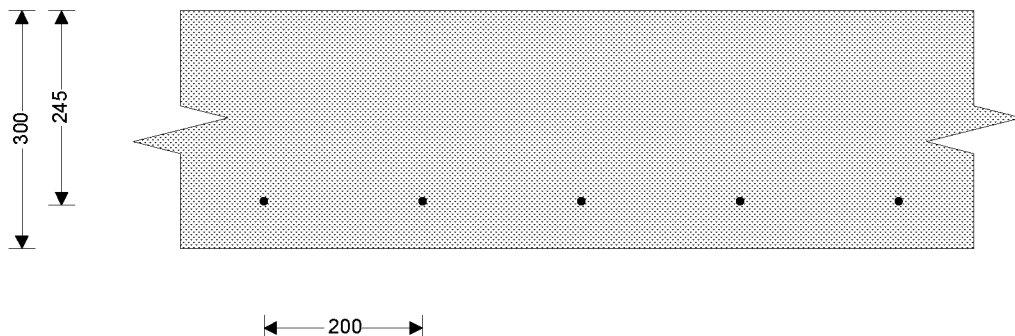
$$M_{\text{toe_wt_base}} = (\gamma_{\text{f}_d} * \gamma_{\text{base}} * t_{\text{base}} * (l_{\text{toe}} + t_{\text{wall}} / 2)^2 / 2) = 1.3 \text{ kNm/m}$$

Moment from weight of downstand

$$M_{\text{toe_wt_ds}} = \gamma_{\text{f}_d} * \gamma_{\text{base}} * d_{\text{ds}} * t_{\text{ds}} * (l_{\text{toe}} - l_{\text{ds}} + (t_{\text{wall}} - t_{\text{ds}}) / 2) = 1.1 \text{ kNm/m}$$

Total moment for toe design

$$M_{\text{toe}} = M_{\text{toe_bear}} - M_{\text{toe_wt_base}} - M_{\text{toe_wt_ds}} = 7.3 \text{ kNm/m}$$



Check toe in bending

Width of toe

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

Depth of reinforcement

$$d_{\text{toe}} = t_{\text{base}} - c_{\text{toe}} - (\phi_{\text{toe}} / 2) = 245.0 \text{ mm}$$

Constant

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

Compression reinforcement is not required

Lever arm

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

$$z_{\text{toe}} = 233 \text{ mm}$$

Area of tension reinforcement required

$$A_{\text{s_toe_des}} = M_{\text{toe}} / (0.87 * f_y * z_{\text{toe}}) = 72 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{\text{s_toe_min}} = k * b * t_{\text{base}} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{\text{s_toe_req}} = \text{Max}(A_{\text{s_toe_des}}, A_{\text{s_toe_min}}) = 390 \text{ mm}^2/\text{m}$$

Reinforcement provided

A393 mesh

Area of reinforcement provided

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

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$$v_{\text{toe}} = V_{\text{toe}} / (b * d_{\text{toe}}) = 0.091 \text{ N/mm}^2$$

Allowable shear stress

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

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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

$$v_{c_toe} = 0.454 \text{ N/mm}^2$$

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

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

Material properties

Characteristic strength of concrete

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

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

$$c_{heel} = 50 \text{ mm}$$

Calculate shear for heel design

Shear from bearing pressure

$$V_{heel_bear} = p_{stem_heel_f} * ((3 * x_{bar_f}) - l_{toe} - t_{wall}) / 2 = 13.4 \text{ kN/m}$$

Shear from weight of base

$$V_{heel_wt_base} = \gamma_{fd} * \gamma_{base} * l_{heel} * t_{base} = 6.9 \text{ kN/m}$$

Shear from weight of moist backfill

$$V_{heel_wt_m} = w_{m_w_f} = 17.6 \text{ kN/m}$$

Shear from surcharge

$$V_{heel_sur} = w_{sur_f} = 11.2 \text{ kN/m}$$

Total shear for heel design

$$V_{heel} = -V_{heel_bear} + V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 22.4 \text{ kN/m}$$

Calculate moment for heel design

Moment from bearing pressure

$$M_{heel_bear} = p_{stem_mid_f} * ((3 * x_{bar_f}) - l_{toe} - t_{wall} / 2)^2 / 6 = 4.4 \text{ kNm/m}$$

Moment from weight of base

$$M_{heel_wt_base} = (\gamma_{fd} * \gamma_{base} * t_{base} * (l_{heel} + t_{wall} / 2)^2 / 2) = 3.2 \text{ kNm/m}$$

Moment from weight of moist backfill

$$M_{heel_wt_m} = w_{m_w_f} * (l_{heel} + t_{wall}) / 2 = 8.1 \text{ kNm/m}$$

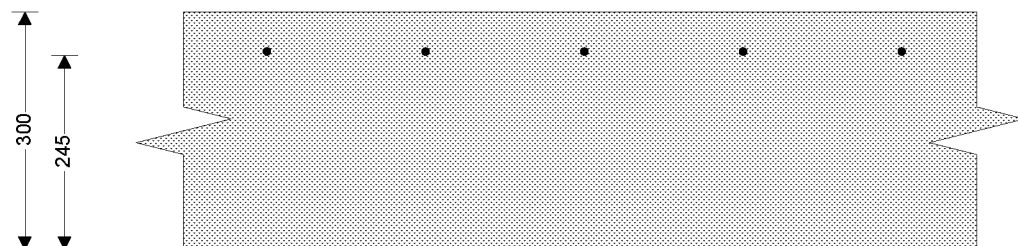
Moment from surcharge

$$M_{heel_sur} = w_{sur_f} * (l_{heel} + t_{wall}) / 2 = 5.1 \text{ kNm/m}$$

Total moment for heel design

$$M_{heel} = -M_{heel_bear} + M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 12 \text{ kNm/m}$$

200



Check heel in bending

Width of heel

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

Depth of reinforcement

$$d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) = 245.0 \text{ mm}$$

Constant

$$K_{heel} = M_{heel} / (b * d_{heel}^2 * f_{cu}) = 0.005$$

Compression reinforcement is not required

Lever arm

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

$$z_{heel} = 233 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_heel_des} = M_{heel} / (0.87 * f_y * z_{heel}) = 118 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_heel_min} = k * b * t_{base} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_heel_req} = \max(A_{s_heel_des}, A_{s_heel_min}) = 390 \text{ mm}^2/\text{m}$$

Reinforcement provided

A393 mesh

Area of reinforcement provided

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

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PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress

$$V_{heel} = V_{heel} / (b \times d_{heel}) = 0.091 \text{ N/mm}^2$$

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

$$V_{c_heel} = 0.454 \text{ N/mm}^2$$

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

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

Material properties

Characteristic strength of concrete

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

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

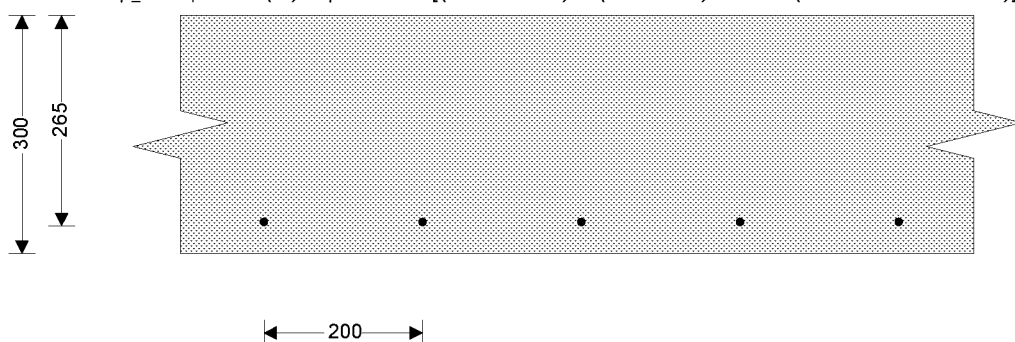
Total shear for downstand design

$$V_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times (d_{cover} + t_{base} + d_{ds} / 2) = 18 \text{ kN/m}$$

Calculate moment for downstand design

Total moment for downstand design

$$M_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times [(d_{cover} + t_{base}) \times (t_{base} + d_{ds}) + d_{ds} \times (t_{base} / 2 + 2 \times d_{ds} / 3)] / 2 = 5.6 \text{ kNm/m}$$



Check downstand in bending

Width of downstand

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

Depth of reinforcement

$$d_{down} = t_{ds} - C_{ds} - (\phi_{down} / 2) = 265.0 \text{ mm}$$

Constant

$$K_{down} = M_{down} / (b \times d_{down}^2 \times f_{cu}) = 0.002$$

Compression reinforcement is not required

Lever arm

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

$$Z_{down} = 252 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_down_des} = M_{down} / (0.87 \times f_y \times Z_{down}) = 51 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_down_min} = k \times b \times t_{ds} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_down_req} = \text{Max}(A_{s_down_des}, A_{s_down_min}) = 390 \text{ mm}^2/\text{m}$$

Reinforcement provided

$$\text{A393 mesh}$$

Area of reinforcement provided

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

PASS - Reinforcement provided at the retaining wall downstand is adequate

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Check shear resistance at downstand

Design shear stress

$$v_{\text{down}} = V_{\text{down}} / (b \times d_{\text{down}}) = \mathbf{0.068 \text{ N/mm}^2}$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

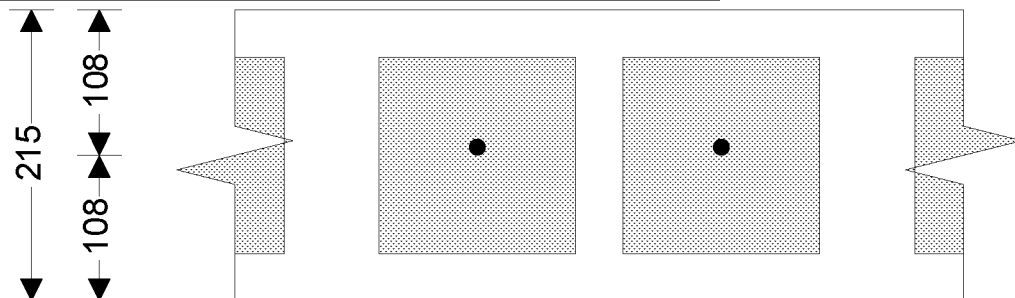
From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{\text{c_down}} = \mathbf{0.434 \text{ N/mm}^2}$$

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

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



◀100 average▶

Wall details

Thickness of wall

$$t_{\text{wall}} = \mathbf{215 \text{ mm}}$$

Depth of stem reinforcement

$$d_{\text{stem}} = \mathbf{108 \text{ mm}}$$

Masonry details

Masonry type

Aggregate concrete blocks no voids

Compressive strength of units

$$p_{\text{unit}} = \mathbf{10.4 \text{ N/mm}^2}$$

Mortar designation

(ii)

Category of manufacturing control of units

Category I

Partial safety factor for material strength

$$\gamma_{\text{mm}} = \mathbf{2.3}$$

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units

$$b_{\text{unit}} = \mathbf{100.0 \text{ mm}}$$

Height of masonry units

$$h_{\text{unit}} = \mathbf{215.0 \text{ mm}}$$

Ratio of height to least horizontal dimension

$$\text{ratio} = h_{\text{unit}} / b_{\text{unit}} = \mathbf{2.2}$$

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength

$$f_k = \mathbf{8.4 \text{ N/mm}^2}$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{\text{s_sur_f}} = \gamma_{\text{f_l}} * K_0 * \text{Surcharge} * (h_{\text{eff}} - t_{\text{base}} - d_{\text{ds}}) = \mathbf{9.4 \text{ kN/m}}$$

Moist backfill above water table

$$F_{\text{s_m_a_f}} = 0.5 * \gamma_{\text{f_e}} * K_0 * \gamma_{\text{m}} * (h_{\text{eff}} - t_{\text{base}} - d_{\text{ds}} - h_{\text{sat}})^2 = \mathbf{7.4 \text{ kN/m}}$$

Applied horizontal load

$$F_{\text{s_h_f}} = \gamma_{\text{f_d}} * F_{\text{dead}} + \gamma_{\text{f_l}} * F_{\text{live}} = \mathbf{2.4 \text{ kN/m}}$$

Calculate shear for stem design

Shear at base of stem

$$V_{\text{stem}} = F_{\text{s_sur_f}} + F_{\text{s_m_a_f}} + F_{\text{s_h_f}} = \mathbf{19.3 \text{ kN/m}}$$

Calculate moment for stem design

Surcharge

$$M_{\text{s_sur}} = F_{\text{s_sur_f}} * (h_{\text{stem}} + t_{\text{base}}) / 2 = \mathbf{6.1 \text{ kNm/m}}$$

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	GW	23/06/2021	LG		LG	

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} * (2 * h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 3.6 \text{ kNm/m}$$

Applied horizontal load

$$M_{s_hor} = F_{s_h_f} * (h_{load} - t_{base} / 2) = 4.7 \text{ kNm/m}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} + M_{s_hor} = 14.4 \text{ kNm/m}$$

Check maximum design moment for wall stem

Width of wall

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

Maximum design moment

$$M_{d_stem} = 0.4 * f_k * b * d_{stem}^2 / \gamma_{mm} = 16.9 \text{ kNm/m}$$

PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor

$$Q = M_{stem} / d_{stem}^2 = 1.247 \text{ N/mm}^2$$

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

Lever arm factor

$$c = 0.782$$

Lever arm

$$Z_{stem} = \min(0.95, c) * d_{stem} = 84.0 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{stem} * \gamma_{ms} / (f_y * Z_{stem}) = 394 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k * b * t_{wall} = 280 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = 394 \text{ mm}^2/\text{m}$$

Reinforcement provided

12 mm dia.bars @ 100 mm centres

Area of reinforcement provided

$$A_{s_stem_prov} = \pi * \phi_{stem}^2 / (4 * s_{stem}) = 1131 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$v_{stem} = V_{stem} / (b * d_{stem}) = 0.179 \text{ N/mm}^2$$

Basic characteristic shear strength of masonry

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

$$f_{vbas} = 0.534 \text{ N/mm}^2$$

Shear span

$$a = M_{stem} / V_{stem} = 747.6 \text{ mm}$$

Characteristic shear strength of masonry

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

$$f_v = 0.534 \text{ N/mm}^2$$

Allowable shear stress

$$V_{adm} = f_v / \gamma_{mv} = 0.267 \text{ N/mm}^2$$

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

$$\text{ratio}_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = 9.80$$

PASS - Span to depth ratio is acceptable

Axial load check

Factored axial load on wall

$$N_{wall} = ([t_{wall} * h_{stem} * \gamma_{wall} + W_{dead}] * \gamma_{t_d}) + (W_{live} * \gamma_{t_l}) = 7.1 \text{ kN/m}$$

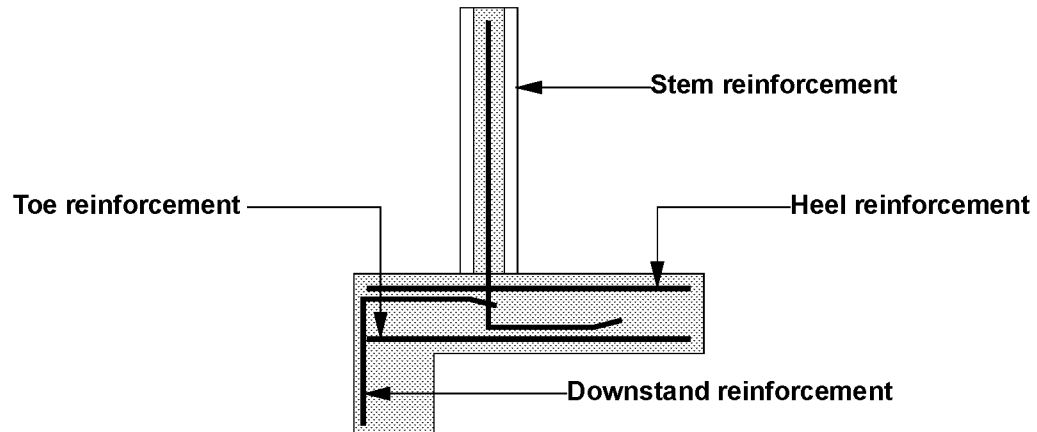
Limiting axial load

$$N_{limit} = 0.1 * f_k * t_{wall} = 180.6 \text{ kN/m}$$

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)

Downstand mesh - A393 - (393 mm²/m)

Stem bars - 12 mm dia. @ 100 mm centres - (1131 mm²/m)

REINFORCED HOLLOW BLOCK WALL SPECIFICATION :

REINFORCEMENT SHOULD BE PLACED CENTRALLY IN EACH BLOCK (2No. PER BLOCK) .

'CLEAN OUT POCKETS' SHALL BE LEFT AT THE BOTTOM OF THE FRONT FACE TO REMOVE MORTAR DROPPINGS PRIOR TO FILLING THE VOIDS.

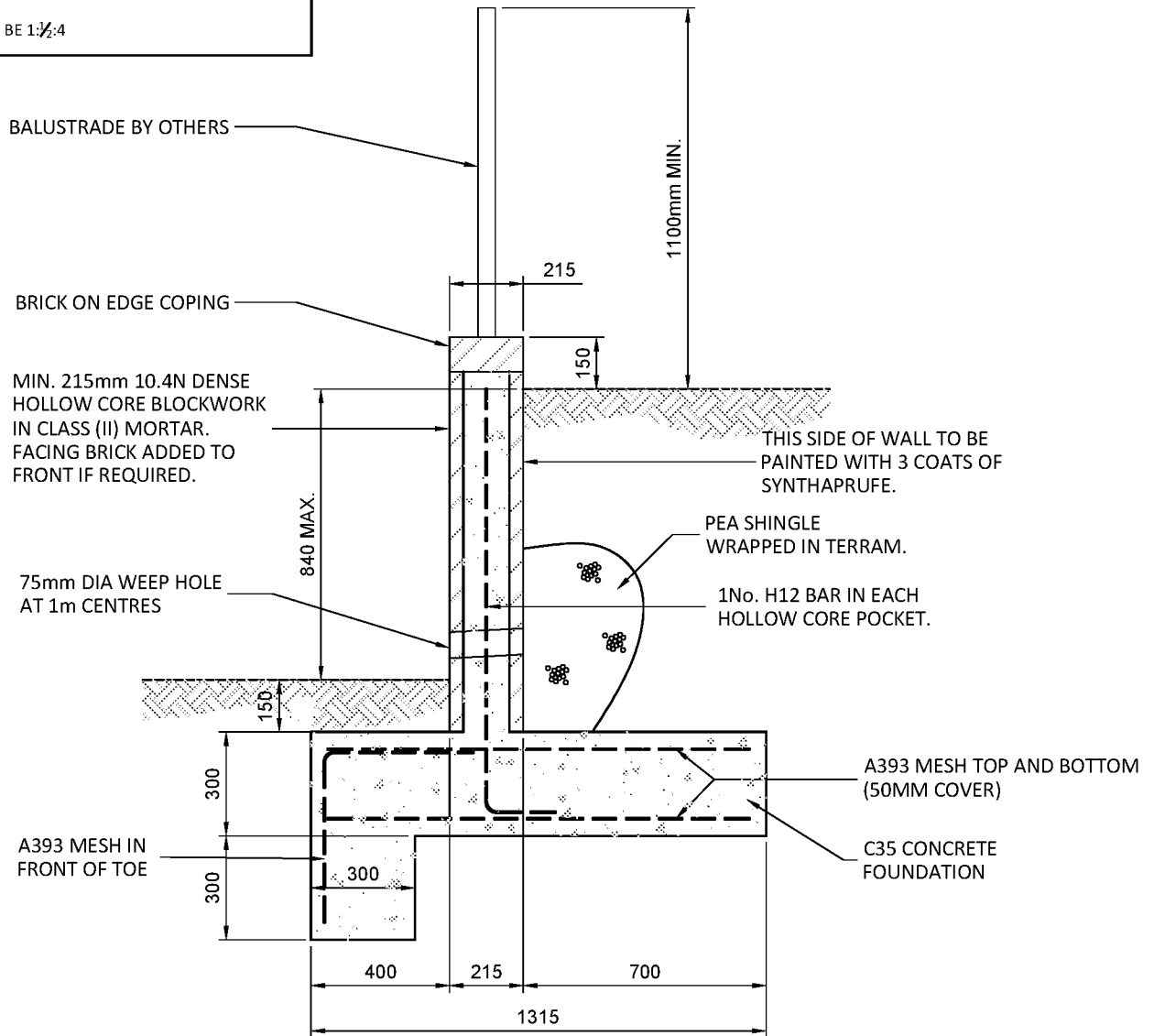
VOIDS SHALL BE FILLED WITH CONCRETE IN MAXIMUM 900mm LIFTS.

CONCRETE MIX TO BE C30 (1:3:2 ~ CEMENT: SAND:10mm MAX. AGGREGATE) MINIMUM CEMENT CONTENT 340kg/m².
SLUMP TO BE BETWEEN 100 AND 175mm.

CONCRETE SHALL BE WELL PUNNED BUT NOT VIBRATED.

WALL STRENGTHS :
HOLLOW BLOCKS TO BE 7.3N/mm² MIN.

ALL MORTAR TO BE 1:½:4



RETAINING WALL - (HOLLOW BLOCK)

Max. Height 840mm

Scale 1:20

(Note: All dimensions in millimeters)

-	-	-	-	-
Rev	Date	Revisions	Drwn	Chk
Client:				
BRIGHT PLAN CIVILS				
Scale:	Date:	Drawn:	Checked:	
1:20	JUNE 2021	GW	LG	
Drawing No:				Rev:
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Drawing Title:

HIGHWAY RETAINING WALL
HOLLOW BLOCK WALL

Project:

CANADA ROAD, ARUNDEL