

 Elite Designers 3 Princeton Court Felsham Road SW15 1AZ	Project 103 to 107 North Hill				Job Ref. 2021-024	
	Section Preliminary Planning/Feasibility				Sheet no./rev. 3	
	Calc. by JGF	Date 17/08/2021	Chk'd by	Date	App'd by	Date

Geotechnical partial and model factors:

Design approach 1:

Model factor on compressive resistance;
 $\gamma_{model} = 1.40$
Model factor on tensile resistance;
 $\gamma_{model,t} = 1.40$
Permanent unfavourable, A1 (Table A.3);
 $\gamma_{G,unfav,A1} = 1.35$
Permanent favourable, A1 (1);
 $\gamma_{G,fav,A1} = 1.00$
Variable unfavourable, A1 (Table A.3);
 $\gamma_{Q,A1} = 1.50$
Permanent unfavourable, A2 (Table A.3);
 $\gamma_{G,unfav,A2} = 1.00$
Permanent favourable, A2 (Table A.3);
 $\gamma_{G,fav,A2} = 1.00$
Variable unfavourable, A2 (Table A.3);
 $\gamma_{Q,A2} = 1.30$

Characteristic axial resistance

Characteristic axial base resistance;
 $R_{sk} = A_{bearing} \times q_{bk} = 25.1 \text{ kN}$

Characteristic axial shaft resistance per stratum
Stratum 1;
 $R_{sk1} = q_{sk1} \times \text{Perim}_{pile} \times t_{strata1} = 628.3 \text{ kN}$
Stratum 2;
 $R_{sk2} = q_{sk2} \times \text{Perim}_{pile} \times t_{strata2} = 942.5 \text{ kN}$
Stratum 3;
 $R_{sk3} = q_{sk3} \times \text{Perim}_{pile} \times (L - D_{strata3}) = 502.7 \text{ kN}$
Characteristic total axial shaft resistance;
 $R_{sk} = R_{sk1} + R_{sk2} + R_{sk3} = 2073.5 \text{ kN}$

Axial compressive resistance

Load combination 1: A1 + M1 + R1

Design compression action;
 $F_{c,d,C1} = \gamma_{G,unfav,A1} \times G_{c,k,unfav} + \gamma_{G,fav,A1} \times G_{c,k,fav} + \gamma_{Q,A1} \times Q_{c,k}$
 $F_{c,d,C1} = 135 \text{ kN}$

Partial resistance factor, bearing (Table A.NA.7);
 $\gamma_{b,R1} = 1.00$

Partial resistance factor, shaft (Table A.NA.7);
 $\gamma_{s,R1} = 1.00$

Design compressive resistance;
 $R_{c,d,C1} = (R_{sk} / \gamma_{b,R1} + R_{sk} / \gamma_{s,R1}) / \gamma_{model} = 1499 \text{ kN}$
 $F_{c,d,C1} / R_{c,d,C1} = 0.09$

PASS - Design compressive resistance exceeds design load

Load combination 2: A2 + M1 + R4

Design compression action;
 $F_{c,d,C2} = \gamma_{G,unfav,A2} \times G_{c,k,unfav} + \gamma_{G,fav,A2} \times G_{c,k,fav} + \gamma_{Q,A2} \times Q_{c,k}$
 $F_{c,d,C2} = 100 \text{ kN}$

Partial resistance factor, bearing (Table A.NA.7);
 $\gamma_{b,R4} = 2.00$

Partial resistance factor, shaft (Table A.NA.7);
 $\gamma_{s,R4} = 1.60$

Design compressive resistance;
 $R_{c,d,C2} = (R_{sk} / \gamma_{b,R4} + R_{sk} / \gamma_{s,R4}) / \gamma_{model} = 934.6 \text{ kN}$
 $F_{c,d,C2} / R_{c,d,C2} = 0.107$

PASS - Design compressive resistance exceeds design load

Axial tensile resistance

Load combination 1: A1 + M1 + R1

Design tension load;
 $F_{t,d,C1} = \gamma_{G,unfav,A1} \times G_{t,k,unfav} + \gamma_{G,fav,A1} \times G_{t,k,fav} + \gamma_{Q,A1} \times Q_{t,k}$
 $F_{t,d,C1} = 33.8 \text{ kN}$

Partial resist. factor, shaft in tension (Table A.NA.7); $\gamma_{s,L,R1} = 1$

Design tensile resistance;
 $R_{t,d,C1} = R_{sk} / (\gamma_{s,L,R1} \times \gamma_{model,t}) = 1481 \text{ kN}$
 $F_{t,d,C1} / R_{t,d,C1} = 0.023$

PASS - Design tensile resistance exceeds design load

Load combination 2: A2 + M1 + R4

Design tension load;
 $F_{t,d,C2} = \gamma_{G,unfav,A2} \times G_{t,k,unfav} + \gamma_{G,fav,A2} \times G_{t,k,fav} + \gamma_{Q,A2} \times Q_{t,k}$
 $F_{t,d,C2} = 25 \text{ kN}$

Partial resist. factor, shaft in tension (Table A.NA.7); $\gamma_{s,L,R4} = 2$

Design tensile resistance;
 $R_{t,d,C2} = R_{sk} / (\gamma_{s,L,R4} \times \gamma_{model,t}) = 740.5 \text{ kN}$
 $F_{t,d,C2} / R_{t,d,C2} = 0.034$

PASS - Design tensile resistance exceeds design load

;
;

RETAINING WALL ANALYSIS & DESIGN (EN1992/EN1996/EN1997)

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 2.9.10

Retaining wall details

Stem type;
Propped cantilever
Stem height;
 $h_{stem} = 3000 \text{ mm}$
Prop height;
 $h_{prop} = 2000 \text{ mm}$
Stem thickness;
 $t_{stem} = 300 \text{ mm}$
Angle to rear face of stem;
 $\alpha = 90 \text{ deg}$
Stem density;
 $\gamma_{stem} = 25 \text{ kN/m}^3$
Toe length;
 $l_{toe} = 1800 \text{ mm}$
Heel length;
 $l_{heel} = 500 \text{ mm}$
Base thickness;
 $l_{base} = 350 \text{ mm}$
Base density;
 $\gamma_{base} = 25 \text{ kN/m}^3$

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Height of retained soil;

Angle of soil surface;

Depth of cover;

Depth of excavation;

Height of water;

Water density;

Retained soil properties

Soil type;

Moist density;

Saturated density;

Characteristic effective shear resistance angle;

Characteristic wall friction angle;

Base soil properties

Soil type;

Soil density;

Characteristic cohesion;

Characteristic effective shear resistance angle;

Characteristic wall friction angle;

Characteristic base friction angle;

Loading details

Variable surcharge load;

Vertical line load at 1950 mm;

;

$h_{ret} = 2500 \text{ mm}$

$\beta = 0 \text{ deg}$

$d_{cover} = 500 \text{ mm}$

$d_{exc} = 200 \text{ mm}$

$h_{water} = 1750 \text{ mm}$

$\gamma_w = 9.8 \text{ kN/m}^3$

Medium dense well graded sand

$\gamma_{mi} = 21 \text{ kN/m}^3$

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

$\phi'_{s,k} = 30 \text{ deg}$

$\delta_{s,k} = 0 \text{ deg}$

Medium dense well graded sand

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

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

$\phi'_{b,k} = 30 \text{ deg}$

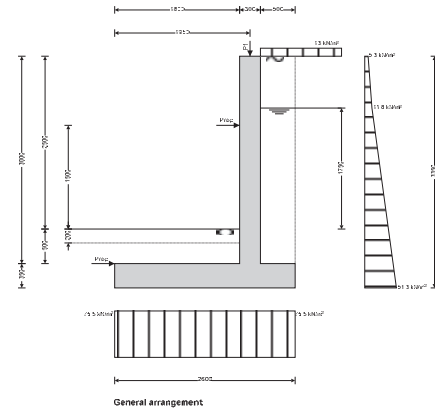
$\delta_{b,k} = 15 \text{ deg}$

$\delta_{bs,k} = 30 \text{ deg}$

Surcharge = 10 kN/m²

$P_{G1} = 75 \text{ kN/m}$

$P_{O1} = 15 \text{ kN/m}$



Calculate retaining wall geometry

Base length;

Saturated soil height;

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 saturated soil;

- Distance to vertical component;

- Distance to horizontal component;

Area of water;

- Distance to vertical component;

- Distance to horizontal component;

Area of moist soil;

- Distance to vertical component;

- Distance to horizontal component;

Area of base soil;

- Distance to vertical component;

$l_{base} = l_{toe} + l_{stem} + l_{heel} = 2600 \text{ mm}$

$h_{sat} = h_{water} + d_{cover} = 2250 \text{ mm}$

$h_{moist} = h_{ret} - h_{water} = 750 \text{ mm}$

$l_{sur} = l_{heel} = 500 \text{ mm}$

$x_{sur,v} = l_{base} - l_{heel} / 2 = 2350 \text{ mm}$

$h_{eff} = h_{base} + d_{cover} + h_{ret} = 3350 \text{ mm}$

$x_{sur,h} = h_{eff} / 2 = 1675 \text{ mm}$

$A_{stem} = h_{stem} \times l_{stem} = 0.9 \text{ m}^2$

$x_{stem} = l_{toe} + l_{stem} / 2 = 1950 \text{ mm}$

$A_{base} = l_{base} \times l_{base} = 0.91 \text{ m}^2$

$x_{base} = l_{base} / 2 = 1300 \text{ mm}$

$A_{sat} = h_{sat} \times l_{heel} = 1.125 \text{ m}^2$

$x_{sat,v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} = 2350 \text{ mm}$

$x_{sat,h} = (h_{sat} + h_{base}) / 3 = 867 \text{ mm}$

$A_{water} = h_{sat} \times l_{heel} = 1.125 \text{ m}^2$

$x_{water,v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} = 2350 \text{ mm}$

$x_{water,h} = (h_{sat} + h_{base}) / 3 = 867 \text{ mm}$

$A_{moist} = h_{moist} \times l_{heel} = 0.375 \text{ m}^2$

$x_{moist,v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = 2350 \text{ mm}$

$x_{moist,h} = (h_{base} \times (l_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + h_{base})^2 / 2) / (h_{sat} + h_{base} + h_{moist} / 2) = 1495 \text{ mm}$

$A_{pass} = d_{cover} \times l_{toe} = 0.9 \text{ m}^2$

$x_{pass,v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 900 \text{ mm}$

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- Distance to horizontal component;
Area of excavated base soil;
- Distance to vertical component;
- Distance to horizontal component;

Design approach 1

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

- Partial factor set;
Permanent unfavourable action;
Permanent favourable action;
Variable unfavourable action;
Variable favourable action;

- Soil parameter set;
Angle of shearing resistance;
Effective cohesion;
Weight density;

Water properties

- Design water density;

Retained soil properties

- Design moist density;
Design saturated density;
Design effective shear resistance angle;
Design wall friction angle;

Base soil properties

- Design soil density;
Design effective shear resistance angle;
Design wall friction angle;
Design base friction angle;
Design effective cohesion;

Using Coulomb theory

- Active pressure coefficient;
Passive pressure coefficient;

Bearing pressure check

Vertical forces on wall

- Wall stem;
Wall base;
Surcharge load;
Line loads;
Saturated retained soil;
Water;
Moist retained soil;
Base soil;
Total;

Horizontal forces on wall

- Surcharge load;
Saturated retained soil;
Water;
Moist retained soil;
Base soil;
Total;

Moments on wall

- Wall stem;
Wall base;
Surcharge load;
Line loads;
Saturated retained soil;
Water;
Moist retained soil;
Base soil;
Total;

Check bearing pressure

- Propping force to stem;
Propping force to base;
Moment from propping force;
Distance to reaction;
Eccentricity of reaction;
Loaded length of base;

$$X_{pass_h} = (d_{cover} + h_{base}) / 3 = 283 \text{ mm}$$
$$A_{exc} = h_{pass} \times l_{base} = 0.54 \text{ m}^2$$
$$X_{exc_v} = h_{base} \times (h_{pass} \times l_{base} \times (h_{base} - l_{base} / 2)) / A_{exc} = 900 \text{ mm}$$
$$X_{exc_h} = (h_{pass} + h_{base}) / 3 = 217 \text{ mm}$$

$$\gamma_G = 1.35$$
$$\gamma_{Gr} = 1.00$$
$$\gamma_Q = 1.50$$
$$\gamma_{Gr} = 0.00$$

$$M_1$$
$$\gamma_{\psi} = 1.00$$
$$\gamma_c = 1.00$$
$$\gamma_s = 1.00$$

$$\gamma_w = \gamma_w / \gamma_s = 9.8 \text{ kN/m}^3$$

$$\gamma_{me}' = \gamma_{me} / \gamma_s = 21 \text{ kN/m}^3$$
$$\gamma_{sa}' = \gamma_{sa} / \gamma_s = 23 \text{ kN/m}^3$$
$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,s}) / \gamma_{\psi}) = 30 \text{ deg}$$
$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,s}) / \gamma_{\psi}) = 0 \text{ deg}$$

$$\gamma_b = \gamma_b / \gamma_s = 18 \text{ kN/m}^3$$
$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,s}) / \gamma_{\psi}) = 30 \text{ deg}$$
$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,s}) / \gamma_{\psi}) = 15 \text{ deg}$$
$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,s}) / \gamma_{\psi}) = 30 \text{ deg}$$
$$c'_{b,d} = c'_{b,k} / \gamma_c = 0 \text{ kN/m}^2$$

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta)) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.333$$
$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = 4.977$$

$$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 30.4 \text{ kN/m}$$
$$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 30.7 \text{ kN/m}$$
$$F_{sur_v} = \gamma_Q \times \text{Surcharge}_0 \times l_{heel} = 7.5 \text{ kN/m}$$
$$F_{P_v} = \gamma_Q \times P_{G1} + \gamma_Q \times P_{G1} = 123.8 \text{ kN/m}$$
$$F_{sat_v} = \gamma_G \times A_{sat} \times (\gamma_{sa}' - \gamma_w) = 20 \text{ kN/m}$$
$$F_{water_v} = \gamma_G \times A_{water} \times \gamma_w = 14.9 \text{ kN/m}$$
$$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{me}' = 10.6 \text{ kN/m}$$
$$F_{pass_v} = \gamma_G \times A_{pass} \times \gamma_b' = 21.9 \text{ kN/m}$$
$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{sat_v} + F_{water_v} + F_{moist_v} + F_{pass_v} = 259.8 \text{ kN/m}$$

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_0 \times h_{eff} = 16.8 \text{ kN/m}$$
$$F_{sat_h} = \gamma_G \times K_A \times (\gamma_{sa}' - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 = 20.1 \text{ kN/m}$$
$$F_{water_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 44.8 \text{ kN/m}$$
$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{me}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = 21.1 \text{ kN/m}$$
$$F_{pass_h} = -\gamma_{Gr} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -31.3 \text{ kN/m}$$
$$F_{total_h} = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{pass_h} = 71.4 \text{ kN/m}$$

$$M_{stem} = F_{stem} \times X_{stem} = 59.2 \text{ kNm/m}$$
$$M_{base} = F_{base} \times X_{base} = 39.9 \text{ kNm/m}$$
$$M_{sur} = F_{sur_v} \times X_{sur_v} + F_{sur_h} \times X_{sur_h} = -10.4 \text{ kNm/m}$$
$$M_P = (\gamma_Q \times P_{G1} + \gamma_Q \times P_{G1}) \times p_1 = 241.3 \text{ kNm/m}$$
$$M_{sat} = F_{sat_v} \times X_{sat_v} + F_{sat_h} \times X_{sat_h} = 29.7 \text{ kNm/m}$$
$$M_{water} = F_{water_v} \times X_{water_v} + F_{water_h} \times X_{water_h} = -3.8 \text{ kNm/m}$$
$$M_{moist} = F_{moist_v} \times X_{moist_v} + F_{moist_h} \times X_{moist_h} = -6.5 \text{ kNm/m}$$
$$M_{pass} = F_{pass_v} \times X_{pass_v} = 19.7 \text{ kNm/m}$$
$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{sat} + M_{water} + M_{moist} + M_{pass} = 369.1 \text{ kNm/m}$$

$$F_{prop_stem} = (F_{total_v} \times h_{base} / 2 - M_{total}) / (h_{prop} + h_{base}) = -13.4 \text{ kN/m}$$
$$F_{prop_base} = F_{total_h} - F_{prop_stem} = 84.8 \text{ kN/m}$$
$$M_{prop} = F_{prop_stem} \times (h_{prop} + h_{base}) = -31.4 \text{ kNm/m}$$
$$\bar{x} = (M_{total} + M_{prop}) / F_{total_v} = 1300 \text{ mm}$$
$$e = \bar{x} - h_{base} / 2 = 0 \text{ mm}$$
$$l_{load} = h_{base} = 2600 \text{ mm}$$

Library item; Partial factors output

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- Bearing pressure at toe;
Bearing pressure at heel;
Effective overburden pressure;
Design effective overburden pressure;
Bearing resistance factors;

Foundation shape factors;

Load inclination factors;

Net ultimate bearing capacity

- Factor of safety;

Design approach 1

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

- Partial factor set;
Permanent unfavourable action;
Permanent favourable action;
Variable unfavourable action;
Variable favourable action;

- Soil parameter set;
Angle of shearing resistance;
Effective cohesion;
Weight density;

Water properties

- Design water density;

Retained soil properties

- Design moist density;
Design saturated density;
Design effective shear resistance angle;
Design wall friction angle;

Base soil properties

- Design soil density;
Design effective shear resistance angle;
Design wall friction angle;
Design base friction angle;
Design effective cohesion;

Using Coulomb theory

- Active pressure coefficient;
Passive pressure coefficient;

Bearing pressure check

Vertical forces on wall

- Wall stem;
Wall base;
Surcharge load;
Line loads;
Saturated retained soil;
Water;
Moist retained soil;
Base soil;
Total;

Horizontal forces on wall

- Surcharge load;
Saturated retained soil;
Water;
Moist retained soil;
Base soil;
Total;

$$Q_{toe} = F_{total_v} / h_{base} = 99.9 \text{ kN/m}^2$$
$$Q_{heel} = F_{total_v} / h_{base} = 99.9 \text{ kN/m}^2$$
$$q = \max((h_{base} + d_{cover}) \times \gamma_b' - (h_{base} + d_{cover} + h_{water}) \times \gamma_w', 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$$
$$q' = q / \gamma_s = 0 \text{ kN/m}^2$$
$$N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 18.401$$
$$N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 30.14$$
$$N_b = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = 20.093$$

$$s_q = 1$$
$$s_{\gamma} = 1$$
$$s_c = 1$$
$$H = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{pass_h} - F_{prop_stem} - F_{prop_base} = 0 \text{ kN/m}$$
$$V = F_{total_v} = 259.8 \text{ kN/m}$$
$$m = 2$$
$$i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = 1$$
$$i_{\gamma} = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{m+1} = 1$$
$$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = 1$$

$$n_1 = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times (\gamma_b' - \gamma_w') \times l_{load} \times N_b \times s_{\gamma} \times i_{\gamma} = 213.9 \text{ kN/m}^2$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

- Partial factor set;
Permanent unfavourable action;
Permanent favourable action;
Variable unfavourable action;
Variable favourable action;

- Soil parameter set;
Angle of shearing resistance;
Effective cohesion;
Weight density;

- Design water density;

$$\gamma_{me}' = \gamma_{me} / \gamma_s = 21 \text{ kN/m}^3$$
$$\gamma_{sa}' = \gamma_{sa} / \gamma_s = 23 \text{ kN/m}^3$$
$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,s}) / \gamma_{\psi}) = 24.8 \text{ deg}$$
$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,s}) / \gamma_{\psi}) = 0 \text{ deg}$$

$$\gamma_b = \gamma_b / \gamma_s = 18 \text{ kN/m}^3$$
$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,s}) / \gamma_{\psi}) = 24.8 \text{ deg}$$
$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,s}) / \gamma_{\psi}) = 12.1 \text{ deg}$$
$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,s}) / \gamma_{\psi}) = 24.8 \text{ deg}$$
$$c'_{b,d} = c'_{b,k} / \gamma_c = 0 \text{ kN/m}^2$$

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta)) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.409$$
$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = 3.473$$

$$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 22.5 \text{ kN/m}$$
$$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 22.8 \text{ kN/m}$$
$$F_{sur_v} = \gamma_Q \times \text{Surcharge}_0 \times l_{heel} = 6.5 \text{ kN/m}$$
$$F_{P_v} = \gamma_Q \times P_{G1} + \gamma_Q \times P_{G1} = 94.5 \text{ kN/m}$$
$$F_{sat_v} = \gamma_G \times A_{sat} \times (\gamma_{sa}' - \gamma_w) = 14.8 \text{ kN/m}$$
$$F_{water_v} = \gamma_G \times A_{water} \times \gamma_w = 11 \text{ kN/m}$$
$$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{me}' = 7.9 \text{ kN/m}$$
$$F_{pass_v} = \gamma_G \times A_{pass} \times \gamma_b' = 16.2 \text{ kN/m}$$
$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{sat_v} + F_{water_v} + F_{moist_v} + F_{pass_v} = 196.2 \text{ kN/m}$$

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_0 \times h_{eff} = 17.8 \text{ kN/m}$$
$$F_{sat_h} = \gamma_G \times K_A \times (\gamma_{sa}' - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 = 18.2 \text{ kN/m}$$
$$F_{water_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 22.1 \text{ kN/m}$$
$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{me}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = 19.2 \text{ kN/m}$$
$$F_{pass_h} = -\gamma_{Gr} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -22.1 \text{ kN/m}$$
$$F_{total_h} = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{pass_h} = 66.3 \text{ kN/m}$$

Library item; Partial factors output

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Moments on wall

Wall stem;
Wall base;
Surcharge load;
Line loads;
Saturated retained soil;
Water;
Moist retained soil;
Base soil;
Total;
 $M_{stem} = F_{stem} \times X_{stem} = \mathbf{43.9 \text{ kNm/m}}$
 $M_{base} = F_{base} \times X_{base} = \mathbf{29.6 \text{ kNm/m}}$
 $M_{sur} = F_{sur,v} \times X_{sur,v} - F_{sur,h} \times X_{sur,h} = \mathbf{-14.6 \text{ kNm/m}}$
 $M_p = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = \mathbf{184.3 \text{ kNm/m}}$
 $M_{sat} = F_{sat,v} \times X_{sat,v} - F_{sat,h} \times X_{sat,h} = \mathbf{19.1 \text{ kNm/m}}$
 $M_{water} = F_{water,v} \times X_{water,v} - F_{water,h} \times X_{water,h} = \mathbf{-2.8 \text{ kNm/m}}$
 $M_{moist} = F_{moist,v} \times X_{moist,v} - F_{moist,h} \times X_{moist,h} = \mathbf{-10.2 \text{ kNm/m}}$
 $M_{pass} = F_{pass,v} \times X_{pass,v} = \mathbf{14.6 \text{ kNm/m}}$
 $M_{total} = M_{stem} + M_{base} + M_{sur} + M_p + M_{sat} + M_{water} + M_{moist} + M_{pass} = \mathbf{263.8 \text{ kNm/m}}$

Check bearing pressure

Propping force to stem;
Propping force to base;
Moment from propping force;
Distance to reaction;
Eccentricity of reaction;
Loaded length of base;
Bearing pressure at toe;
Bearing pressure at heel;
Effective overburden pressure;
Design effective overburden pressure;
Bearing resistance factors;
 $F_{prop_stem} = (F_{total,v} \times l_{base} / 2 - M_{total}) / (l_{prop} + l_{base}) = \mathbf{-3.7 \text{ kN/m}}$
 $F_{prop_base} = F_{total,h} - F_{prop_stem} = \mathbf{70 \text{ kN/m}}$
 $M_{prop} = F_{prop_stem} \times (l_{prop} + l_{base}) = \mathbf{-8.8 \text{ kNm/m}}$
 $\bar{X} = (M_{total} + M_{prop}) / F_{total,v} = \mathbf{1300 \text{ mm}}$
 $e = \bar{X} - l_{base} / 2 = \mathbf{0 \text{ mm}}$
 $l_{load} = l_{base} = \mathbf{2600 \text{ mm}}$
 $q_{toe} = F_{total,v} / l_{base} = \mathbf{75.5 \text{ kN/m}^2}$
 $q_{heel} = F_{total,v} / l_{base} = \mathbf{75.5 \text{ kN/m}^2}$
 $q = \max((l_{base} + d_{cover}) \times \gamma'_b - (l_{base} + d_{cover} + h_{water}) \times \gamma'_w, 0 \text{ kN/m}^2) = \mathbf{0 \text{ kN/m}^2}$
 $q' = q / \gamma_1 = \mathbf{0 \text{ kN/m}^2}$
 $N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = \mathbf{10.431}$
 $N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = \mathbf{20.418}$
 $N_f = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = \mathbf{8.712}$
 $s_q = 1$
 $s_r = 1$
 $s_c = 1$
 $H = F_{sur,h} + F_{sat,h} + F_{water,h} + F_{moist,h} + F_{pass,h} - F_{prop_stem} - F_{prop_base} = \mathbf{0 \text{ kN/m}}$
 $V = F_{total,v} = \mathbf{196.2 \text{ kN/m}}$
 $m = 2$
 $i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = \mathbf{1}$
 $i_r = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{m+1} = \mathbf{1}$
 $i_c = i_q \cdot (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = \mathbf{1}$

Foundation shape factors;

Load inclination factors;

Net ultimate bearing capacity

$$n_u = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times (\gamma'_b - \gamma'_w) \times l_{load} \times N_f \times s_r \times i_r = \mathbf{92.8 \text{ kN/m}^2}$$

Factor of safety;

$$FoS_{up} = n_u / \max(q_{toe}, q_{heel}) = \mathbf{1.229}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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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

Tedds calculation version 2.9.10

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

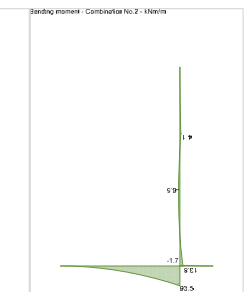
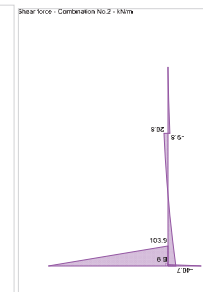
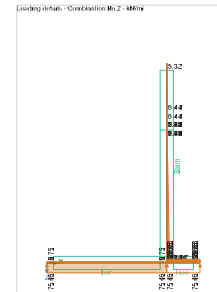
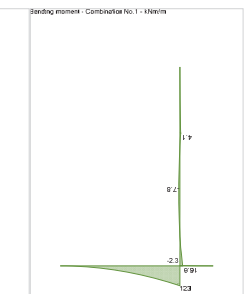
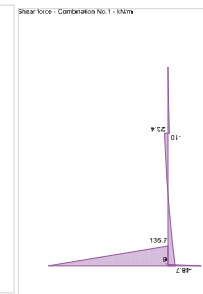
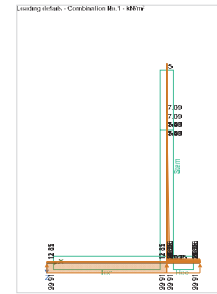
Concrete strength class; C30/37
Characteristic compressive cylinder strength; $f_{ck} = \mathbf{30 \text{ N/mm}^2}$
Characteristic compressive cube strength; $f_{ck,cube} = \mathbf{37 \text{ N/mm}^2}$
Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{38 \text{ N/mm}^2}$
Mean value of axial tensile strength; $f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{2.9 \text{ N/mm}^2}$
5% fractile of axial tensile strength; $f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.0 \text{ N/mm}^2}$
Secant modulus of elasticity of concrete; $E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = \mathbf{32837 \text{ N/mm}^2}$
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; $f_{ed} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0 \text{ N/mm}^2}$
Maximum aggregate size; $h_{agg} = \mathbf{20 \text{ mm}}$
Ultimate strain - Table 3.1; $\epsilon_{cu2} = \mathbf{0.0035}$
Shortening strain - Table 3.1; $\epsilon_{cu3} = \mathbf{0.0035}$
Effective compression zone height factor; $\lambda = \mathbf{0.80}$
Effective strength factor; $\eta = \mathbf{1.00}$
Bending coefficient k₁; $K_1 = \mathbf{0.40}$
Bending coefficient k₂; $K_2 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = \mathbf{1.00}$
Bending coefficient k₃; $K_3 = \mathbf{0.40}$
Bending coefficient k₄; $K_4 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = \mathbf{1.00}$

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

Front face of stem; $c_{ef} = \mathbf{40 \text{ mm}}$
Rear face of stem; $c_{er} = \mathbf{50 \text{ mm}}$
Top face of base; $c_{bt} = \mathbf{50 \text{ mm}}$
Bottom face of base; $c_{bb} = \mathbf{75 \text{ mm}}$



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Check stem design at 1087 mm

Depth of section;
Rectangular section in flexure - Section 6.1
Design bending moment combination 1;
Depth to tension reinforcement;

h = **300** mm
M = **7.8** kNm/m
 $d = h - C_{sf} - \phi_{stl} / 2 = \mathbf{245}$ mm
 $K = M / (d^2 \times f_{sk}) = \mathbf{0.004}$
 $K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$
K' = 0.207

K' > K - No compression reinforcement is required

Lever arm;
Depth of neutral axis;
Area of tension reinforcement required;
Tension reinforcement provided;
Area of tension reinforcement provided;
Minimum area of reinforcement - exp.9.1N;
Maximum area of reinforcement - cl.9.2.1.1(3);
z = min(0.5 + 0.5 × (1 - 2 × K / (η × α_{cc} / γ_c))^{0.5}, 0.95) × d = **233** mm
x = 2.5 × (d - z) = **31** mm
A_{st1,req} = M / (f_{yd} × z) = **77** mm²/m
10 dia.bars @ 200 c/c
A_{st1,prov} = π × φ_{stl}² / (4 × S_{stl}) = **393** mm²/m
A_{st1,min} = max(0.26 × f_{ctm} / f_{yk}, 0.0013) × d = **369** mm²/m
A_{st1,max} = 0.04 × h = **12000** mm²/m
max(A_{st1,req}, A_{st1,min}) / A_{st1,prov} = **0.94**

PASS - Area of reinforcement provided is greater than area of reinforcement required
Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio;
Required tension reinforcement ratio;
Required compression reinforcement ratio;
Structural system factor - Table 7.4N;
Reinforcement factor - exp.7.17;
Limiting span to depth ratio - exp.7.16.a;
Actual span to depth ratio;

ρ₀ = √(f_{sk} / 1 N/mm²) / 1000 = **0.005**
ρ = A_{st1,req} / d = **0.000**
ρ' = A_{st1,2,req} / d₂ = **0.000**
K₀ = **1**
K_s = min(500 N/mm² / (f_{yk} × A_{st1,req} / A_{st1,prov}), 1.5) = **1.5**
min(K_s × K₀ × [11 + 1.5 × √(f_{sk} / 1 N/mm²) × ρ₀ / ρ + 3.2 × √(f_{sk} / 1 N/mm²) × (ρ₀ / ρ - 1)^{3/2}], 40 × K₀) = **40**
h_{prop} / d = **8.2**

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width;
Variable load factor - EN1990 – Table A1.1;
Serviceability bending moment;
Tensile stress in reinforcement;
Load duration;
Load duration factor;
Effective area of concrete in tension;

W_{max} = **0.3** mm
ψ₂ = **0.6**
M_{s1s} = **5.6** kNm/m
σ_s = M_{s1s} / (A_{st1,prov} × z) = **61.2** N/mm²
Long term
k_t = **0.4**
A_{ce,eff} = min(2.5 × (h - d), (h - x) / 3, h / 2)
A_{ce,eff} = **89792** mm²/m

Mean value of concrete tensile strength;
Reinforcement ratio;
Modular ratio;
Bond property coefficient;
Strain distribution coefficient;

f_{ct,eff} = f_{ctm} = **2.9** N/mm²
ρ_{p,eff} = A_{st1,prov} / A_{ce,eff} = **0.004**
α_{se} = E_s / E_{cm} = **6.091**
K₁ = **0.8**
K₂ = **0.5**
K₃ = **3.4**
K₄ = **0.425**

Maximum crack spacing - exp.7.11;
Maximum crack width - exp.7.8;
S_{r,max} = K₃ × C_{sf} + K₁ × K₂ × K₄ × φ_{stl} / ρ_{p,eff} = **525** mm
W_k = S_{r,max} × max(σ_s - k_t × (f_{ct,eff} / ρ_{p,eff}) × (1 + α_{se} × ρ_{p,eff}), 0.6 × σ_s) / E_s
W_k = **0.096** mm
W_k / W_{max} = **0.321**

PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem

Depth of section;
Rectangular section in flexure - Section 6.1
Design bending moment combination 1;
Depth to tension reinforcement;

h = **300** mm
M = **16.6** kNm/m
 $d = h - C_{sf} - \phi_{stl} / 2 = \mathbf{242}$ mm
 $K = M / (d^2 \times f_{sk}) = \mathbf{0.009}$
 $K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$
K' = 0.207

K' > K - No compression reinforcement is required

Lever arm;
Depth of neutral axis;
Area of tension reinforcement required;
Tension reinforcement provided;
Area of tension reinforcement provided;
Minimum area of reinforcement - exp.9.1N;
Maximum area of reinforcement - cl.9.2.1.1(3);
z = min(0.5 + 0.5 × (1 - 2 × K / (η × α_{cc} / γ_c))^{0.5}, 0.95) × d = **230** mm
x = 2.5 × (d - z) = **30** mm
A_{st,req} = M / (f_{yd} × z) = **166** mm²/m
16 dia.bars @ 200 c/c
A_{st,prov} = π × φ_{stl}² / (4 × S_{stl}) = **1005** mm²/m
A_{st,min} = max(0.26 × f_{ctm} / f_{yk}, 0.0013) × d = **364** mm²/m
A_{st,max} = 0.04 × h = **12000** mm²/m
max(A_{st,req}, A_{st,min}) / A_{st,prov} = **0.363**

PASS - Area of reinforcement provided is greater than area of reinforcement required
Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio;
ρ₀ = √(f_{sk} / 1 N/mm²) / 1000 = **0.005**

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Required tension reinforcement ratio;
Required compression reinforcement ratio;
Structural system factor - Table 7.4N;
Reinforcement factor - exp.7.17;
Limiting span to depth ratio - exp.7.16.a;
Actual span to depth ratio;

ρ = A_{st,req} / d = **0.001**
ρ' = A_{st,2,req} / d₂ = **0.000**
K₀ = **1**
K_s = min(500 N/mm² / (f_{yk} × A_{st,req} / A_{st,prov}), 1.5) = **1.5**
min(K_s × K₀ × [11 + 1.5 × √(f_{sk} / 1 N/mm²) × ρ₀ / ρ + 3.2 × √(f_{sk} / 1 N/mm²) × (ρ₀ / ρ - 1)^{3/2}], 40 × K₀) = **40**
h_{prop} / d = **8.3**

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width;
Variable load factor - EN1990 – Table A1.1;
Serviceability bending moment;
Tensile stress in reinforcement;
Load duration;
Load duration factor;
Effective area of concrete in tension;

W_{max} = **0.3** mm
ψ₂ = **0.6**
M_{s1s} = **11.9** kNm/m
σ_s = M_{s1s} / (A_{st,prov} × z) = **51.4** N/mm²
Long term
k_t = **0.4**
A_{ce,eff} = min(2.5 × (h - d), (h - x) / 3, h / 2)
A_{ce,eff} = **89917** mm²/m
f_{ct,eff} = f_{ctm} = **2.9** N/mm²

Mean value of concrete tensile strength;
Reinforcement ratio;
Modular ratio;
Bond property coefficient;
Strain distribution coefficient;

ρ_{p,eff} = A_{st,prov} / A_{ce,eff} = **0.011**
α_{se} = E_s / E_{cm} = **6.091**
K₁ = **0.8**
K₂ = **0.5**
K₃ = **3.4**
K₄ = **0.425**

Maximum crack spacing - exp.7.11;
Maximum crack width - exp.7.8;
S_{r,max} = K₃ × C_{sf} + K₁ × K₂ × K₄ × φ_{stl} / ρ_{p,eff} = **413** mm
W_k = S_{r,max} × max(σ_s - k_t × (f_{ct,eff} / ρ_{p,eff}) × (1 + α_{se} × ρ_{p,eff}), 0.6 × σ_s) / E_s
W_k = **0.064** mm
W_k / W_{max} = **0.213**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force;

V = **48.7** kN/m
C_{rd,c} = 0.18 / γ_c = **0.120**
k = min(1 + √(200 mm / d), 2) = **1.909**
ρ₁ = min(A_{st,prov} / d, 0.02) = **0.004**
V_{min} = 0.035 N^{1/2}/mm × k^{3/2} × f_{cd}^{0.5} = **0.506** N/mm²
V_{Rd,c} = max(C_{rd,c} × k × (100 N²/mm⁴ × ρ₁ × f_{sk})^{1/3}, V_{min}) × d
V_{Rd,c} = **128.5** kN/m
V / V_{Rd,c} = **0.379**

PASS - Design shear resistance exceeds design shear force

Check stem design at top

Depth of section;
Rectangular section in flexure - Section 6.1
Design bending moment combination 2;
Depth to tension reinforcement;

h = **300** mm
M = **4.1** kNm/m
 $d = h - C_{sf} - \phi_{stl} / 2 = \mathbf{244}$ mm
 $K = M / (d^2 \times f_{sk}) = \mathbf{0.002}$
 $K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$
K' = 0.207

K' > K - No compression reinforcement is required

Lever arm;
Depth of neutral axis;
Area of tension reinforcement required;
Tension reinforcement provided;
Area of tension reinforcement provided;
Minimum area of reinforcement - exp.9.1N;
Maximum area of reinforcement - cl.9.2.1.1(3);
z = min(0.5 + 0.5 × (1 - 2 × K / (η × α_{cc} / γ_c))^{0.5}, 0.95) × d = **232** mm
x = 2.5 × (d - z) = **31** mm
A_{st1,req} = M / (f_{yd} × z) = **41** mm²/m
12 dia.bars @ 200 c/c
A_{st1,prov} = π × φ_{stl}² / (4 × S_{stl}) = **565** mm²/m
A_{st1,min} = max(0.26 × f_{ctm} / f_{yk}, 0.0013) × d = **368** mm²/m
A_{st1,max} = 0.04 × h = **12000** mm²/m
max(A_{st1,req}, A_{st1,min}) / A_{st1,prov} = **0.65**

PASS - Area of reinforcement provided is greater than area of reinforcement required
Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio;
Required tension reinforcement ratio;
Required compression reinforcement ratio;
Structural system factor - Table 7.4N;
Reinforcement factor - exp.7.17;
Limiting span to depth ratio - exp.7.16.a;
Actual span to depth ratio;

ρ₀ = √(f_{sk} / 1 N/mm²) / 1000 = **0.005**
ρ = A_{st1,req} / d = **0.000**
ρ' = A_{st1,2,req} / d₂ = **0.000**
K₀ = **0.4**
K_s = min(500 N/mm² / (f_{yk} × A_{st1,req} / A_{st1,prov}), 1.5) = **1.5**
min(K_s × K₀ × [11 + 1.5 × √(f_{sk} / 1 N/mm²) × ρ₀ / ρ + 3.2 × √(f_{sk} / 1 N/mm²) × (ρ₀ / ρ - 1)^{3/2}], 40 × K₀) = **16**
(h_{stem} - h_{prop}) / d = **4.1**

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width;
Variable load factor - EN1990 – Table A1.1;
Serviceability bending moment;

W_{max} = **0.3** mm
ψ₂ = **0.6**
M_{s1s} = **2.2** kNm/m

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Tensile stress in reinforcement;
Load duration;
Load duration factor;
Effective area of concrete in tension;

$\sigma_s = M_{ds} / (A_{st,prov} \times Z) = \mathbf{16.7 \text{ N/mm}^2}$
Long term
 $k_1 = \mathbf{0.4}$
 $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = \mathbf{89633 \text{ mm}^2/m}$
 $f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$
 $\rho_{p,eff} = A_{st,prov} / A_{c,eff} = \mathbf{0.006}$
 $\alpha_{se} = E_s / E_{cm} = \mathbf{6.091}$
 $k_1 = \mathbf{0.8}$
 $k_2 = \mathbf{0.5}$
 $k_3 = \mathbf{3.4}$
 $k_4 = \mathbf{0.425}$

Mean value of concrete tensile strength;
Reinforcement ratio;
Modular ratio;

Bond property coefficient;
Strain distribution coefficient;

Maximum crack spacing - exp.7.11;
Maximum crack width - exp.7.8;

$s_{r,max} = k_3 \times C_{ar} + k_1 \times k_2 \times k_4 \times \phi_{st1} / \rho_{p,eff} = \mathbf{494 \text{ mm}}$
 $w_k = s_{r,max} \times \max(\sigma_s - k_1 \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_{se} \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = \mathbf{0.025 \text{ mm}}$
 $w_k / w_{max} = \mathbf{0.082}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force;

$V = \mathbf{23.4 \text{ kN/m}}$
 $C_{rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.905}$
 $\rho_l = \min(A_{st,prov} / d, 0.02) = \mathbf{0.002}$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ak}^{0.5} = \mathbf{0.504 \text{ N/mm}^2}$

Design shear resistance - exp.6.2a & 6.2b;

$V_{rd,c} = \max(C_{rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ak})^{1/3}, v_{min}) \times d$
 $V_{rd,c} = \mathbf{123 \text{ kN/m}}$
 $V / V_{rd,c} = \mathbf{0.190}$

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1);
Maximum spacing of reinforcement – cl.9.6.3(2);
Transverse reinforcement provided;

$A_{st,req} = \max(0.25 \times A_{st,prov}, 0.001 \times f_{ctem}) = \mathbf{300 \text{ mm}^2/m}$
 $s_{st,max} = \mathbf{400 \text{ mm}}$
10 dia.bars @ 200 c/c
 $A_{st,prov} = \pi \times \phi_{st}^2 / (4 \times s_{st}) = \mathbf{393 \text{ mm}^2/m}$

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

Check base design at toe

Depth of section;

$h = \mathbf{350 \text{ mm}}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1;
Depth to tension reinforcement;

$M = \mathbf{123 \text{ kNm/m}}$
 $d = h - C_{ob} - \phi_{st} / 2 = \mathbf{265 \text{ mm}}$
 $K = M / (d^2 \times f_{ak}) = \mathbf{0.058}$
 $K' = (2 \times \eta \times \alpha_{ed} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\delta - K_1) / (2 \times K_2)$
 $K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm;
Depth of neutral axis;
Area of tension reinforcement required;
Tension reinforcement provided;
Area of tension reinforcement provided;
Minimum area of reinforcement - exp.9.1N;
Maximum area of reinforcement - cl.9.2.1.1(3);

$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{ed} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{251 \text{ mm}}$
 $x = 2.5 \times (d - z) = \mathbf{36 \text{ mm}}$
 $A_{st,req} = M / (f_{yk} \times z) = \mathbf{1129 \text{ mm}^2/m}$
20 dia.bars @ 150 c/c
 $A_{st,prov} = \pi \times \phi_{st}^2 / (4 \times s_{st}) = \mathbf{2094 \text{ mm}^2/m}$
 $A_{st,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{399 \text{ mm}^2/m}$
 $A_{st,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/m}$
 $\max(A_{st,req}, A_{st,min}) / A_{st,prov} = \mathbf{0.539}$

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width;
Variable load factor - EN1990 – Table A1.1;
Serviceability bending moment;
Tensile stress in reinforcement;
Load duration;
Load duration factor;
Effective area of concrete in tension;

$w_{max} = \mathbf{0.3 \text{ mm}}$
 $\psi_2 = \mathbf{0.6}$
 $M_{ds} = \mathbf{89.8 \text{ kNm/m}}$
 $\sigma_s = M_{ds} / (A_{st,prov} \times Z) = \mathbf{171 \text{ N/mm}^2}$
Long term
 $k_1 = \mathbf{0.4}$
 $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = \mathbf{104631 \text{ mm}^2/m}$
 $f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$
 $\rho_{p,eff} = A_{st,prov} / A_{c,eff} = \mathbf{0.020}$
 $\alpha_{se} = E_s / E_{cm} = \mathbf{6.091}$
 $k_1 = \mathbf{0.8}$
 $k_2 = \mathbf{0.5}$
 $k_3 = \mathbf{3.4}$
 $k_4 = \mathbf{0.425}$

Mean value of concrete tensile strength;
Reinforcement ratio;
Modular ratio;
Bond property coefficient;
Strain distribution coefficient;

Maximum crack spacing - exp.7.11;
Maximum crack width - exp.7.8;

$s_{r,max} = k_3 \times C_{ob} + k_1 \times k_2 \times k_4 \times \phi_{st} / \rho_{p,eff} = \mathbf{425 \text{ mm}}$
 $w_k = s_{r,max} \times \max(\sigma_s - k_1 \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_{se} \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = \mathbf{0.225 \text{ mm}}$

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$w_k / w_{max} = \mathbf{0.751}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force;

$V = \mathbf{136.7 \text{ kN/m}}$
 $C_{rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.869}$
 $\rho_l = \min(A_{st,prov} / d, 0.02) = \mathbf{0.008}$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ak}^{0.5} = \mathbf{0.490 \text{ N/mm}^2}$
 $V_{rd,c} = \max(C_{rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ak})^{1/3}, v_{min}) \times d$
 $V_{rd,c} = \mathbf{170.7 \text{ kN/m}}$
 $V / V_{rd,c} = \mathbf{0.801}$

Check base design at heel

Depth of section;

$h = \mathbf{350 \text{ mm}}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1;
Depth to tension reinforcement;

$M = \mathbf{2.3 \text{ kNm/m}}$
 $d = h - C_{st} - \phi_{st} / 2 = \mathbf{294 \text{ mm}}$
 $K = M / (d^2 \times f_{ak}) = \mathbf{0.001}$
 $K' = (2 \times \eta \times \alpha_{ed} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\delta - K_1) / (2 \times K_2)$
 $K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm;
Depth of neutral axis;
Area of tension reinforcement required;
Tension reinforcement provided;
Area of tension reinforcement provided;
Minimum area of reinforcement - exp.9.1N;
Maximum area of reinforcement - cl.9.2.1.1(3);

$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{ed} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{279 \text{ mm}}$
 $x = 2.5 \times (d - z) = \mathbf{37 \text{ mm}}$
 $A_{st,req} = M / (f_{yk} \times z) = \mathbf{19 \text{ mm}^2/m}$
12 dia.bars @ 200 c/c
 $A_{st,prov} = \pi \times \phi_{st}^2 / (4 \times s_{st}) = \mathbf{565 \text{ mm}^2/m}$
 $A_{st,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{443 \text{ mm}^2/m}$
 $A_{st,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/m}$
 $\max(A_{st,req}, A_{st,min}) / A_{st,prov} = \mathbf{0.783}$

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width;
Variable load factor - EN1990 – Table A1.1;
Serviceability bending moment;
Tensile stress in reinforcement;
Load duration;
Load duration factor;
Effective area of concrete in tension;

$w_{max} = \mathbf{0.3 \text{ mm}}$
 $\psi_2 = \mathbf{0.6}$
 $M_{ds} = \mathbf{1.1 \text{ kNm/m}}$
 $\sigma_s = M_{ds} / (A_{st,prov} \times Z) = \mathbf{7.2 \text{ N/mm}^2}$
Long term
 $k_1 = \mathbf{0.4}$
 $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = \mathbf{104417 \text{ mm}^2/m}$
 $\rho_{p,eff} = A_{st,prov} / A_{c,eff} = \mathbf{0.005}$
 $\alpha_{se} = E_s / E_{cm} = \mathbf{6.091}$
 $k_1 = \mathbf{0.8}$
 $k_2 = \mathbf{0.5}$
 $k_3 = \mathbf{3.4}$
 $k_4 = \mathbf{0.425}$

Mean value of concrete tensile strength;
Reinforcement ratio;
Modular ratio;
Bond property coefficient;
Strain distribution coefficient;

Maximum crack spacing - exp.7.11;
Maximum crack width - exp.7.8;

$s_{r,max} = k_3 \times C_{st} + k_1 \times k_2 \times k_4 \times \phi_{st} / \rho_{p,eff} = \mathbf{547 \text{ mm}}$
 $w_k = s_{r,max} \times \max(\sigma_s - k_1 \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_{se} \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = \mathbf{0.012 \text{ mm}}$
 $w_k / w_{max} = \mathbf{0.039}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force;

$V = \mathbf{9 \text{ kN/m}}$
 $C_{rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.825}$
 $\rho_l = \min(A_{st,prov} / d, 0.02) = \mathbf{0.002}$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ak}^{0.5} = \mathbf{0.473 \text{ N/mm}^2}$
 $V_{rd,c} = \max(C_{rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ak})^{1/3}, v_{min}) \times d$
 $V_{rd,c} = \mathbf{138.9 \text{ kN/m}}$
 $V / V_{rd,c} = \mathbf{0.065}$

PASS - Design shear resistance exceeds design shear force

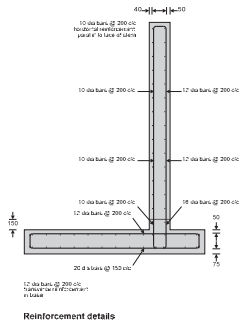
Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2);
Maximum spacing of reinforcement – cl.9.3.1.1(3);
Transverse reinforcement provided;
Area of transverse reinforcement provided;

$A_{st,req} = 0.2 \times A_{st,prov} = \mathbf{419 \text{ mm}^2/m}$
 $s_{st,max} = \mathbf{450 \text{ mm}}$
12 dia.bars @ 200 c/c
 $A_{st,prov} = \pi \times \phi_{st}^2 / (4 \times s_{st}) = \mathbf{565 \text{ mm}^2/m}$

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

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MASONRY WALL PANEL DESIGN (EN1996)

MASONRY WALL PANEL DESIGN

In accordance with EN1996-1-1:2005 + A1:2012 incorporating Corrigenda February 2006 and July 2009 and the UK national annex

Masonry panel details

Unreinforced masonry wall without openings

Panel length; L = 4800 mm
Panel height; h = 2800 mm

Panel support conditions

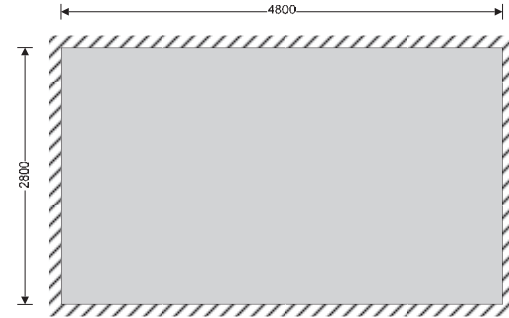
Outer leaf; All edges supported
Inner leaf; All edges supported

Effective height of masonry walls - Section 5.5.1.2

Reduction factor; $p_2 = 1.000$
Effective height of wall - eq 5.2; $h_{ef} = p_2 \times h = 2800$ mm

Tedds calculation version 1.2.16

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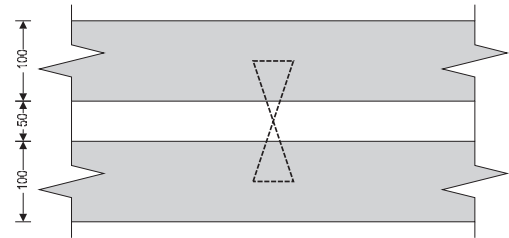


Cavity wall construction details

Outer leaf thickness; $t_1 = 100$ mm
Cavity thickness; $t_c = 50$ mm
Inner leaf thickness; $t_2 = 100$ mm

Effective thickness of masonry walls - Section 5.5.1.3

Relative E factor; $K_{rel} = 1.000$
Effective thickness - eq 5.11; $t_{ef} = (K_{rel} \times t_1^3 + t_2^3)^{1/3} = 126$ mm



Masonry outer leaf details

Masonry type;
Compressive strength of masonry; $f_{c1} = 10.4$ N/mm²
Height of unit; $h_{u1} = 215$ mm
Width of unit; $w_{u1} = 100$ mm
Conditioning factor; $k_1 = 1.0$

- Conditioning to the air dry condition in accordance with cl.7.3.2

Shape factor - Table A.1; $d_{s1} = 1.38$
Norm. mean compressive strength of masonry; $f_{b1} = f_{c1} \times k_1 \times d_{s1} = 14.352$ N/mm²
Density of masonry; $\gamma_1 = 18$ kN/m³
Mortar type; **M6 - General purpose mortar**
Compressive strength of masonry mortar; $f_{m1} = 6$ N/mm²
Compressive strength factor - Table NA.4; $K = 0.75$
Characteristic compressive strength of masonry - eq 3.1

$f_{k1} = K \times f_{b1}^{0.7} \times f_{m1}^{0.3} = 8.286$ N/mm²

Characteristic flexural strength of masonry having a plane of failure parallel to the bed joints - Table NA.6

$f_{k11} = 0.25$ N/mm²

Characteristic flexural strength of masonry having a plane of failure perpendicular to the bed joints - Table NA.6

$f_{k21} = 0.75$ N/mm²

Masonry inner leaf details

Masonry type;
Compressive strength of masonry; $f_{c2} = 10.4$ N/mm²
Height of unit; $h_{u2} = 215$ mm
Width of unit; $w_{u2} = 140$ mm
Conditioning factor; $k_2 = 1.0$

- Conditioning to the air dry condition in accordance with cl.7.3.2

Shape factor - Table A.1; $d_{s2} = 1.3$
Norm. mean compressive strength of masonry; $f_{b2} = f_{c2} \times k_2 \times d_{s2} = 13.52$ N/mm²
Density of masonry; $\gamma_2 = 18$ kN/m³
Mortar type; **M6 - General purpose mortar**
Compressive strength of masonry mortar; $f_{m2} = 6$ N/mm²
Compressive strength factor - Table NA.4; $K = 0.75$

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Characteristic compressive strength of masonry - eq.3.1

$$f_{k2} = K \times f_{k2}^{0.7} \times f_{m2}^{0.3} = \mathbf{7.947 \text{ N/mm}^2}$$

Characteristic flexural strength of masonry having a plane of failure parallel to the bed joints - Table NA.6

$$f_{k12} = \mathbf{0.25 \text{ N/mm}^2}$$

Characteristic flexural strength of masonry having a plane of failure perpendicular to the bed joints - Table NA.6

$$f_{k22} = \mathbf{0.75 \text{ N/mm}^2}$$

Lateral loading details

Characteristic wind load on panel;

$$W_k = \mathbf{0.700 \text{ kN/m}^2}$$

Vertical loading details

Permanent load on top of outer leaf;

$$G_{k1} = \mathbf{40 \text{ kN/m}};$$

Variable load on top of outer leaf;

$$Q_{k1} = \mathbf{15 \text{ kN/m}};$$

Partial factors for material strength

Category of manufacturing control;

Category II

Class of execution control;

Class 2

Partial factor for masonry in compressive flexure;

$$\gamma_{Mc} = \mathbf{3.00}$$

Partial factor for masonry in tensile flexure;

$$\gamma_{Mt} = \mathbf{2.70}$$

Partial factor for masonry in shear;

$$\gamma_{Mv} = \mathbf{2.50}$$

Slenderness ratio of masonry walls - Section 5.5.1.4

Allowable slenderness ratio;

$$SR_{all} = \mathbf{27}$$

Slenderness ratio;

$$SR = h_{ef} / l_{ef} = \mathbf{22.2}$$

PASS - Slenderness ratio is less than maximum allowable

Unreinforced masonry walls subjected to mainly vertical loading - Section 6.1

Partial safety factors for design loads

Partial safety factor for permanent load;

$$\gamma_{IG} = \mathbf{1.35}$$

Partial safety factor for variable imposed load;

$$\gamma_{IQ} = \mathbf{1.5}$$

Partial safety factor for variable wind load;

$$\gamma_{Wk} = \mathbf{0.75}$$

Considering outer leaf

Reduction factor for slenderness and eccentricity - Section 6.1.2.2

Vertical load at top of wall;

$$N_{ed1} = \gamma_{IG} \times G_{k1} + \gamma_{IQ} \times Q_{k1} = \mathbf{76.5 \text{ kN/m}}$$

Moment at top of wall due to vertical load;

$$M_{ed1} = \gamma_{IG} \times G_{k1} \times e_{G1} + \gamma_{IQ} \times Q_{k1} \times e_{Q1} = \mathbf{0 \text{ kNm/m}}$$

Initial eccentricity - cl.5.5.1.1;

$$e_{intk} = h_{ef} / 450 = \mathbf{6.2 \text{ mm}}$$

Moment at top of wall due to horizontal load;

$$M_{Ed1} = \mathbf{0 \text{ kNm/m}}$$

Eccentricity at top of wall due to horizontal load;

$$e_{h1} = \mathbf{0 \text{ mm}}$$

Eccentricity at top of wall - eq.6.5;

$$e_{t1} = \max(M_{ed1} / N_{ed1} + e_{h1} + e_{intk}, 0.05 \times t_1) = \mathbf{6.2 \text{ mm}}$$

Reduction factor at top of wall - eq.6.4;

$$\Phi_{t1} = \max(1 - 2 \times e_{t1} / t_1, 0) = \mathbf{0.876}$$

Vertical load at middle of wall;

$$N_{mid1} = \gamma_{IG} \times (G_{k1} + \gamma_1 \times t_1 \times h / 2) + \gamma_{IQ} \times Q_{k1} = \mathbf{79.902 \text{ kN/m}}$$

Moment at middle of wall due to vertical load;

$$M_{mid1} = \gamma_{IG} \times G_{k1} \times e_{G1} + \gamma_{IQ} \times Q_{k1} \times e_{Q1} = \mathbf{0 \text{ kNm/m}}$$

Moment at middle of wall due to horizontal load;

$$M_{Ed1} = \mathbf{0.047 \text{ kNm/m}}$$

Eccentricity at middle of wall due to horizontal load;

$$e_{hm1} = M_{Ed1} / N_{mid1} = \mathbf{0.6 \text{ mm}}$$

Eccentricity at middle of wall due to loads - eq.6.7;

$$e_{m1} = M_{Ed1} / N_{mid1} + e_{hm1} + e_{intk} = \mathbf{6.8 \text{ mm}}$$

Eccentricity at middle of wall due to creep;

$$e_{k1} = \mathbf{0 \text{ mm}}$$

Eccentricity at middle of wall - eq.6.6;

$$e_{mk1} = \max(e_{m1} + e_{k1}, 0.05 \times t_1) = \mathbf{6.8 \text{ mm}}$$

From eq.G.2;

$$A_{t1} = 1 - 2 \times e_{mk1} / t_1 = \mathbf{0.864}$$

Short term secant modulus of elasticity factor;

$$K_E = \mathbf{1000}$$

Modulus of elasticity - cl.3.7.2;

$$E_1 = K_E \times f_{k1} = \mathbf{8286 \text{ N/mm}^2}$$

Slenderness - eq.G.4;

$$\lambda_1 = (h_{ef} / l_{ef}) \times \sqrt{(f_{k1} / E_1)} = \mathbf{0.703}$$

From eq.G.3;

$$u_1 = (\lambda_1 \times 0.063) / (0.73 - 1.17 \times e_{mk1} / t_1) = \mathbf{0.984}$$

Reduction factor at middle of wall - eq.G.1;

$$\Phi_{m1} = \max(A_{t1} \times e^{-\lambda_1 u_1 \times t_1^2 / 2}, 0) = \mathbf{0.532}$$

Reduction factor for slenderness and eccentricity;

$$\Phi_1 = \min(\Phi_{t1}, \Phi_{m1}) = \mathbf{0.532}$$

Verification of unreinforced masonry walls subjected to mainly vertical loading - Section 6.1.2

Design value of the vertical load;

$$N_{ed1} = \max(N_{ed1}, N_{mid1}) = \mathbf{79.902 \text{ kN/m}}$$

Design compressive strength of masonry;

$$f_{d1} = f_{k1} / \gamma_{Mc} = \mathbf{2.762 \text{ N/mm}^2}$$

Vertical resistance of wall - eq.6.2;

$$N_{Rd1} = \Phi_1 \times t_1 \times f_{d1} = \mathbf{147.059 \text{ kN/m}}$$

PASS - Design vertical resistance exceeds applied design vertical load

Considering inner leaf

Reduction factor for slenderness and eccentricity - Section 6.1.2.2

Vertical load at top of wall;

$$N_{ed2} = \gamma_{IG} \times G_{k2} + \gamma_{IQ} \times Q_{k2} = \mathbf{0 \text{ kN/m}}$$

Moment at top of wall due to vertical load;

$$M_{ed2} = \gamma_{IG} \times G_{k2} \times e_{G2} + \gamma_{IQ} \times Q_{k2} \times e_{Q2} = \mathbf{0 \text{ kNm/m}}$$

Initial eccentricity - cl.5.5.1.1;

$$e_{intk} = h_{ef} / 450 = \mathbf{6.2 \text{ mm}}$$

Moment at top of wall due to horizontal load;

$$M_{Ed2} = \mathbf{0 \text{ kNm/m}}$$

Eccentricity at top of wall due to horizontal load;

$$e_{h2} = \mathbf{0 \text{ mm}}$$

Eccentricity at top of wall - eq.6.5;

$$e_{t2} = \max(e_{h2} + e_{intk}, 0.05 \times t_2) = \mathbf{6.2 \text{ mm}}$$

Reduction factor at top of wall - eq.6.4;

$$\Phi_{t2} = \max(1 - 2 \times e_{t2} / t_2, 0) = \mathbf{0.876}$$

Vertical load at middle of wall;

$$N_{mid2} = \gamma_{IG} \times (G_{k2} + \gamma_2 \times t_2 \times h / 2) + \gamma_{IQ} \times Q_{k2} = \mathbf{3.402 \text{ kN/m}}$$

Moment at middle of wall due to vertical load;

$$M_{mid2} = \gamma_{IG} \times G_{k2} \times e_{G2} + \gamma_{IQ} \times Q_{k2} \times e_{Q2} = \mathbf{0 \text{ kNm/m}}$$

Moment at middle of wall due to horizontal load;

$$M_{Ed2} = \mathbf{0.031 \text{ kNm/m}}$$

Eccentricity at middle of wall due to horizontal load;

$$e_{hm2} = M_{Ed2} / N_{mid2} = \mathbf{9.1 \text{ mm}}$$

Eccentricity at middle of wall due to loads - eq.6.7;

$$e_{m2} = M_{Ed2} / N_{mid2} + e_{hm2} + e_{intk} = \mathbf{15.3 \text{ mm}}$$

Eccentricity at middle of wall due to creep;

$$e_{k2} = \mathbf{0 \text{ mm}}$$

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Eccentricity at middle of wall - eq.6.6;

$$e_{mk2} = \max(e_{m2} + e_{k2}, 0.05 \times t_2) = \mathbf{15.3 \text{ mm}}$$

From eq.G.2;

$$A_{t2} = 1 - 2 \times e_{mk2} / t_2 = \mathbf{0.695}$$

Short term secant modulus of elasticity factor;

$$K_E = \mathbf{1000}$$

Modulus of elasticity - cl.3.7.2;

$$E_2 = K_E \times f_{k2} = \mathbf{7947 \text{ N/mm}^2}$$

Slenderness - eq.G.4;

$$\lambda_2 = (h_{ef} / l_{ef}) \times \sqrt{(f_{k2} / E_2)} = \mathbf{0.703}$$

From eq.G.3;

$$u_2 = (\lambda_2 \times 0.063) / (0.73 - 1.17 \times e_{mk2} / t_2) = \mathbf{1.16}$$

Reduction factor at middle of wall - eq.G.1;

$$\Phi_{m2} = \max(A_{t2} \times e^{-\lambda_2 u_2 \times t_2^2 / 2}, 0) = \mathbf{0.354}$$

Reduction factor for slenderness and eccentricity;

$$\Phi_2 = \min(\Phi_{t2}, \Phi_{m2}) = \mathbf{0.354}$$

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Partial safety factors for design loads

Partial safety factor for permanent load;

$$\gamma_{IG} = \mathbf{1}$$

Partial safety factor for variable imposed load;

$$\gamma_{IQ} = \mathbf{0}$$

Partial safety factor for variable wind load;

$$\gamma_{Wk} = \mathbf{1.5}$$

Limiting height and length to thickness ratios for walls under the serviceability limit state - Annex F

Length to thickness ratio;

$$L / l_{ef} = \mathbf{38.098}$$

Limiting height to thickness ratio - Figure F.1;

$$53.805$$

Height to thickness ratio;

$$h / l_{ef} = \mathbf{22.224}$$

PASS - Limiting height to thickness ratio is not exceeded

Design moments of resistance in panels

Considering outer leaf

Self weight at middle of wall;

$$S_{wt1} = 0.5 \times h \times t_1 \times \gamma_1 = \mathbf{2.52 \text{ kN/m}}$$

Design compressive strength of masonry;

$$f_{d1} = f_{k1} / \gamma_{Mc} = \mathbf{2.762 \text{ N/mm}^2}$$

Design vertical compressive stress;

$$\sigma_{d1} = \min(\gamma_{IG} \times (G_{k1} + S_{wt1}) / t_1, 0.15 \times \Phi_1 \times f_{d1}) = \mathbf{0.221 \text{ N/mm}^2}$$

Design flexural strength of masonry parallel to bed joints

$$f_{sd11} = f_{k11} / \gamma_{Mc} = \mathbf{0.093 \text{ N/mm}^2}$$

Apparent design flexural strength of masonry parallel to bed joints

$$f_{sd11,app} = f_{sd11} + \sigma_{d1} = \mathbf{0.313 \text{ N/mm}^2}$$

Design flexural strength of masonry perpendicular to bed joints

$$f_{sd21} = f_{k21} / \gamma_{Mc} = \mathbf{0.278 \text{ N/mm}^2}$$

Elastic section modulus of wall;

$$Z_1 = t_1^2 / 6 = \mathbf{1666667 \text{ mm}^3/\text{m}}$$

Moment of resistance parallel to bed joints - eq.6.15

$$M_{Rd11} = f_{sd11,app} \times Z_1 = \mathbf{0.522 \text{ kNm/m}}$$

Moment of resistance perpendicular to bed joints - eq.6.15

$$M_{Rd21} = f_{sd21} \times Z_1 = \mathbf{0.463 \text{ kNm/m}}$$

Considering inner leaf

Self weight at middle of wall;

$$S_{wt2} = 0.5 \times h \times t_2 \times \gamma_2 = \mathbf{2.52 \text{ kN/m}}$$

Design compressive strength of masonry;

$$f_{d2} = f_{k2} / \gamma_{Mc} = \mathbf{2.649 \text{ N/mm}^2}$$

Design vertical compressive stress;

$$\sigma_{d2} = \min(\gamma_{IG} \times (G_{k2} + S_{wt2}) / t_2, 0.15 \times \Phi_2 \times f_{d2}) = \mathbf{0.025 \text{ N/mm}^2}$$

Design flexural strength of masonry parallel to bed joints

$$f_{sd12} = f_{k12} / \gamma_{Mc} = \mathbf{0.093 \text{ N/mm}^2}$$

Apparent design flexural strength of masonry parallel to bed joints

$$f_{sd12,app} = f_{sd12} + \sigma_{d2} = \mathbf{0.118 \text{ N/mm}^2}$$

Design flexural strength of masonry perpendicular to bed joints

$$f_{sd22} = f_{k22} / \gamma_{Mc} = \mathbf{0.278 \text{ N/mm}^2}$$

Elastic section modulus of wall;

$$Z_2 = t_2^2 / 6 = \mathbf{1666667 \text{ mm}^3/\text{m}}$$

Moment of resistance parallel to bed joints - eq.6.15

$$M_{Rd12} = f_{sd12,app} \times Z_2 = \mathbf{0.196 \text{ kNm/m}}$$

Moment of resistance perpendicular to bed joints - eq.6.15

$$M_{Rd22} = f_{sd22} \times Z_2 = \mathbf{0.463 \text{ kNm/m}}$$

Calculate design wind load acting on each leaf

Outer leaf design wind load;

$$W_{k1} = M_{Rd21} \times W_k / (M_{Rd21} + M_{Rd22}) = \mathbf{0.350 \text{ kN/m}^2}$$

Inner leaf design wind load;

$$W_{k2} = M_{Rd22} \times W_k / (M_{Rd21} + M_{Rd22}) = \mathbf{0.350 \text{ kN/m}^2}$$

Design moment in panels

Considering outer leaf

Orthogonal strength ratio;

$$\mu_1 = f_{sd11,app} / f_{sd21} = \mathbf{1.13}$$

Using yield line analysis to calculate bending moment coefficient

Bending moment coefficient;

$$\alpha_1 = \mathbf{0.020}$$

Design moment in wall;

$$M_{ed1} = \gamma_{Wk} \times \alpha_1 \times W_{k1} \times L^2 = \mathbf{0.242 \text{ kNm/m}}$$

PASS - Resistance moment exceeds design moment

Considering inner leaf

Orthogonal strength ratio;

$$\mu_2 = f_{sd12,app} / f_{sd22} = \mathbf{0.42}$$

Using yield line analysis to calculate bending moment coefficient

Bending moment coefficient;

$$\alpha_2 = \mathbf{0.037}$$

Design moment in wall;

$$M_{ed2} = \gamma_{Wk} \times \alpha_2 \times W_{k2} \times L^2 = \mathbf{0.449 \text{ kNm/m}}$$

PASS - Resistance moment exceeds design moment

 Elite Designers 3 Princeton Court Felsham Road SW15 1AZ	Project		103 to 107 North Hill		Job Ref.		2021-024	
	Section		Preliminary Planning/Feasibility		Sheet no./rev.		17	
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	JGF	17/08/2021						

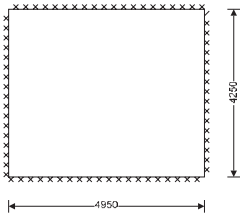
 Elite Designers 3 Princeton Court Felsham Road SW15 1AZ	Project		103 to 107 North Hill		Job Ref.		2021-024	
	Section		Preliminary Planning/Feasibility		Sheet no./rev.		18	
	Calc. by	Date	Chk'd by	Date	App'd by	Date		
	JGF	17/08/2021						

RC SLAB DESIGN (EN1992)

RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.18



Slab definition

; Type of slab; Overall slab depth; Shorter effective span of panel; Longer effective span of panel; Support conditions; Top outer layer of reinforcement; Bottom outer layer of reinforcement;

Two way spanning with restrained edges
h = **200** mm
l_x = **4250** mm
l_y = **4950** mm
Four edges continuous (interior panel)
Short span direction
Short span direction

Loading
Characteristic permanent action; Characteristic variable action; Partial factor for permanent action; Partial factor for variable action; Quasi-permanent value of variable action; Design ultimate load; Quasi-permanent load;

G_k = **12.0** kN/m²
Q_k = **3.0** kN/m²
γ_G = **1.35**
γ_Q = **1.50**
ψ₂ = **0.30**
q = γ_G × G_k + γ_Q × Q_k = **20.7** kN/m²
q_{SL,S} = 1.0 × G_k + ψ₂ × Q_k = **12.9** kN/m²

Concrete properties
Concrete strength class; Characteristic cylinder strength; Partial factor (Table 2.1N); Compressive strength factor (cl. 3.1.6); Design compressive strength (cl. 3.1.6); Mean axial tensile strength (Table 3.1); Maximum aggregate size;

C25/30
f_{ck} = **25** N/mm²
γ_C = **1.50**
α_{cc} = **0.85**
f_{cd} = **14.2** N/mm²
f_{ctm} = 0.30 N/mm² × (f_{ck} / 1 N/mm²)^{2/3} = **2.6** N/mm²
d_g = **20** mm

Reinforcement properties
Characteristic yield strength; Partial factor (Table 2.1N); Design yield strength (fig. 3.8);

f_{yk} = **500** N/mm²
γ_S = **1.15**
f_{yd} = f_{yk} / γ_S = **434.8** N/mm²

Concrete cover to reinforcement
Nominal cover to outer top reinforcement; Nominal cover to outer bottom reinforcement; Fire resistance period to top of slab; Fire resistance period to bottom of slab; Axia distance to top reinf (Table 5.8); Axia distance to bottom reinf (Table 5.8); Min. top cover requirement with regard to bond; Min. btm cover requirement with regard to bond; Reinforcement fabrication; Cover allowance for deviation; Min. required nominal cover to top reinf; Min. required nominal cover to bottom reinf;

c_{nom,t} = **30** mm
c_{nom,b} = **30** mm
R_{top} = **60** min
R_{btm} = **60** min
a_{t,t} = **10** mm
a_{t,b} = **10** mm
c_{min,b,t} = **10** mm
c_{min,b,b} = **8** mm
Not subject to QA system
Δc_{dev} = **10** mm
c_{nom,t,min} = **20.0** mm
c_{nom,b,min} = **18.0** mm

PASS - There is sufficient cover to the top reinforcement
PASS - There is sufficient cover to the bottom reinforcement

Reinforcement design at midspan in short span direction (cl.6.1)
Bending moment coefficient; Design bending moment; Reinforcement provided; Area provided; Effective depth to tension reinforcement; K factor; Redistribution ratio;

β_{sl,p} = **0.0306**
M_{sl,p} = β_{sl,p} × q × l_x² = **11.4** kNm/m
8 mm dia. bars at 200 mm centres
A_{sl,p} = 251 mm²/m
d_{sl,p} = h - c_{nom,b} - φ_{sl,p} / 2 = **166.0** mm
K = M_{sl,p} / (b × d_{sl,p}² × f_{ak}) = **0.017**
δ = 1.0

K' factor; Lever arm; Area of reinforcement required for bending; Minimum area of reinforcement required; Area of reinforcement required;

K' = 0.598 × δ - 0.18 × δ² - 0.21 = **0.208**
z = min(0.95 × d_{sl,p}, d_{sl,p}/2 × (1 + √(1 - 3.53 × K))) = **157.7** mm
A_{sl,p,m} = M_{sl,p} / (f_{yd} × z) = **167** mm²/m
A_{sl,p,min} = max(0.26 × (f_{ctm}/f_{yk}) × b × d_{sl,p}, 0.0013 × b × d_{sl,p}) = **221** mm²/m
A_{sl,p,req} = max(A_{sl,p,m}, A_{sl,p,min}) = **221** mm²/m

K < K' - Compression reinforcement is not required

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing
Reinforcement service stress; Maximum allowable spacing (Table 7.3N); Actual bar spacing;

σ_{sl,p} = (f_{yk} / γ_S) × min((A_{sl,p,m}/A_{sl,p}), 1.0) × q_{SL,S} / q = **179.8** N/mm²
s_{max,x,p} = **275** mm
s_{x,p} = **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan in long span direction (cl.6.1)
Bending moment coefficient; Design bending moment; Reinforcement provided; Area provided; Effective depth to tension reinforcement; K factor; Redistribution ratio; K' factor;

β_{sl,p} = **0.0240**
M_{sl,p} = β_{sl,p} × q × l_y² = **9.0** kNm/m
8 mm dia. bars at 200 mm centres
A_{sl,p} = 251 mm²/m
d_{sl,p} = h - c_{nom,b} - φ_{sl,p} - φ_{sl,p} / 2 = **158.0** mm
K = M_{sl,p} / (b × d_{sl,p}² × f_{ak}) = **0.014**
δ = 1.0
K' = 0.598 × δ - 0.18 × δ² - 0.21 = **0.208**

K < K' - Compression reinforcement is not required

Lever arm; Area of reinforcement required for bending; Minimum area of reinforcement required; Area of reinforcement required;

z = min(0.95 × d_{sl,p}, d_{sl,p}/2 × (1 + √(1 - 3.53 × K))) = **150.1** mm
A_{sl,p,m} = M_{sl,p} / (f_{yd} × z) = **138** mm²/m
A_{sl,p,min} = max(0.26 × (f_{ctm}/f_{yk}) × b × d_{sl,p}, 0.0013 × b × d_{sl,p}) = **211** mm²/m
A_{sl,p,req} = max(A_{sl,p,m}, A_{sl,p,min}) = **211** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing
Reinforcement service stress; Maximum allowable spacing (Table 7.3N); Actual bar spacing;

σ_{sl,p} = (f_{yk} / γ_S) × min((A_{sl,p,m}/A_{sl,p}), 1.0) × q_{SL,S} / q = **148.2** N/mm²
s_{max,y,p} = **300** mm
s_{y,p} = **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at continuous support in short span direction (cl.6.1)
Bending moment coefficient; Design bending moment; Reinforcement provided; Area provided; Effective depth to tension reinforcement; K factor; Redistribution ratio; K' factor;

β_{sl,n} = **0.0402**
M_{sl,n} = β_{sl,n} × q × l_x² = **15.0** kNm/m
10 mm dia. bars at 200 mm centres
A_{sl,n} = 393 mm²/m
d_{sl,n} = h - c_{nom,t} - φ_{sl,n} / 2 = **165.0** mm
K = M_{sl,n} / (b × d_{sl,n}² × f_{ak}) = **0.022**
δ = 1.0
K' = 0.598 × δ - 0.18 × δ² - 0.21 = **0.208**

K < K' - Compression reinforcement is not required

Lever arm; Area of reinforcement required for bending; Minimum area of reinforcement required; Area of reinforcement required;

z = min(0.95 × d_{sl,n}, d_{sl,n}/2 × (1 + √(1 - 3.53 × K))) = **156.8** mm
A_{sl,n,m} = M_{sl,n} / (f_{yd} × z) = **221** mm²/m
A_{sl,n,min} = max(0.26 × (f_{ctm}/f_{yk}) × b × d_{sl,n}, 0.0013 × b × d_{sl,n}) = **220** mm²/m
A_{sl,n,req} = max(A_{sl,n,m}, A_{sl,n,min}) = **221** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing
Reinforcement service stress; Maximum allowable spacing (Table 7.3N); Actual bar spacing;

σ_{sl,n} = (f_{yk} / γ_S) × min((A_{sl,n,m}/A_{sl,n}), 1.0) × q_{SL,S} / q = **152.3** N/mm²
s_{max,x,n} = **300** mm
s_{x,n} = **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at continuous support in long span direction (cl.6.1)
Bending moment coefficient; Design bending moment; Reinforcement provided; Area provided; Effective depth to tension reinforcement; K factor; Redistribution ratio; K' factor;

β_{sl,n} = **0.0320**
M_{sl,n} = β_{sl,n} × q × l_y² = **12.0** kNm/m
8 mm dia. bars at 200 mm centres
A_{sl,n} = 251 mm²/m
d_{sl,n} = h - c_{nom,t} - φ_{sl,n} - φ_{sl,n} / 2 = **156.0** mm
K = M_{sl,n} / (b × d_{sl,n}² × f_{ak}) = **0.020**
δ = 1.0
K' = 0.598 × δ - 0.18 × δ² - 0.21 = **0.208**

K < K' - Compression reinforcement is not required

Lever arm; Area of reinforcement required for bending; Minimum area of reinforcement required; Area of reinforcement required;

z = min(0.95 × d_{sl,n}, d_{sl,n}/2 × (1 + √(1 - 3.53 × K))) = **148.2** mm
A_{sl,n,m} = M_{sl,n} / (f_{yd} × z) = **186** mm²/m
A_{sl,n,min} = max(0.26 × (f_{ctm}/f_{yk}) × b × d_{sl,n}, 0.0013 × b × d_{sl,n}) = **208** mm²/m
A_{sl,n,req} = max(A_{sl,n,m}, A_{sl,n,min}) = **208** mm²/m

PASS - Area of reinforcement provided exceeds area required

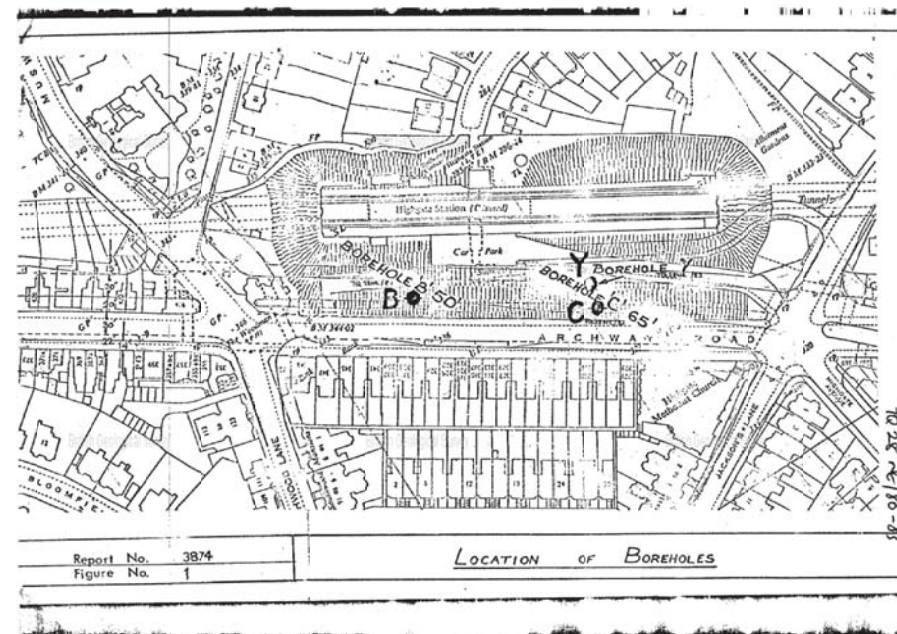
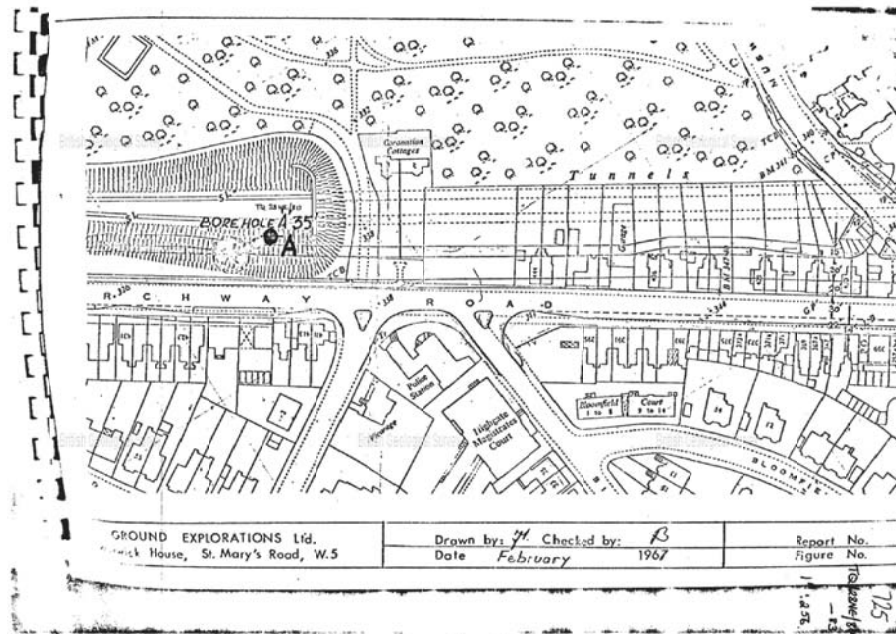
Check reinforcement spacing
Reinforcement service stress;

σ_{sl,n} = (f_{yk} / γ_S) × min((A_{sl,n,m}/A_{sl,n}), 1.0) × q_{SL,S} / q = **200.2** N/mm²

Appendix C: Damage category classification from CIRIA C580

Category of damage		Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain %
0	Negligible	Hairline cracks of less than about 0.1mm are classes as negligible.	<0.1	0.0-0.05
1	Very Slight	<u>Fine cracks that can easily be treated during normal decoration.</u> Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection.	<1	0.05-0.075
2	Slight	<u>Cracks easily filled. Redecoration probably required.</u> Several slight fractures showing inside of building. Cracks are visible externally and <u>some repointing may be required externally</u> to ensure weathertightness. Doors and windows may stick slightly.	<5	0.075-0.15
3	Moderate	<u>The cracks require some opening up and can be patched by a mason.</u> <u>Recurrent cracks can be masked by suitable linings.</u> Repointing of external brickwork and <u>possibly a small amount of brickwork to be replaced.</u> Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5-15 or a number of cracks >3	0.15-0.3
4	Severe	<u>Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.</u> Windows and frames distorted, floors sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15-25 but also depends on number of cracks	>0.3
5	Very Severe	<u>This requires a major repair involving partial or complete rebuilding.</u> Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	Usually >25 but depends on number of cracks	

Appendix D: Borehole





British
Geological
Survey

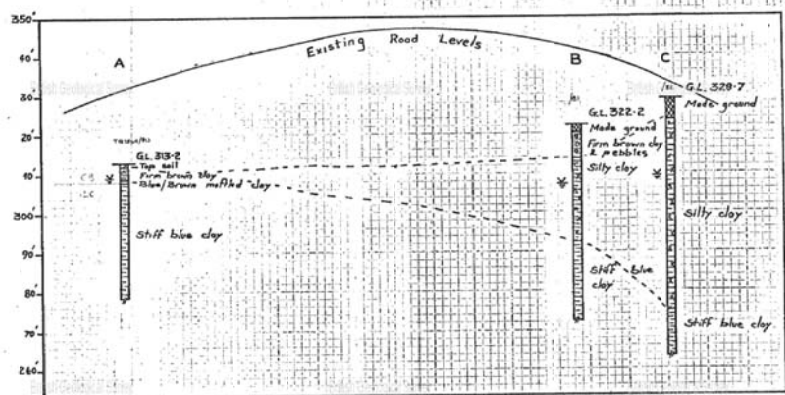
Version 2.0.6.3

BGS ID: 590668 : BGS Reference: TQ28NE80

British National Grid (27700) : 528250, 188350

[Report an issue with this borehole](#)

<< < Prev Page 3 of 4 > Next >>



Borehole Sections

Standing water level
Scale: Horizontal 1:2500
Vertical 1":20'-0"

GROUND EXPLORATIONS Ltd.
Warwick House, St. Mary's Road, W.5

Drawn by: *TH* Checked by: *PS*
Date February 1957

Report No. 3874
Figure No. 2

BOREHOLE No. A

TQ/28NE/10

2825, 8835

Contract Name ARCTWAY ROAD

Report No.

3874/SJ3

Client London Borough of Haringey,

Site Address

Address Hornsey Town Hall,

Highgate

The Broadway,

London, N.6.

Crouch End, N.8.

Standing Water Level 4'3"

Method of Boring Shell/Auger.

Water Struck

Diameter 6 inches.

Ground Level 313.2 (+93.46)

Start 29.12.56. Finish 31.12.56.

Remarks

JARS	CORES	BULK
4252 6"	4254 3'6"	
4253 1'6"	4257 8'6"	
4255 5'0"	4259 13'6"	
4256 6'0"	4261 18'6"	
4258 11'0"	4263 23'6"	
4260 16'0"	4265 28'6"	
4262 21'0"	4267 33'6"	
4264 26'0"		
4266 31'0"		
4268 35'0"		
4269 Water		

Description	Thickness	Depth
Topsoil	1'0"	1'0" 0-30
Firm brown clay ? LC	3'6"	4'6" 1-38
Stiff blue/brown mottled clay	1'0"	5'6" 1-48
Stiff blue fissured clay.	12'6"	18'0" 5-58
Claystone	6"	18'6" 5-64
Stiff blue fissured clay.	16'6"	35'0" 10-48
TOTALS	35'0"	35'0"



[Report an issue with this borehole](#)



Site Analytical Services Ltd.		REF: 07/15290
LOCATION:	66 Swindon Avenue, Higggate, London NE4 4ND	FIG: 1
TITLE:	Site Sketch Plan	SCALE: NTS

Site Analytical Services Ltd

REF: 07/13290

TITLE:	Site Sketch Map	DATE:	August 2, 1975
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DATE: AUGUST 2001

SCALE: NIS

GEA Geotechnical & Environmental Associates		Tytterhanger House Coursers Road St Albans AL4 0PG		Site 14 View Road, Highgate, London, N6 0DB		Borehole Number BH4	
Boring Method Cable Percussion		Casing Diameter 150mm cased to 10.00m		Ground Level (mOD)		Client Mr & Mrs Hellebo	
Location		Dates 08/01/2007		Engineer Fluid Structures		Job Number J06303	
Sheet 1/2							
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description
0.50	D1					(0.50)	Made Ground (brown silty slightly sandy clay with rootlets, brick fragments, gravel and pockets of yellowish brown sand)
0.60	D2					0.60	Firm orange-brown mottled pale grey sandy CLAY
1.00-1.45	SPT N=7 D3			2,2/2,1,2,2		(0.90)	
1.70	D4					1.70	Firm orange-brown and bluish grey mottled very silty sandy CLAY
2.00-2.45	U5					(1.30)	
2.50	D6					3.00	Firm grey fissured silty CLAY with partings of orange-brown silt and occasional claystone fragments
3.00-3.45	SPT N=10 D5 D7			2,3/3,4,3		(2.00)	
4.00-4.45	U9					6.00	Firm grey very silty very sandy CLAY with pockets of brown clay and yellowish brown silty sand
4.50	D10						
5.00-5.45	SPT N=12 D12 D11			2,2/3,2,3,4			
5.50-6.95	U13						
7.00	D14						
8.00-8.45	SPT N=13 D16 D15			3,2/3,4,3,3			
8.50-9.95	U17						
Remarks: Excavating services inspection pit from GL to 1.0 m for 1 hour 50mm diameter groundwater monitoring standpipe installed to a depth of 8.0 m - ground water monitored at a level of 1.7 m approximately five weeks after installation.							
Scale (approx)						Logged By	
1:50						BHW	
Figure No.						J06303.BH4	

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GEA Geotechnical & Environmental Associates		Tytterhanger House Coursers Road St Albans AL4 0PG		Site 14 View Road, Highgate, London, N6 0DB		Borehole Number BH4	
Boring Method Cable Percussion		Casing Diameter 150mm cased to 10.00m		Ground Level (mOD)		Client Mr & Mrs Hellebo	
Location		Dates 06/01/2007		Engineer Fluid Structures		Job Number J06303	
Sheet 2/2							
Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description
10.00	D18						
11.00-11.45	SPT N=12 D20 D19			3,3/3,3,2,4			
12.50-12.95	SPT N=14 D22 D21			2,4/3,4,4,3		(10.00)	
14.00	D23						
14.50-14.95	SPT N=16 D23 D24			3,4/5,3,3,5			
15.00				08/01/2007: 13.20m			
Complete at 15.00m							
Remarks:							
Scale (approx)						Logged By	
1:50						BHW	
Figure No.						J06303.BH4	

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