

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 2.9.21

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 2150$ mm
Stem thickness	$t_{\text{stem}} = 440$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{\text{stem}} = 25$ kN/m ³
Heel length	$l_{\text{heel}} = 1700$ mm
Base thickness	$t_{\text{base}} = 350$ mm
Key position	$p_{\text{key}} = 1790$ mm
Key depth	$d_{\text{key}} = 500$ mm
Key thickness	$t_{\text{key}} = 350$ mm
Base density	$\gamma_{\text{base}} = 25$ kN/m ³
Height of retained soil	$h_{\text{ret}} = 1950$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{\text{cover}} = 200$ mm
Depth of excavation	$d_{\text{exc}} = 200$ mm

Retained soil properties

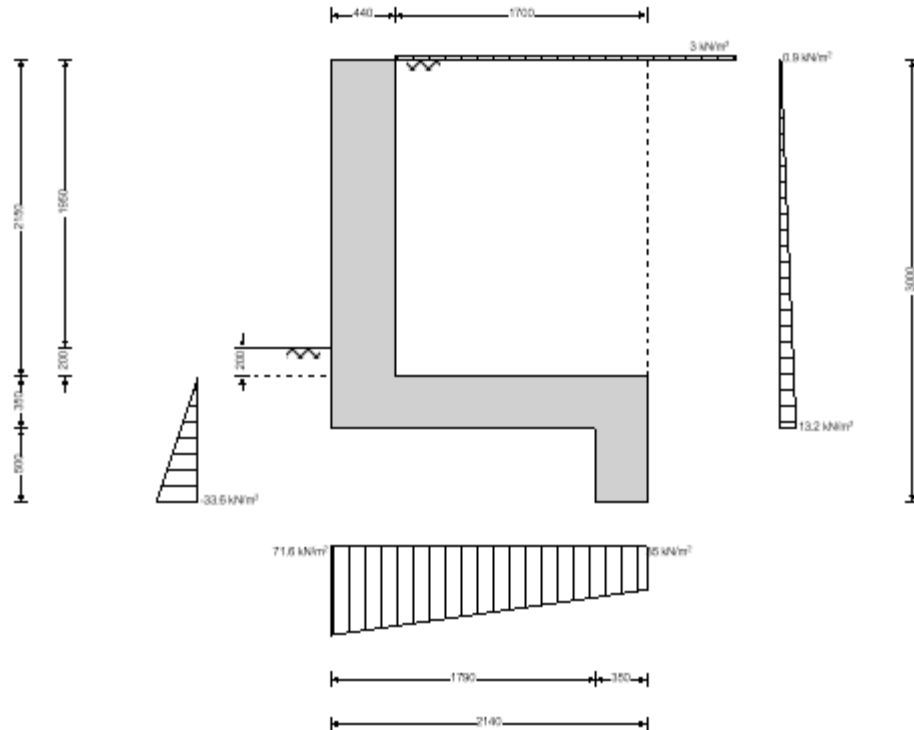
Soil type	Medium dense gravel
Moist density	$\gamma_{\text{mr}} = 17$ kN/m ³
Saturated density	$\gamma_{\text{sr}} = 20.5$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{\text{r,k}} = 30$ deg
Characteristic wall friction angle	$\delta_{\text{r,k}} = 15$ deg

Base soil properties

Soil type	Firm clay
Soil density	$\gamma_{\text{b}} = 18$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{\text{b,k}} = 18$ deg
Characteristic wall friction angle	$\delta_{\text{b,k}} = 9$ deg
Characteristic base friction angle	$\delta_{\text{bb,k}} = 12$ deg
Presumed bearing capacity	$P_{\text{bearing}} = 100$ kN/m ²

Loading details

Permanent surcharge load	Surcharge _G = 1.5 kN/m ²
Variable surcharge load	Surcharge _Q = 1.5 kN/m ²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

$$l_{base} = l_{stem} + l_{heel} = 2140 \text{ mm}$$

Base height

$$h_{base} = t_{base} + d_{key} = 850 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 2150 \text{ mm}$$

Length of surcharge load

$$l_{sur} = l_{heel} = 1700 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 1290 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 3000 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 - d_{key} = 1000 \text{ mm}$$

- Distance to horizontal component above key

$$x_{sur_{h_a}} = (h_{eff} - d_{key}) / 2 = 1250 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{stem} \times t_{stem} = 0.946 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = 220 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key} = 0.924 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base} = 1240 \text{ mm}$$

Area of moist soil

$$A_{moist} = h_{moist} \times l_{heel} = 3.655 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = 1290 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 - d_{key} = 500 \text{ mm}$$

- Distance to horizontal component above key

$$x_{moist_{h_a}} = (h_{eff} - d_{key}) / 3 = 833 \text{ mm}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2) = 0.301$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))}]^2) = \mathbf{2.359}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{23.7 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = \mathbf{23.1 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (Surcharge_G + Surcharge_Q) \times l_{heel} = \mathbf{5.1 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr} = \mathbf{62.1 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{114 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,k}) \times (Surcharge_G + Surcharge_Q) \times (h_{eff} - d_{key}) = \mathbf{2.2 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{mr} \times (h_{eff} - d_{key})^2 / 2 = \mathbf{15.5 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = \max(-K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-17.7 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{5.2 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{28.6 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{4.4 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{72.4 \text{ kNm/m}}$$

Base soil

$$M_{pass} = -F_{pass_h} \times X_{pass_h} = \mathbf{-2.6 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{108 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{948 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-122 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{2140 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{71.6 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{35 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{1.398}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

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

Partial factor set

A1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.350}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.500}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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

Soil parameter set

M1

Angle of shearing resistance

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

Effective cohesion

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

Weight density

$$\gamma_r = 1.00$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 17 \text{ kN/m}^3$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 20.5 \text{ kN/m}^3$$

Design effective shear resistance angle

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

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_\psi) = 15 \text{ deg}$$

Base soil properties

Design soil density

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

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_\psi) = 18 \text{ deg}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_\psi) = 9 \text{ deg}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_\psi) = 12 \text{ deg}$$

Design effective cohesion

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

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.301$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = 2.359$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 23.7 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 23.1 \text{ kN/m}$$

Surcharge load

$$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times l_{heel} = 2.6 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 62.1 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = 111.4 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = 3.7 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 30.1 \text{ kN/m}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} = 33.8 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 15.1 \text{ kN/m}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 23.7 \text{ kN/m}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = 38.8 \text{ kN/m}$$

Factor of safety

$$FoS_{Sl} = F_{rest} / F_{total_h} = 1.149$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 23.7 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 23.1 \text{ kN/m}$$

Surcharge load

$$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times l_{heel} = 2.6 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 62.1 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = 111.4 \text{ kN/m}$$

**Tekla® Tedds**

Grade Consulting Ltd.

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Llanelli SA14 9RT

Project

38 - 40 Pentwyn, Baglan - 1.95m Wall - W1

Job no.

GC-642

Calcs for

Atrium Planning Ltd.

Start page no./Revision

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Calcs by

IG

Calcs date

27/04/2024

Checked by

IG

Checked date

27/04/2024

Approved by

IG

Approved date

27/04/2024

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times (h_{eff} - d_{key}) = \mathbf{3.1 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2 = \mathbf{20.9 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-15.1 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{8.8 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h_a} = \mathbf{3.9 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h_a} = \mathbf{17.4 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} \times X_{exc_h} = \mathbf{3.3 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{24.6 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{5.2 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{28.6 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{80.2 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{114 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{4.639}$$

*PASS - Maximum restoring moment is greater than overturning moment***Design approach 1****Partial factors on actions - Table A.3 - Combination 2**

Partial factor set

A2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.000}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.300}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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

Soil parameter set

M2

Angle of shearing resistance

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

Effective cohesion

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

Weight density

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

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = \mathbf{17 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = \mathbf{20.5 \text{ kN/m}^3}$$

Design effective shear resistance angle

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

Design wall friction angle

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

Base soil properties

Design soil density

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

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{14.6 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{7.2 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{9.7 \text{ deg}}$$

Design effective cohesion

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

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.371}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = \mathbf{1.965}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{23.7 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{23.1 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times l_{heel} = \mathbf{2.6 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr'} = \mathbf{62.1 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{111.4 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = \mathbf{3.8 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr'} \times h_{eff}^2 / 2 = \mathbf{27.7 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{31.5 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{pass} + h_{base})^2 / 2 = \mathbf{12.7 \text{ kN/m}}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = \mathbf{18.9 \text{ kN/m}}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{31.6 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.004}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{23.7 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{23.1 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times l_{heel} = \mathbf{2.6 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr'} = \mathbf{62.1 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{111.4 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times (h_{eff} - d_{key}) = \mathbf{3.1 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr'} \times (h_{eff} - d_{key})^2 / 2 = \mathbf{19.3 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-12.7 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{9.7 \text{ kN/m}}$$

Overtuning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h_a} = \mathbf{3.9 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h_a} = \mathbf{16.1 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} \times X_{exc_h} = \mathbf{2.7 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{22.7 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{5.2 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{28.6 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{80.2 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{114 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{5.018}$$

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.21

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

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0 \text{ N/mm}^2}$$

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

Top face of base

$$C_{bt} = \mathbf{50 \text{ mm}}$$

Bottom face of base

$$C_{bb} = \mathbf{75 \text{ mm}}$$

Masonry details - Section 3.1

Masonry type

Aggregate concrete - Group 1

Normalised mean compressive strength

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

Characteristic flexural strength - cl.6.3.4(1)

$$f_{xk} = \mathbf{0 \text{ N/mm}^2}$$

Initial shear strength - Table NA.5

$$f_{vko} = \mathbf{0.15 \text{ N/mm}^2}$$

Mortar details - Section 3.2

Mortar type

General purpose - M6, prescribed mix

Compressive strength of mortar

 $f_m = 6 \text{ N/mm}^2$

Ultimate limit states - Table NA.1

Class of execution control

1

Category of manufacture control

1

Partial factor for direct or flexural compression

 $\gamma_{Mc} = 2.0$

Partial factor for flexural tension

 $\gamma_{Mt} = 2.3$

Partial factor for shear

 $\gamma_{Mv} = 2.0$

Characteristic strengths of concrete infill - Table 3.2

Concrete infill strength class

C28/35

Characteristic compressive strength

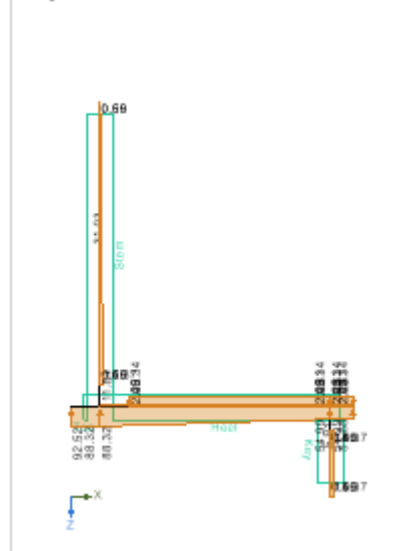
 $f_{ck, \text{infill}} = 25 \text{ N/mm}^2$

Characteristic shear strength

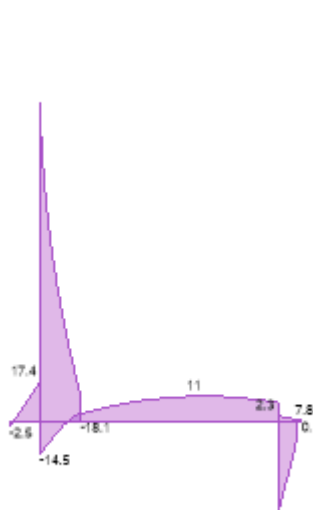
 $f_{cvk, \text{infill}} = 0.45 \text{ N/mm}^2$

Design shear strength

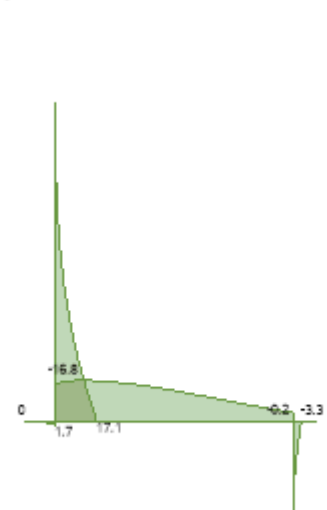
 $f_{cvd, \text{infill}} = f_{cvk, \text{infill}} / \gamma_{Mv} = 0.225 \text{ N/mm}^2$

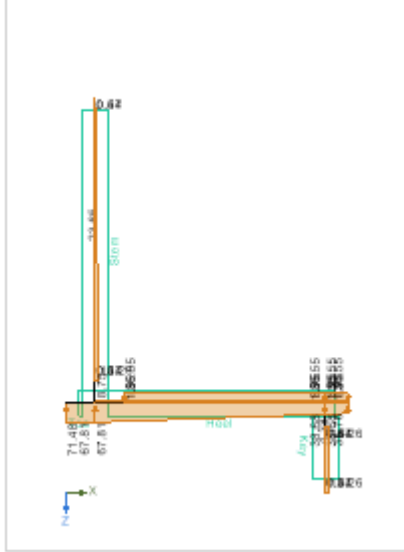
Loading details - Combination No.1 - kN/m²


Shear force - Combination No.1 - kN/m

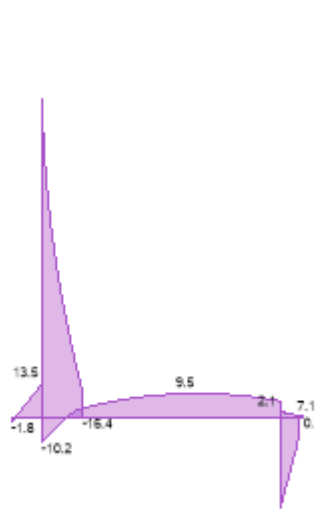


Bending moment - Combination No.1 - kNm/m

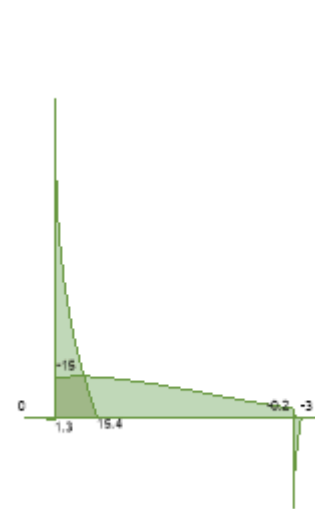


Loading details - Combination No.2 - kN/m²


Shear force - Combination No.2 - kN/m



Bending moment - Combination No.2 - kNm/m



Check stem design at base of stem

Depth of section

 $t = 440 \text{ mm}$

Cavity wall details

Front leaf thickness

 $t_f = 100 \text{ mm}$

Rear leaf thickness

 $t_r = 100 \text{ mm}$

Masonry characteristics

Compressive strength constants - Table NA.4

 $K = 0.750$

Characteristic compressive strength - cl.3.6.1.2(1)

 $f_k = K \times f_b^{0.7} \times f_m^{0.3} = 6.613 \text{ N/mm}^2$

Design compressive strength

 $f_d = \min(f_k, f_{ck,inf}) / \gamma_{Mc} = 3.307 \text{ N/mm}^2$

Design flexural strength

 $f_{xd} = f_{xk} / \gamma_{Mt} = 0 \text{ N/mm}^2$

Height of masonry

 $h_{wt} = h_{stem} = 2150 \text{ mm}$

Compressive axial force combination 0

 $F_x = \gamma_{Gf} \times \gamma_{stem} \times h_{wt} \times t = 23.7 \text{ kN/m}$

Moment combination 0

 $M_x = \gamma_{Gf} \times \gamma_{stem} \times h_{wt} \times t^2 / 2 = 5.2 \text{ kNm/m}$

Eccentricity of axial load

 $e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = 22 \text{ mm}$

Capacity reduction factor - exp.6.4

 $\Phi = 1 - 2 \times e / t = 0.9$

Design vertical resistance - exp.6.2

 $N_{Rd} = \Phi \times t \times f_d = 1309.5 \text{ kN/m}$

Design vertical compressive stress

 $\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = 0.054 \text{ N/mm}^2$

Apparent design flexural strength - exp.6.16

 $f_{xd,app} = f_{xd} + \sigma_d = 0.054 \text{ N/mm}^2$

Limit of charact. shear strength - exp. 3.1

 $f_{vk,lim} = 0.065 \times f_b = 0.676 \text{ N/mm}^2$

Characteristic shear strength - exp.3.5

 $f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = 0.172 \text{ N/mm}^2$

Design shear strength

 $f_{vd} = f_{vk} / \gamma_{Mv} = 0.086 \text{ N/mm}^2$

Library item: Masonry characteristics output

Reinforced masonry members subjected to bending, bending and axial loading, or axial loading - Section 6.6

Design bending moment combination 1

 $M = 13.9 \text{ kNm/m}$

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

 $A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = 565 \text{ mm}^2/\text{m}$

Depth to tension reinforcement

 $d = 150 \text{ mm}$

Minimum area of reinforcement - cl.8.2.3(1)

 $A_{sr,min} = 0.0005 \times d = 75 \text{ mm}^2/\text{m}$

Lever arm - exp.6.23

 $z = d \times \min(1 - 0.5 \times A_{sr,prov} \times f_{yd} / (d \times f_d), 0.95) = 113 \text{ mm}$

Moment of resistance - exp.6.22 and exp.6.24a

$$M_{Rd} = \min(A_{sr,prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2) = \mathbf{27.7 \text{ kNm/m}}$$

$$M / M_{Rd} = \mathbf{0.503}$$

PASS - Moment of resistance exceeds applied design moment

Reinforced masonry members subjected to shear loading - Section 6.7

Design shear force

$$V = \mathbf{18.119 \text{ kN/m}}$$

Design shear resistance - exp.6.40

$$V_{Rd} = \min(f_{vd}, f_{c,vd,infill}) \times d = \mathbf{12.863 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{1.409}$$

Design shear resistance is less than applied design shear force - try concrete shear alone

Determine shear resistance due to concrete infill alone - Clause 6.7.1(3)

Effective depth taking in to account concrete only

$$d = d_{stem} - t_r = \mathbf{50 \text{ mm}}$$

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

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

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{sr,prov} / d, 0.02) = \mathbf{0.011}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck,infill}^{0.5} = \mathbf{0.495 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = \mathbf{36.6 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.496}$$

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem

Minimum area of reinforcement - cl.8.2.3(4)

$$A_{sx,req} = 0.0005 \times d = \mathbf{75 \text{ mm}^2/\text{m}}$$

Transverse reinforcement provided

$$12 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{sx,prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) = \mathbf{565 \text{ mm}^2/\text{m}}$$

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

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

$$M = \mathbf{16.8 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{294 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.006}$$

$$K' = (2 \times \eta \times \alpha_{cc}/\gamma_c) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{279 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{37 \text{ mm}}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = \mathbf{139 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

$$12 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{565 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{443 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = \mathbf{0.783}$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$



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Serviceability bending moment

$M_{sls} = 12 \text{ kNm/m}$

Tensile stress in reinforcement

$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = 75.7 \text{ N/mm}^2$

Load duration

Long term

Load duration factor

$k_t = 0.4$

Effective area of concrete in tension

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

$A_{c,eff} = 104417 \text{ mm}^2/\text{m}$

Mean value of concrete tensile strength

$f_{ct,eff} = f_{ctm} = 2.9 \text{ N/mm}^2$

Reinforcement ratio

$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = 0.005$

Modular ratio

$\alpha_e = E_s / E_{cm} = 6.091$

Bond property coefficient

$k_1 = 0.8$

Strain distribution coefficient

$k_2 = 0.5$

$k_3 = 3.4$

$k_4 = 0.425$

Maximum crack spacing - exp.7.11

$s_{r,max} = k_3 \times C_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p,eff} = 547 \text{ mm}$

Maximum crack width - exp.7.8

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

$w_k = 0.124 \text{ mm}$

$w_k / w_{max} = 0.414$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$V = 2.4 \text{ kN/m}$

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.825$

Longitudinal reinforcement ratio

$\rho_l = \min(A_{bt,prov} / d, 0.02) = 0.002$

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.473 \text{ N/mm}^2$

Design shear resistance - exp.6.2a & 6.2b

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

$V_{Rd,c} = 138.9 \text{ kN/m}$

$V / V_{Rd,c} = 0.018$

PASS - Design shear resistance exceeds design shear force

Check key design

Depth of section

$h = 350 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$M = 2 \text{ kNm/m}$

Depth to tension reinforcement

$d = h - C_{bb} - \phi_k / 2 = 269 \text{ mm}$

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

$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$

$K' = 0.207$

K' > K - No compression reinforcement is required

Lever arm

$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 256 \text{ mm}$

Depth of neutral axis

$x = 2.5 \times (d - z) = 34 \text{ mm}$

Area of tension reinforcement required

$A_{k,req} = M / (f_{yd} \times z) = 18 \text{ mm}^2/\text{m}$

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

$A_{k,prov} = \pi \times \phi_k^2 / (4 \times S_k) = 565 \text{ mm}^2/\text{m}$

Minimum area of reinforcement - exp.9.1N

$A_{k,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 405 \text{ mm}^2/\text{m}$

Maximum area of reinforcement - cl.9.2.1.1(3)

$A_{k,max} = 0.04 \times h = 14000 \text{ mm}^2/\text{m}$

$\max(A_{k,req}, A_{k,min}) / A_{k,prov} = 0.716$

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

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Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{\text{Sls}} = 1.4 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{\text{Sls}} / (A_{k,\text{prov}} \times z) = 9.8 \text{ N/mm}^2$$

Load duration

Long term

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

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

$$A_{c,\text{eff}} = 105458 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength

$$f_{ct,\text{eff}} = f_{ctm} = 2.9 \text{ N/mm}^2$$

Reinforcement ratio

$$\rho_{p,\text{eff}} = A_{k,\text{prov}} / A_{c,\text{eff}} = 0.005$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = 6.091$$

Bond property coefficient

$$k_1 = 0.8$$

Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11

$$s_{r,\text{max}} = k_3 \times C_{bb} + k_1 \times k_2 \times k_4 \times \phi_k / \rho_{p,\text{eff}} = 635 \text{ mm}$$

Maximum crack width - exp.7.8

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

$$w_k = 0.019 \text{ mm}$$

$$w_k / w_{\max} = 0.062$$

*PASS - Maximum crack width is less than limiting crack width***Rectangular section in shear - Section 6.2**

Design shear force

$$V = 7.8 \text{ kN/m}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.862$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{k,\text{prov}} / d, 0.02) = 0.002$$

$$v_{\min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.487 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = 131.1 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.060$$

*PASS - Design shear resistance exceeds design shear force***Secondary transverse reinforcement to base - Section 9.3**

Minimum area of reinforcement – cl.9.3.1.1(2)

$$A_{b,\text{req}} = 0.2 \times A_{b,\text{prov}} = 113 \text{ mm}^2/\text{m}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{b,\text{max}} = 450 \text{ mm}$$

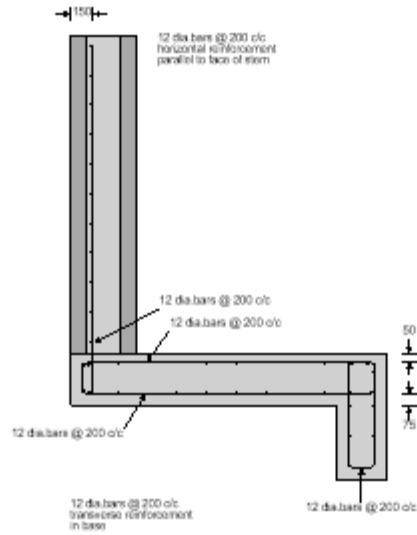
Transverse reinforcement provided

$$12 \text{ dia. bars @ } 200 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{b,\text{prov}} = \pi \times \phi_{b,x}^2 / (4 \times s_{b,x}) = 565 \text{ mm}^2/\text{m}$$

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


Reinforcement details

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

Tedds calculation version 2.9.21

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 1500 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 215 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 150 \text{ mm}$
Heel length	$l_{\text{heel}} = 1100 \text{ mm}$
Base thickness	$t_{\text{base}} = 350 \text{ mm}$
Key position	$p_{\text{key}} = 1115 \text{ mm}$
Key depth	$d_{\text{key}} = 500 \text{ mm}$
Key thickness	$t_{\text{key}} = 350 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 1300 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 200 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 200 \text{ mm}$

Retained soil properties

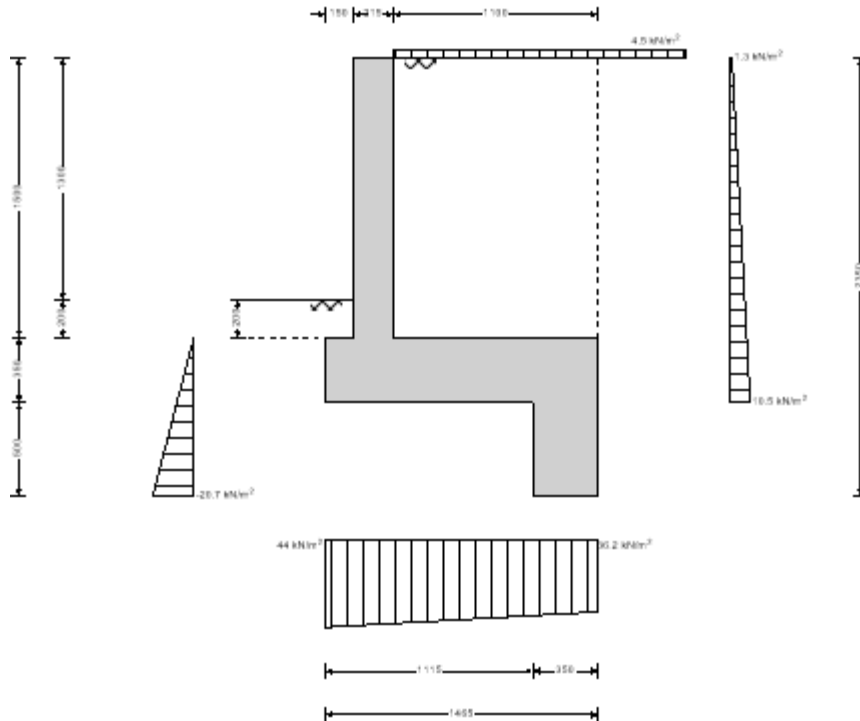
Soil type	Medium dense gravel
Moist density	$\gamma_{\text{mr}} = 17 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 20.5 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r.k}} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r.k}} = 15 \text{ deg}$

Base soil properties

Soil type	Firm clay
Soil density	$\gamma_{\text{b}} = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{b.k}} = 18 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b.k}} = 9 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb.k}} = 12 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 100 \text{ kN/m}^2$

Loading details

Permanent surcharge load	Surcharge _G = 1.5 kN/m²
Variable surcharge load	Surcharge _Q = 3 kN/m²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{stem} + l_{heel} = 1465 \text{ mm}$$

Base height

$$h_{base} = t_{base} + d_{key} = 850 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 1500 \text{ mm}$$

Length of surcharge load

$$l_{sur} = l_{heel} = 1100 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 915 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 2350 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 - d_{key} = 675 \text{ mm}$$

- Distance to horizontal component above key

$$x_{sur_h_a} = (h_{eff} - d_{key}) / 2 = 925 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{stem} \times t_{stem} = 0.323 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = 258 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key} = 0.688 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base} = 874 \text{ mm}$$

Area of moist soil

$$A_{moist} = h_{moist} \times l_{heel} = 1.65 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = 915 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 - d_{key} = 283 \text{ mm}$$

- Distance to horizontal component above key

$$x_{moist_h_a} = (h_{eff} - d_{key}) / 3 = 617 \text{ mm}$$

Area of base soil

$$A_{pass} = d_{cover} \times l_{toe} = 0.03 \text{ m}^2$$

- Distance to vertical component

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 75 \text{ mm}$$

- Distance to horizontal component

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 - d_{key} = -150 \text{ mm}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta)] / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.301}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))}]^2) = \mathbf{2.359}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{8.1 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = \mathbf{17.2 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (Surcharge_G + Surcharge_Q) \times l_{heel} = \mathbf{5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr} = \mathbf{28.1 \text{ kN/m}}$$

Base soil

$$F_{pass_v} = A_{pass} \times \gamma_b = \mathbf{0.5 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} + F_{pass_v} = \mathbf{58.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,k}) \times (Surcharge_G + Surcharge_Q) \times (h_{eff} - d_{key}) = \mathbf{2.4 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{mr} \times (h_{eff} - d_{key})^2 / 2 = \mathbf{8.5 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = \max(-K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-10.9 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{2.1 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{15 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{2.9 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{23.3 \text{ kNm/m}}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} - F_{pass_h} \times X_{pass_h} = \mathbf{-1.6 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{41.7 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{709 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-24 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{1465 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{44 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{36.2 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{2.271}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

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

Partial factor set

A1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.350}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.500}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_{\gamma} = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 17 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 20.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi}) = 30 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi}) = 15 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_{\gamma} = 18 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi}) = 18 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi}) = 9 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi}) = 12 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.301$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = 2.359$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 8.1 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 17.2 \text{ kN/m}$
Surcharge load	$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times l_{heel} = 1.7 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 28.1 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = 55 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = 4.5 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 18.5 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = 22.9 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 15.1 \text{ kN/m}$
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 11.7 \text{ kN/m}$
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = 26.8 \text{ kN/m}$
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = 1.171$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 8.1 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 17.2 \text{ kN/m}$

Surcharge load

$$F_{sur_v} = (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times l_{heel} = \mathbf{1.7 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{28.1 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{55 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times (h_{eff} - d_{key}) = \mathbf{3.5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2 = \mathbf{11.4 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{pass} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-14.9 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{0 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h_a} = \mathbf{3.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h_a} = \mathbf{7.1 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} \times X_{exc_h} = \mathbf{3.2 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{13.5 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{2.1 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{15 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{25.7 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{42.8 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{3.159}$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

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

Partial factor set

A2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.000}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.300}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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

Soil parameter set

M2

Angle of shearing resistance

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

Effective cohesion

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

Weight density

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

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = \mathbf{17 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = \mathbf{20.5 \text{ kN/m}^3}$$

Design effective shear resistance angle

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

Design wall friction angle

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

Base soil properties

Design soil density

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

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{14.6 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi}) = \mathbf{7.2 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi}) = \mathbf{9.7 \text{ deg}}$$

Design effective cohesion

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

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]) = \mathbf{0.371}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]) = \mathbf{1.965}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma G_f \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.1 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma G_f \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{17.2 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = (\gamma G_f \times \text{Surcharge}_G + \gamma Q_f \times \text{Surcharge}_Q) \times l_{\text{heel}} = \mathbf{1.7 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma G_f \times A_{\text{moist}} \times \gamma_{\text{mr}} = \mathbf{28.1 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} = \mathbf{55 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma G \times \text{Surcharge}_G + \gamma Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = \mathbf{4.6 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = \mathbf{17 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = \mathbf{21.6 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma G_f \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{12.7 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{9.3 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{22 \text{ kN/m}}$$

Factor of safety

$$F_{\text{OSsl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.018}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma G_f \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.1 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma G_f \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{17.2 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = (\gamma G_f \times \text{Surcharge}_G + \gamma Q_f \times \text{Surcharge}_Q) \times l_{\text{heel}} = \mathbf{1.7 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma G_f \times A_{\text{moist}} \times \gamma_{\text{mr}} = \mathbf{28.1 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} = \mathbf{55 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma G \times \text{Surcharge}_G + \gamma Q \times \text{Surcharge}_Q) \times (h_{\text{eff}} - d_{\text{key}}) = \mathbf{3.6 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}} \times (h_{\text{eff}} - d_{\text{key}})^2 / 2 = \mathbf{10.6 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = \max(-\gamma G_f \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2, -(F_{\text{moist}_h} + F_{\text{sur}_h})) = \mathbf{-12.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{1.5 \text{ kN/m}}$$

Overtuning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times X_{\text{sur}_h_a} = \mathbf{3.4 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times X_{\text{moist}_h_a} = \mathbf{6.5 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} \times X_{exc_h} = \mathbf{2.7 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{12.6 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{2.1 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{15 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{25.7 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{42.8 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{3.393}$$

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.21

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

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0 \text{ N/mm}^2}$$

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 k_1

$$K_1 = \mathbf{0.40}$$

Bending coefficient k_2

$$K_2 = 1.00 \times (0.6 + 0.0014 / \epsilon_{cu2}) = \mathbf{1.00}$$

Bending coefficient k_3

$$K_3 = \mathbf{0.40}$$

Bending coefficient k_4

$$K_4 = 1.00 \times (0.6 + 0.0014 / \epsilon_{cu2}) = \mathbf{1.00}$$

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

$$f_{yd} = f_{yk} / \gamma_S = \mathbf{435 \text{ N/mm}^2}$$

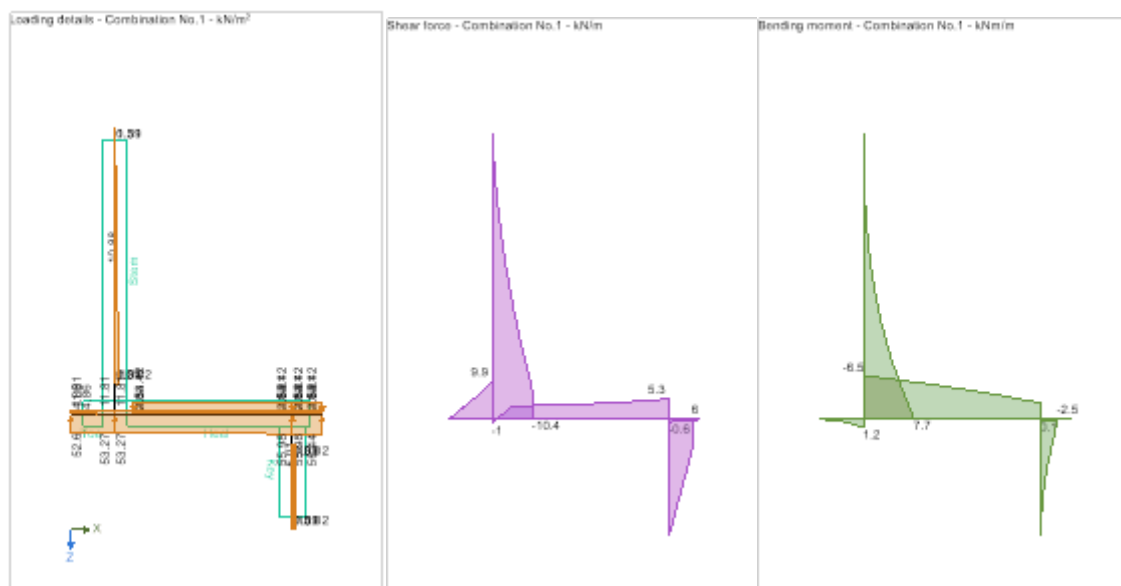
Cover to reinforcement

Top face of base

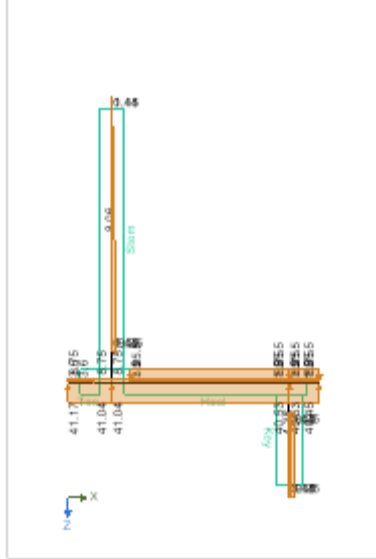
$$C_{bt} = \mathbf{50 \text{ mm}}$$

Bottom face of base

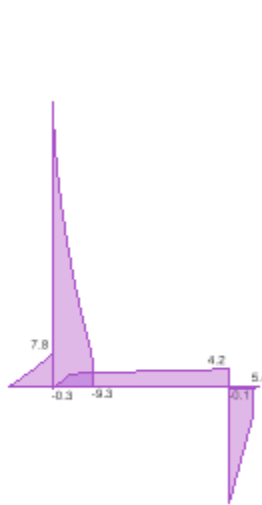
$$C_{bb} = \mathbf{75 \text{ mm}}$$



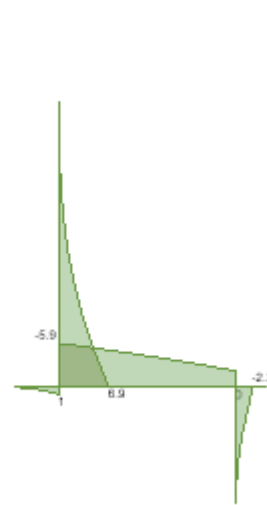
Loading details - Combination No.2 - kN/m²



Shear force - Combination No.2 - kN/m



Bending moment - Combination No.2 - kNm/m



Check stem design at base of stem

Depth of section

 $t = 215 \text{ mm}$

Hollow wall details

Face shell thickness

 $t_{\text{shell}} = 35 \text{ mm}$

Web shell thickness

 $t_{\text{web}} = 35 \text{ mm}$

Masonry characteristics

Compressive strength constants - Table NA.4

 $K = 0.750$

Characteristic compressive strength - cl.3.6.1.2(1)

 $f_k = K \times f_b^{0.7} \times f_m^{0.3} = 6.613 \text{ N/mm}^2$

Design compressive strength

 $f_d = \min(f_k, f_{ck, \text{infill}}) / \gamma_{Mc} = 3.307 \text{ N/mm}^2$

Design flexural strength

 $f_{xd} = f_{xk} / \gamma_{Mt} = 0 \text{ N/mm}^2$

Height of masonry

 $h_{wt} = h_{\text{stem}} = 1500 \text{ mm}$

Compressive axial force combination 0

 $F_x = \gamma_{Gf} \times \gamma_{\text{stem}} \times h_{wt} \times t = 8.1 \text{ kN/m}$

Moment combination 0

 $M_x = \gamma_{Gf} \times \gamma_{\text{stem}} \times h_{wt} \times t^2 / 2 = 0.9 \text{ kNm/m}$

Eccentricity of axial load

 $e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = 10.8 \text{ mm}$

Capacity reduction factor - exp.6.4

 $\Phi = 1 - 2 \times e / t = 0.9$

Design vertical resistance - exp.6.2

 $N_{Rd} = \Phi \times t \times f_d = 639.9 \text{ kN/m}$

Design vertical compressive stress

 $\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = 0.038 \text{ N/mm}^2$

Apparent design flexural strength - exp.6.16

 $f_{xd, \text{app}} = f_{xd} + \sigma_d = 0.038 \text{ N/mm}^2$

Limit of charact. shear strength - exp. 3.1

 $f_{vk, \text{lim}} = 0.065 \times f_b = 0.676 \text{ N/mm}^2$

Characteristic shear strength - exp.3.5

 $f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk, \text{lim}}) = 0.165 \text{ N/mm}^2$

Design shear strength

 $f_{vd} = f_{vk} / \gamma_{Mv} = 0.083 \text{ N/mm}^2$

Library item: Masonry characteristics output

Reinforced masonry members subjected to bending, bending and axial loading, or axial loading - Section 6.6

Design bending moment combination 1

 $M = 5.9 \text{ kNm/m}$

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

 $A_{sr, \text{prov}} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = 565 \text{ mm}^2/\text{m}$

Depth to tension reinforcement

 $d = 140 \text{ mm}$

Minimum area of reinforcement - cl.8.2.3(1)

 $A_{sr, \text{min}} = 0.0005 \times d = 70 \text{ mm}^2/\text{m}$

Lever arm - exp.6.23

 $z = d \times \min(1 - 0.5 \times A_{sr, \text{prov}} \times f_{yd} / (d \times f_d), 0.95) = 103 \text{ mm}$

**Tekla® Tedds**

Grade Consulting Ltd.

Cae Hir, Pencoed

Llangennech

Llanelli SA14 9RT

Project

38 - 40 Pentwyn, Baglan - 1.3m Wall W2 & W3

Job no.

GC-642

Calcs for

Atrium Planning Ltd.

Start page no./Revision

10 2

Calcs by

IG

Calcs date

21/11/2024

Checked by

IG

Checked date

21/11/2024

Approved by

IG

Approved date

21/11/2024

Moment of resistance - exp.6.22 and exp.6.24a

$$M_{Rd} = \min(A_{sr,prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2) = \mathbf{25.3 \text{ kNm/m}}$$

$$M / M_{Rd} = \mathbf{0.233}$$

*PASS - Moment of resistance exceeds applied design moment***Reinforced masonry members subjected to shear loading - Section 6.7**

Design shear force

$$V = \mathbf{10.367 \text{ kN/m}}$$

Design shear resistance - exp.6.40

$$V_{Rd} = \min(f_{vd}, f_{c,vd,infill}) \times d = \mathbf{11.55 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.898}$$

*PASS - Design shear resistance exceeds applied design shear force***Horizontal reinforcement parallel to face of stem**

Minimum area of reinforcement - cl.8.2.3(4)

$$A_{sx,req} = 0.0005 \times d = \mathbf{70 \text{ mm}^2/\text{m}}$$

Transverse reinforcement provided

12 dia.bars @ 200 c/c

Area of transverse reinforcement provided

$$A_{sx,prov} = \pi \times \phi_{sx}^2 / (4 \times S_{sx}) = \mathbf{565 \text{ mm}^2/\text{m}}$$

*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

$$M = \mathbf{0.4 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - C_{bb} - \phi_{bb} / 2 = \mathbf{269 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.000}$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{256 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{34 \text{ mm}}$$

Area of tension reinforcement required

$$A_{bb,req} = M / (f_{yd} \times z) = \mathbf{4 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

$$A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times S_{bb}) = \mathbf{565 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{405 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bb,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = \mathbf{0.716}$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{Sls} = \mathbf{0.3 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{Sls} / (A_{bb,prov} \times z) = \mathbf{1.9 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

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

$$A_{c,eff} = \mathbf{105458 \text{ mm}^2/\text{m}}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = \mathbf{0.005}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 635 \text{ mm}$$

Maximum crack width - exp.7.8

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

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

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

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 5.4 \text{ kN/m}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.862$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = 0.002$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.487 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = 131.1 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.041$$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

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

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 6.4 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = 294 \text{ mm}$$

$$K = M / (d^2 \times f_{ck}) = 0.002$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = 0.207$$

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

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 279 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = 37 \text{ mm}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = 52 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$12 \text{ dia. bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = 565 \text{ mm}^2/\text{m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 443 \text{ mm}^2/\text{m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = 14000 \text{ mm}^2/\text{m}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = 0.783$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sls} = 4.2 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = 26.6 \text{ N/mm}^2$$

Load duration

Long term

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

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

$$A_{c,eff} = 104417 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = \mathbf{0.005}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p,eff} = \mathbf{547 \text{ mm}}$$

Maximum crack width - exp.7.8

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

$$w_k = \mathbf{0.044 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.145}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{3.4 \text{ kN/m}}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.825}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = \mathbf{0.002}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.473 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = \mathbf{138.9 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.025}$$

PASS - Design shear resistance exceeds design shear force

Check key design

Depth of section

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

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = \mathbf{1.5 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - C_{bb} - \phi_k / 2 = \mathbf{269 \text{ mm}}$$

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

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{256 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{34 \text{ mm}}$$

Area of tension reinforcement required

$$A_{k,req} = M / (f_{yd} \times z) = \mathbf{13 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

$$12 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{k,prov} = \pi \times \phi_k^2 / (4 \times S_k) = \mathbf{565 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{k,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{405 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{k,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{k,req}, A_{k,min}) / A_{k,prov} = \mathbf{0.716}$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{1 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{k,prov} \times z) = \mathbf{7.3 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

 $k_t = 0.4$

Effective area of concrete in tension

 $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = 105458 \text{ mm}^2/\text{m}$

Mean value of concrete tensile strength

 $f_{ct,eff} = f_{ctm} = 2.9 \text{ N/mm}^2$

Reinforcement ratio

 $\rho_{p,eff} = A_{k,prov} / A_{c,eff} = 0.005$

Modular ratio

 $\alpha_e = E_s / E_{cm} = 6.091$

Bond property coefficient

 $k_1 = 0.8$

Strain distribution coefficient

 $k_2 = 0.5$
 $k_3 = 3.4$
 $k_4 = 0.425$

Maximum crack spacing - exp.7.11

 $s_{r,max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_k / \rho_{p,eff} = 635 \text{ mm}$

Maximum crack width - exp.7.8

 $w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = 0.014 \text{ mm}$
 $w_k / w_{max} = 0.046$
PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

 $V = 6 \text{ kN/m}$
 $C_{Rd,c} = 0.18 / \gamma_c = 0.120$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.862$

Longitudinal reinforcement ratio

 $\rho_l = \min(A_{k,prov} / d, 0.02) = 0.002$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.487 \text{ N/mm}^2$

Design shear resistance - exp.6.2a & 6.2b

 $V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
 $V_{Rd,c} = 131.1 \text{ kN/m}$
 $V / V_{Rd,c} = 0.045$
PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)

 $A_{bx,req} = 0.2 \times A_{bb,prov} = 113 \text{ mm}^2/\text{m}$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

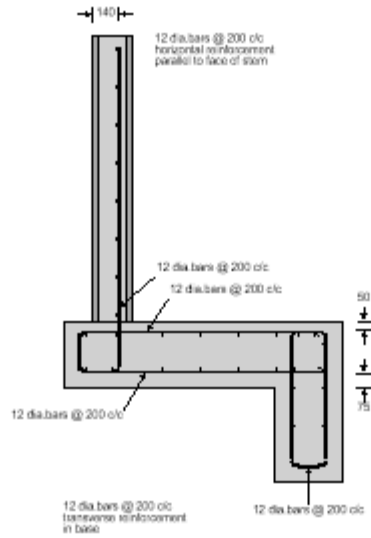
 $s_{bx,max} = 450 \text{ mm}$

Transverse reinforcement provided

12 dia.bars @ 200 c/c

Area of transverse reinforcement provided

 $A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = 565 \text{ mm}^2/\text{m}$
PASS - Area of reinforcement provided is greater than area of reinforcement required


Reinforcement details

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 2.9.21

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 1500 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 215 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 150 \text{ mm}$
Heel length	$l_{\text{heel}} = 1000 \text{ mm}$
Base thickness	$t_{\text{base}} = 350 \text{ mm}$
Key position	$p_{\text{key}} = 1015 \text{ mm}$
Key depth	$d_{\text{key}} = 500 \text{ mm}$
Key thickness	$t_{\text{key}} = 350 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 1300 \text{ mm}$
Angle of soil surface	$\beta = 2.25 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 200 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 200 \text{ mm}$

Retained soil properties

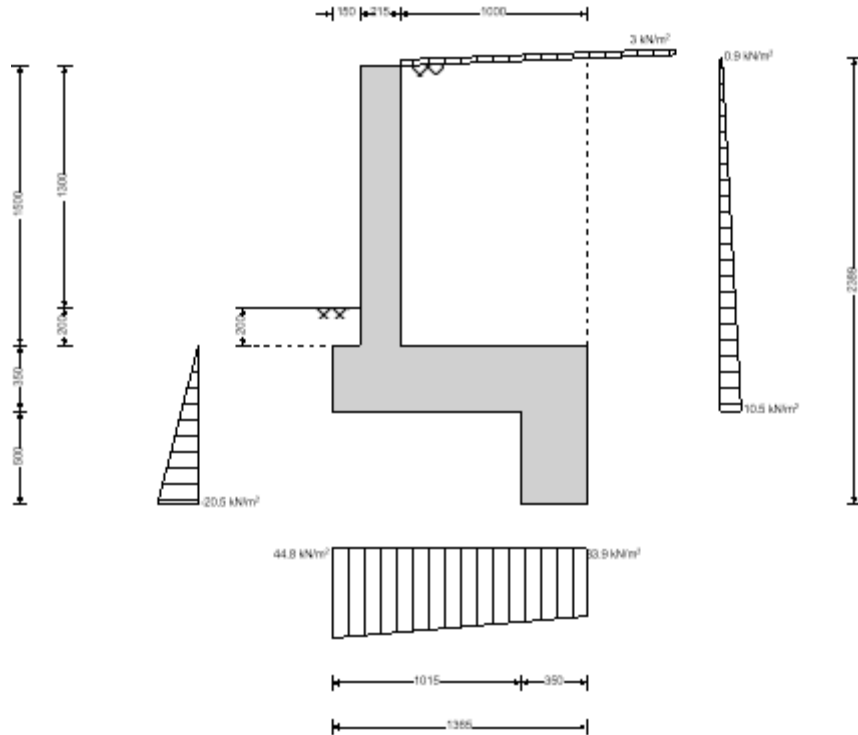
Soil type	Medium dense gravel
Moist density	$\gamma_{\text{mr}} = 17 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 20.5 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r.k}} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r.k}} = 15 \text{ deg}$

Base soil properties

Soil type	Firm clay
Soil density	$\gamma_{\text{b}} = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{b.k}} = 18 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b.k}} = 9 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb.k}} = 12 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 100 \text{ kN/m}^2$

Loading details

Permanent surcharge load	Surcharge _G = 1.5 kN/m ²
Variable surcharge load	Surcharge _Q = 1.5 kN/m ²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{stem} + l_{heel} = 1365 \text{ mm}$$

Base height

$$h_{base} = t_{base} + d_{key} = 850 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 1500 \text{ mm}$$

Length of surcharge load

$$l_{sur} = l_{heel} = 1000 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 865 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta) = 2389 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 - d_{key} = 695 \text{ mm}$$

- Distance to horizontal component above key

$$x_{sur_h_a} = (h_{eff} - d_{key}) / 2 = 945 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{stem} \times t_{stem} = 0.323 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = 258 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key} = 0.653 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base} = 819 \text{ mm}$$

Area of moist soil

$$A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2 = 1.52 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist} = 867 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 - d_{key} = 296 \text{ mm}$$

- Distance to horizontal component above key

$$x_{moist_h_a} = (h_{eff} - d_{key}) / 3 = 630 \text{ mm}$$

Area of base soil

$$A_{pass} = d_{cover} \times l_{toe} = 0.03 \text{ m}^2$$

- Distance to vertical component

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 75 \text{ mm}$$

- Distance to horizontal component

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 - d_{key} = -150 \text{ mm}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta)] / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.309}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))}]^2) = \mathbf{2.359}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{8.1 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = \mathbf{16.3 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (\text{Surcharge}_G + \text{Surcharge}_Q) \times l_{heel} = \mathbf{3 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr} = \mathbf{25.8 \text{ kN/m}}$$

Base soil

$$F_{pass_v} = A_{pass} \times \gamma_b = \mathbf{0.5 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} + F_{pass_v} = \mathbf{53.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,k}) \times (\text{Surcharge}_G + \text{Surcharge}_Q) \times (h_{eff} - d_{key}) = \mathbf{1.7 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{mr} \times (h_{eff} - d_{key})^2 / 2 = \mathbf{9.1 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = \max(-K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-10.8 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{2.1 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{13.4 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{1.4 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{19.7 \text{ kNm/m}}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} - F_{pass_h} \times X_{pass_h} = \mathbf{-1.6 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{35 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{651 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-32 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{1365 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{44.8 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{33.9 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{2.23}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

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

Partial factor set

A1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.350}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.500}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_{\gamma} = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 17 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 20.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi}) = 30 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi}) = 15 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_{\gamma} = 18 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi}) = 18 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi}) = 9 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi}) = 12 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.309$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = 2.359$

Sliding check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 8.1 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 16.3 \text{ kN/m}$
Surcharge load	$F_{\text{sur}_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times l_{\text{heel}} = 1.5 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 25.8 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} = 51.7 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = 3.1 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 19.6 \text{ kN/m}$
Total	$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 22.6 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 15.1 \text{ kN/m}$
Base friction	$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 11 \text{ kN/m}$
Resistance to sliding	$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 26.1 \text{ kN/m}$
Factor of safety	$F_{\text{oSsl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.155$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 8.1 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 16.3 \text{ kN/m}$

Surcharge load

$$F_{sur_v} = (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times l_{heel} = \mathbf{1.5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma'_{mr} = \mathbf{25.8 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{51.7 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times (h_{eff} - d_{key}) = \mathbf{2.4 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma'_{mr} \times (h_{eff} - d_{key})^2 / 2 = \mathbf{12.2 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma'_b \times (h_{pass} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = \mathbf{-14.7 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{0 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h_a} = \mathbf{2.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h_a} = \mathbf{7.7 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} \times X_{exc_h} = \mathbf{3.2 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{13.2 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{2.1 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{13.4 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{22.4 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{37.8 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{2.874}$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

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

Partial factor set

A2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.000}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.300}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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

Soil parameter set

M2

Angle of shearing resistance

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

Effective cohesion

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

Weight density

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

Retained soil properties

Design moist density

$$\gamma'_{mr} = \gamma_{mr} / \gamma_{\gamma} = \mathbf{17 \text{ kN/m}^3}$$

Design saturated density

$$\gamma'_{sr} = \gamma_{sr} / \gamma_{\gamma} = \mathbf{20.5 \text{ kN/m}^3}$$

Design effective shear resistance angle

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

Design wall friction angle

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

Base soil properties

Design soil density

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

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{14.6 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi}) = \mathbf{7.2 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi}) = \mathbf{9.7 \text{ deg}}$$

Design effective cohesion

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

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]) = \mathbf{0.382}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]) = \mathbf{1.965}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.1 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{16.3 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = (\gamma_{\text{Gf}} \times \text{Surcharge}_G + \gamma_{\text{Qf}} \times \text{Surcharge}_Q) \times l_{\text{heel}} = \mathbf{1.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}} = \mathbf{25.8 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} = \mathbf{51.7 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = \mathbf{3.1 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = \mathbf{18.1 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = \mathbf{21.2 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{12.7 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{8.8 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{21.5 \text{ kN/m}}$$

Factor of safety

$$F_{\text{OSl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.012}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.1 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{16.3 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = (\gamma_{\text{Gf}} \times \text{Surcharge}_G + \gamma_{\text{Qf}} \times \text{Surcharge}_Q) \times l_{\text{heel}} = \mathbf{1.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}} = \mathbf{25.8 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} = \mathbf{51.7 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times (h_{\text{eff}} - d_{\text{key}}) = \mathbf{2.4 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}} \times (h_{\text{eff}} - d_{\text{key}})^2 / 2 = \mathbf{11.3 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = \max(-\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2, -(F_{\text{moist}_h} + F_{\text{sur}_h})) = \mathbf{-12.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{1.1 \text{ kN/m}}$$

Overtuning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times X_{\text{sur}_h_a} = \mathbf{2.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times X_{\text{moist}_h_a} = \mathbf{7.1 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} \times X_{exc_h} = \mathbf{2.7 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{12.2 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{2.1 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{13.4 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{22.4 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{37.8 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{3.105}$$

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.21

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

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0 \text{ N/mm}^2}$$

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 k_1

$$K_1 = \mathbf{0.40}$$

Bending coefficient k_2

$$K_2 = 1.00 \times (0.6 + 0.0014 / \epsilon_{cu2}) = \mathbf{1.00}$$

Bending coefficient k_3

$$K_3 = \mathbf{0.40}$$

Bending coefficient k_4

$$K_4 = 1.00 \times (0.6 + 0.0014 / \epsilon_{cu2}) = \mathbf{1.00}$$

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

Top face of base

$$C_{bt} = \mathbf{50 \text{ mm}}$$

Bottom face of base

$$C_{bb} = \mathbf{75 \text{ mm}}$$

$$z = d \times \min(1 - 0.5 \times A_{sr,prov} \times f_{yd} / (d \times f_d), 0.95) = \mathbf{103 \text{ mm}}$$

Moment of resistance - exp.6.22 and exp.6.24a

$$M_{Rd} = \min(A_{sr,prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2) = \mathbf{25.3 \text{ kNm/m}}$$

$$M / M_{Rd} = \mathbf{0.209}$$

PASS - Moment of resistance exceeds applied design moment
Reinforced masonry members subjected to shear loading - Section 6.7

Design shear force

$$V = \mathbf{9.634 \text{ kN/m}}$$

Design shear resistance - exp.6.40

$$V_{Rd} = \min(f_{vd}, f_{cvd,infill}) \times d = \mathbf{11.55 \text{ kN/m}}$$

$$V / V_{Rd} = \mathbf{0.834}$$

PASS - Design shear resistance exceeds applied design shear force
Horizontal reinforcement parallel to face of stem

Minimum area of reinforcement - cl.8.2.3(4)

$$A_{sx,req} = 0.0005 \times d = \mathbf{70 \text{ mm}^2/\text{m}}$$

Transverse reinforcement provided

$$12 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{sx,prov} = \pi \times \phi_{sx}^2 / (4 \times S_{sx}) = \mathbf{565 \text{ mm}^2/\text{m}}$$

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

$$M = \mathbf{0.8 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - C_{bb} - \phi_{bb} / 2 = \mathbf{269 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.000}$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{256 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{34 \text{ mm}}$$

Area of tension reinforcement required

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

Tension reinforcement provided

$$12 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times S_{bb}) = \mathbf{565 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{405 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bb,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = \mathbf{0.716}$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{0.6 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bb,prov} \times z) = \mathbf{4.2 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

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

$$A_{c,eff} = \mathbf{105458 \text{ mm}^2/\text{m}}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = \mathbf{0.005}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 635 \text{ mm}$$

Maximum crack width - exp.7.8

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

$$w_k = 0.008 \text{ mm}$$

$$w_k / w_{max} = 0.027$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 7 \text{ kN/m}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.862$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = 0.002$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.487 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = 131.1 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.053$$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

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

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 5.2 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = 294 \text{ mm}$$

$$K = M / (d^2 \times f_{ck}) = 0.002$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = 0.207$$

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

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 279 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = 37 \text{ mm}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = 43 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$12 \text{ dia. bars @ 200 c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = 565 \text{ mm}^2/\text{m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 443 \text{ mm}^2/\text{m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = 14000 \text{ mm}^2/\text{m}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = 0.783$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sls} = 3.6 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = 22.7 \text{ N/mm}^2$$

Load duration

$$\text{Long term}$$

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

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

$$A_{c,eff} = 104417 \text{ mm}^2/\text{m}$$

**Tekla® Tedds**

Grade Consulting Ltd.

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Llanelli SA14 9RT

Project

38 - 40 Pentwyn, Baglan - 1.3m Wall W4

Job no.

GC-642

Calcs for

Atrium Planning Ltd.

Start page no./Revision

12 1

Calcs by

IG

Calcs date

27/04/2024

Checked by

IG

Checked date

27/04/2024

Approved by

IG

Approved date

27/04/2024

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = \mathbf{0.005}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p,eff} = \mathbf{547 \text{ mm}}$$

Maximum crack width - exp.7.8

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

$$w_k = \mathbf{0.037 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.124}$$

*PASS - Maximum crack width is less than limiting crack width***Rectangular section in shear - Section 6.2**

Design shear force

$$V = \mathbf{2.3 \text{ kN/m}}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.825}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = \mathbf{0.002}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.473 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

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

$$V_{Rd,c} = \mathbf{138.9 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.016}$$

*PASS - Design shear resistance exceeds design shear force***Check key design**

Depth of section

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

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = \mathbf{1.4 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - C_{bb} - \phi_k / 2 = \mathbf{269 \text{ mm}}$$

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

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = \mathbf{256 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{34 \text{ mm}}$$

Area of tension reinforcement required

$$A_{k,req} = M / (f_{yd} \times z) = \mathbf{13 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

$$\mathbf{12 \text{ dia.bars @ } 200 \text{ c/c}}$$

Area of tension reinforcement provided

$$A_{k,prov} = \pi \times \phi_k^2 / (4 \times S_k) = \mathbf{565 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{k,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{405 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{k,max} = 0.04 \times h = \mathbf{14000 \text{ mm}^2/\text{m}}$$

$$\max(A_{k,req}, A_{k,min}) / A_{k,prov} = \mathbf{0.716}$$

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

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

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{1 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{k,prov} \times z) = \mathbf{7.2 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

 $k_t = 0.4$

Effective area of concrete in tension

 $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
 $A_{c,eff} = 105458 \text{ mm}^2/\text{m}$

Mean value of concrete tensile strength

 $f_{ct,eff} = f_{ctm} = 2.9 \text{ N/mm}^2$

Reinforcement ratio

 $\rho_{p,eff} = A_{k,prov} / A_{c,eff} = 0.005$

Modular ratio

 $\alpha_e = E_s / E_{cm} = 6.091$

Bond property coefficient

 $k_1 = 0.8$

Strain distribution coefficient

 $k_2 = 0.5$
 $k_3 = 3.4$
 $k_4 = 0.425$

Maximum crack spacing - exp.7.11

 $s_{r,max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_k / \rho_{p,eff} = 635 \text{ mm}$

Maximum crack width - exp.7.8

 $w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = 0.014 \text{ mm}$
 $w_k / w_{max} = 0.046$
PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

 $V = 5.8 \text{ kN/m}$
 $C_{Rd,c} = 0.18 / \gamma_c = 0.120$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.862$

Longitudinal reinforcement ratio

 $\rho_l = \min(A_{k,prov} / d, 0.02) = 0.002$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.487 \text{ N/mm}^2$

Design shear resistance - exp.6.2a & 6.2b

 $V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
 $V_{Rd,c} = 131.1 \text{ kN/m}$
 $V / V_{Rd,c} = 0.044$
PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)

 $A_{bx,req} = 0.2 \times A_{bb,prov} = 113 \text{ mm}^2/\text{m}$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

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

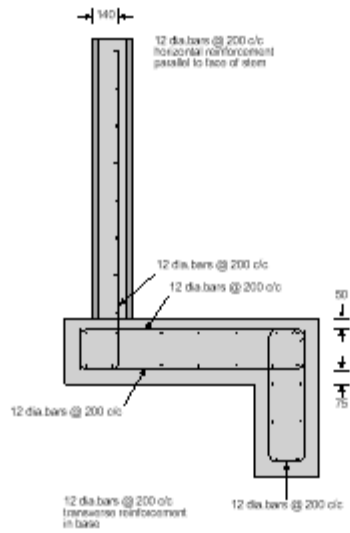
Transverse reinforcement provided

12 dia.bars @ 200 c/c

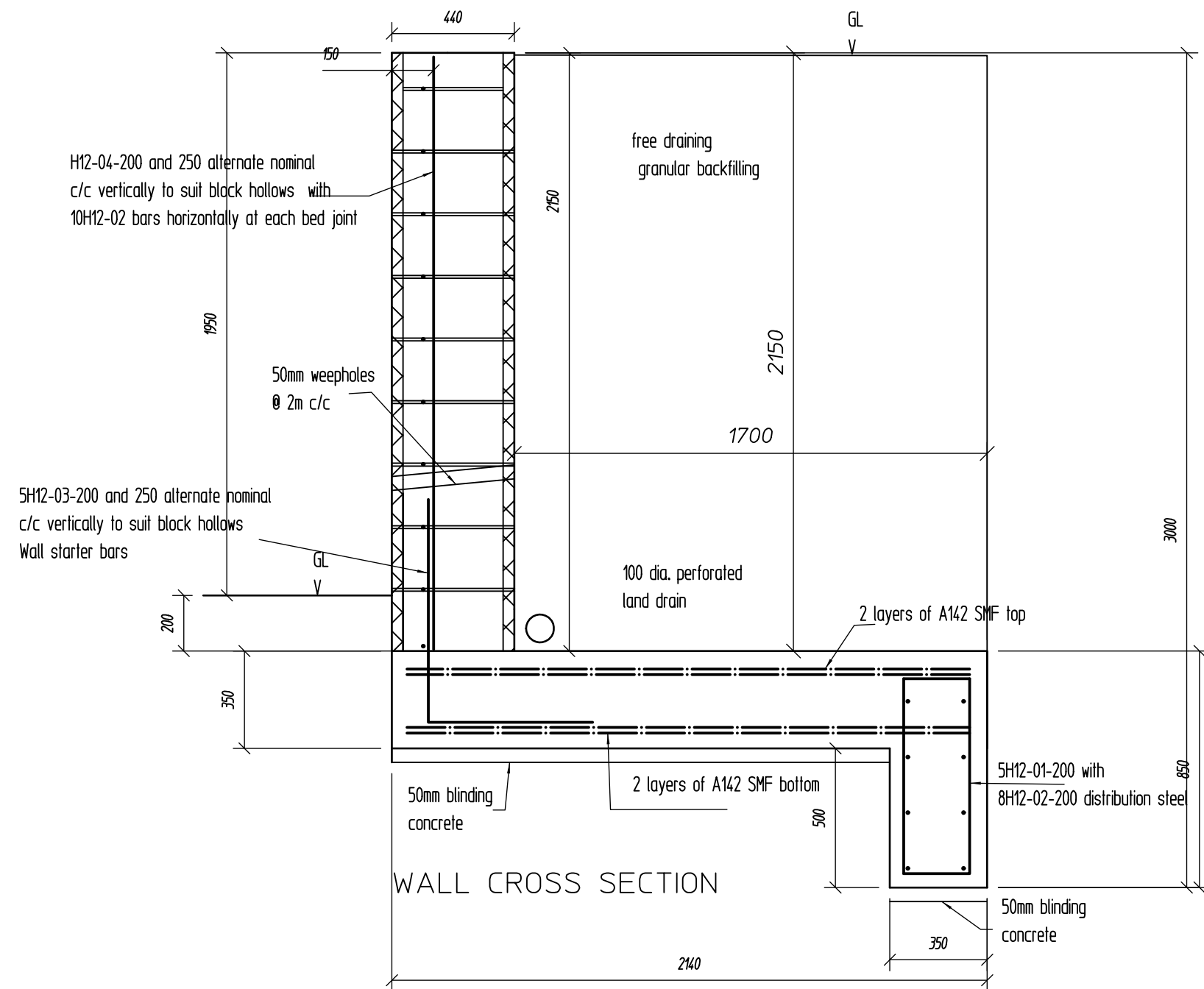
Area of transverse reinforcement provided

 $A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = 565 \text{ mm}^2/\text{m}$
PASS - Area of reinforcement provided is greater than area of reinforcement required

Project				Job no.	
38 - 40 Pentwyn, Baglan - 1.3m Wall W4				GC-642	
Calcs for				Start page no./Revision	
Atrium Planning Ltd.				14 1	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
IG	27/04/2024	IG	27/04/2024	IG	27/04/2024



Reinforcement details



- Notes
1. All dimensions shall be checked against site dimensions.
Any discrepancies to be reported to the Engineer.
 2. Concrete for foundation and cavity fill shall be designated mix RC35.
 3. Concrete base shall be founded on solid natural ground, any soft spots shall be backfilled in lean-mix concrete.
 4. Reinforced base shall sit on 50mm thick blinding concrete.
 5. Wall Shall be 600mm thick hollow blockwork with concrete cavity fill as noted and shall be constructed in increments of no more than 900mm high and allowed to fully set before hollows are filled with concrete, and laying of granular backfilling.
 6. 100mm perforated land drain at base level to the rear of the wall with 50mm weepholes at 2m centres along retaining wall.
 7. Blockwork shall have a compressible strength of 7N.
 8. See drawing GC-654/ ___ for layout details and Bar Bending Schedule GC-654/RX1(S) for bar bending details.
 9. Reinforcement shall have a minimum concrete cover of 40mm for base and 100mm min wall stem. Minimum lap lengths for bars shall be 42d.
 10. Mesh reinforcement in base shall be supplied in 4.8m x 2.4m sheets and cut to size on site. Mesh to be laid so that top sheet overlap bottom sheet.

NOTE
REINFORCEMENT SCHEDULE SHOWS BARS REQUIRED FOR 1m LENGTH OF WALL ONLY. FINAL TOTALS AND LENGTHS SHALL BE CONFIRMED BEFORE THE REINFORCEMENT IS SUPPLIED

Rev A - 12/9/24 - Minor dimensional amendments

Project				Title				Drg No.		GRADE CONSULTING Ltd. Tel: 01554 707045 info@gradeconsulting.co.uk www.gradeconsulting.co.uk			
38-40 Pentwyn, Baglan				WALL OPTION 1 W1.2 SCHEDULE FOR 1m RUN ONLY				Drg No.					
								RX1(S)					
member	bar mark	type and size	no. of mbrs.	no. in each	total no.	length of each bar mm *	shape code	A mm**	B mm **	C mm**	D mm**	E/r mm**	
	01	H12			5	2200	51	250	750				
	02	H12			18	1000	00	1000					
	03	H12			5	1400	11	510					
	04	H12			5	2150	00	2150					
						1400	11	510					
	1 No. 4.8m x 2.4m SHEET OF A142 SMF REQUIRED PER 1m RUN												
All bending details are in accordance with BS 8666						* Specified to the nearest 25mm		** Specified to the nearest 25mm					

GRADE CONSULTING Ltd.

Tel: 01554 707045
info@gradeconsulting.co.uk
www.gradeconsulting.co.uk

Project

38-40 Pentwyn, Baglan

Title

PROPOSED RETAINING WALL
CROSS SECTION - WALL OPTION 1 W1.2

Drg No.

GC-642

Drawn

LD

date

04/24

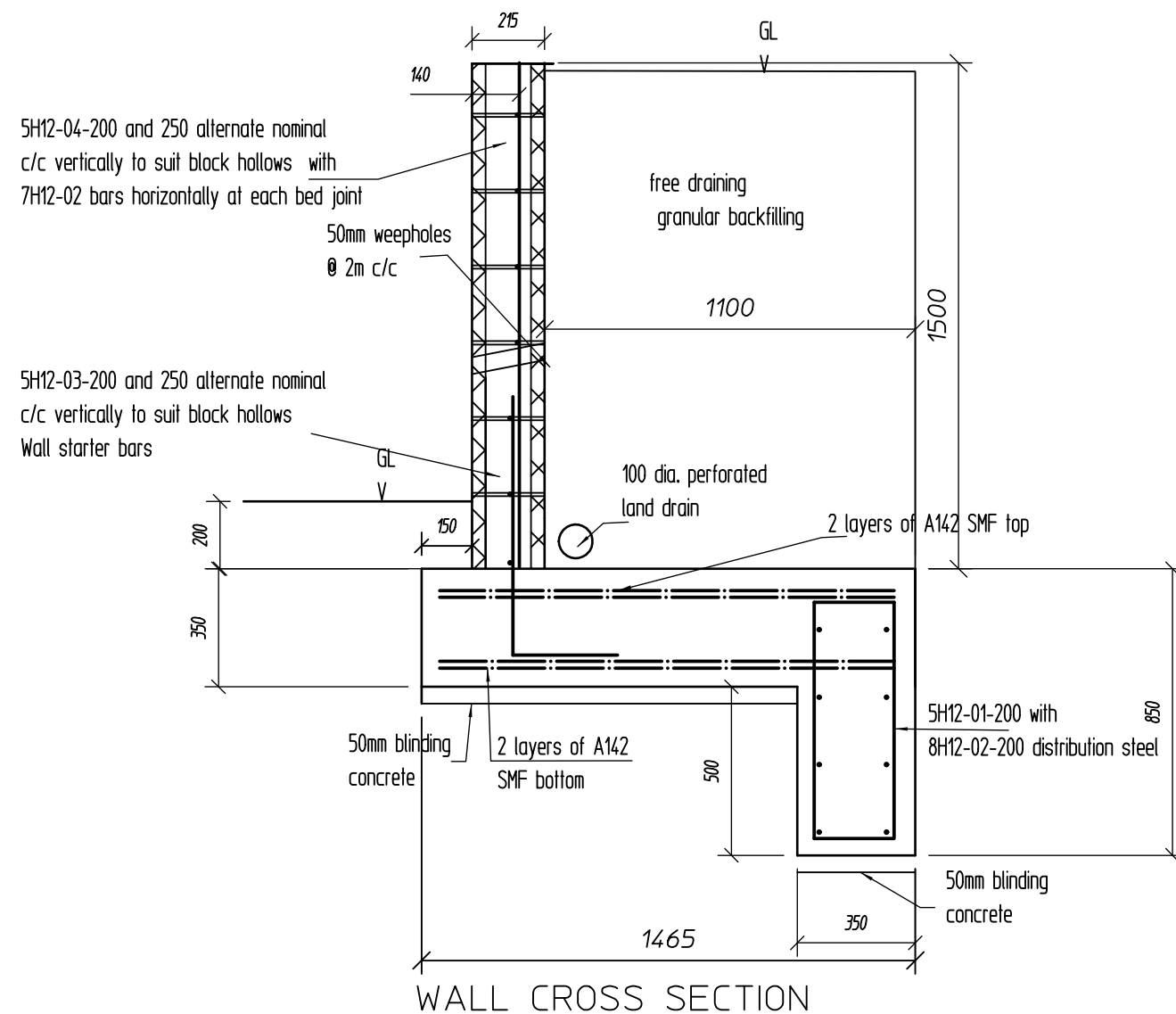
RX1.2A

Checked

LD

Scale

1/20



Notes

1. All dimensions shall be checked against site dimensions. Any discrepancies to be reported to the Engineer.
2. Concrete for foundation and cavity fill shall be designated mix RC35.
3. Concrete base shall be founded on solid natural ground, any soft spots shall be backfilled in lean-mix concrete.
4. Reinforced base shall sit on 50mm thick blinding concrete.
5. Wall Shall be 600mm thick hollow blockwork with concrete cavity fill as noted and shall be constructed in increments of no more than 900mm high and allowed to fully set before hollows are filled with concrete, and laying of granular backfilling.
6. 100mm perforated land drain at base level to the rear of the wall with 50mm weepholes at 2m centres along retaining wall.
7. Blockwork shall have a compressible strength of 7N.
8. See drawing GC-654/ ___ for layout details and Bar Bending Schedule GC-654/RX2(S) for bar bending details.
9. Reinforcement shall have a minimum concrete cover of 40mm for base and 100mm min wall stem. Minimum lap lengths for bars shall be 42d.
10. Mesh reinforcement in base shall be supplied in 4.8m x 2.4m sheets and cut to size on site. Mesh to be laid so that top sheet overlap bottom sheet.

NOTE

REINFORCEMENT SCHEDULE SHOWS BARS REQUIRED FOR 1m LENGTH OF WALL ONLY. FINAL TOTALS AND LENGTHS SHALL BE CONFIRMED BEFORE THE REINFORCEMENT IS SUPPLIED

Rev B- 21/11/24 - Heel now 1100mm from 800mm.

Rev A- 12/9/24 - Minor layout alterations. Title block amended

Project				Title				Drg No.		GRADE CONSULTING Ltd.			
38-40 Pentwyn, Baglan				WALLS 2 & 3 SCHEDULE FOR 1m RUN ONLY				GC-642		Tel: 01554 707045 info@gradeconsulting.co.uk www.gradeconsulting.co.uk			
								RX2(S)					
member	bar mark	type and size	no. of mbrs.	no. in each	total no.	length of each bar mm *	shape code	A mm**	B mm **	C mm**	D mm**	E/r mm**	
	01	H12			5	2200	51	250	750				
	02	H12			15	1000	00	1000					
	03	H12			5	1325	11	510					
	04	H12			5	1500	00	1500					
2 No. 4.8m x 2.4m SHEET OF A142 SMF REQUIRED PER 1m RUN													
All bending details are in accordance with BS 8666						* Specified to the nearest 25mm			** Specified to the nearest 25mm				

GRADE CONSULTING Ltd.

Tel: 01554 707045
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Project

38-40 Pentwyn, Baglan

Title

PROPOSED RETAINING WALL
CROSS SECTION - WALLS 2 & 3

Drg No.

GC-642
RX2B

Drawn

LD

Checked

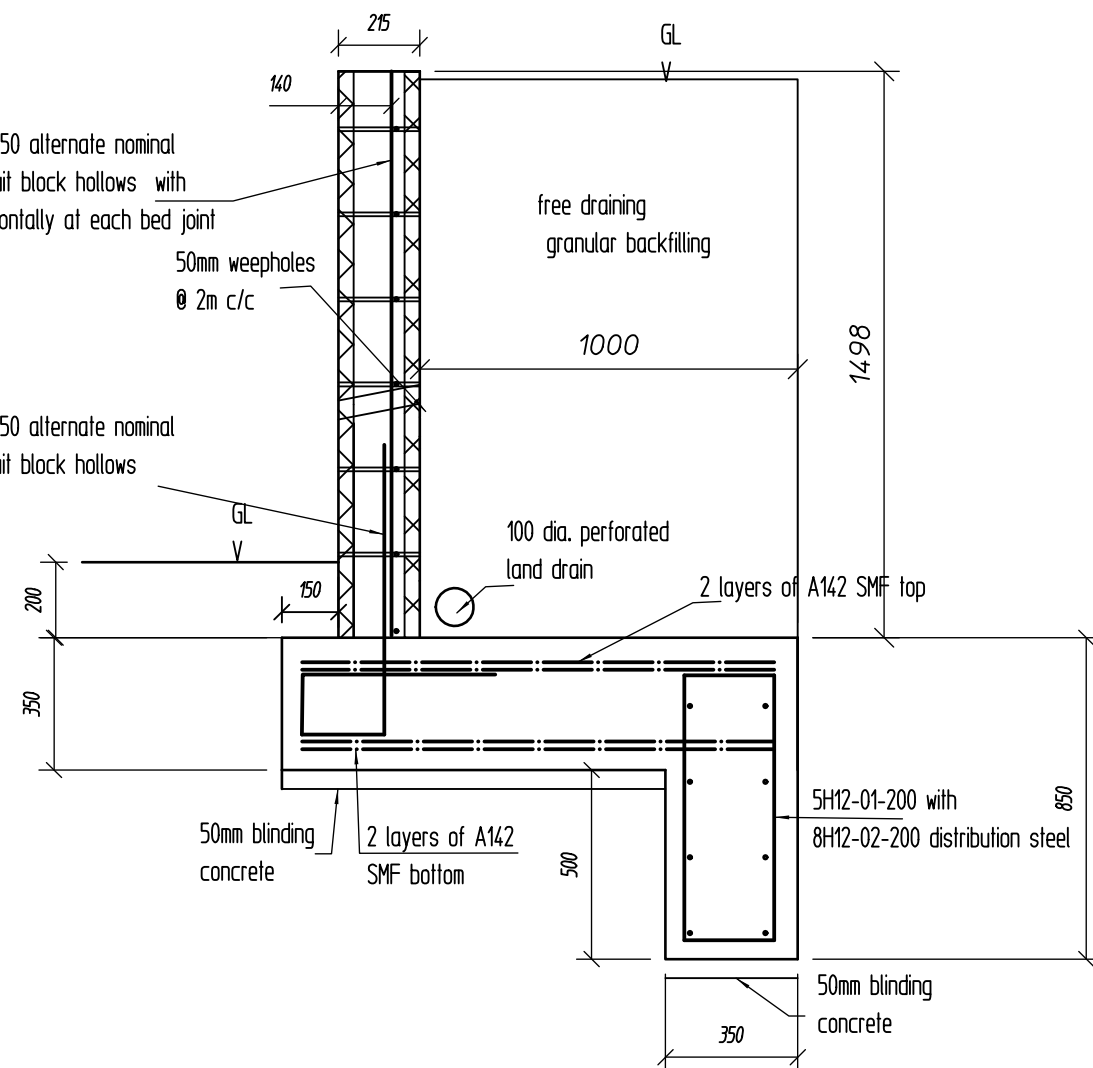
LD

date

04/24

Scale

1/20

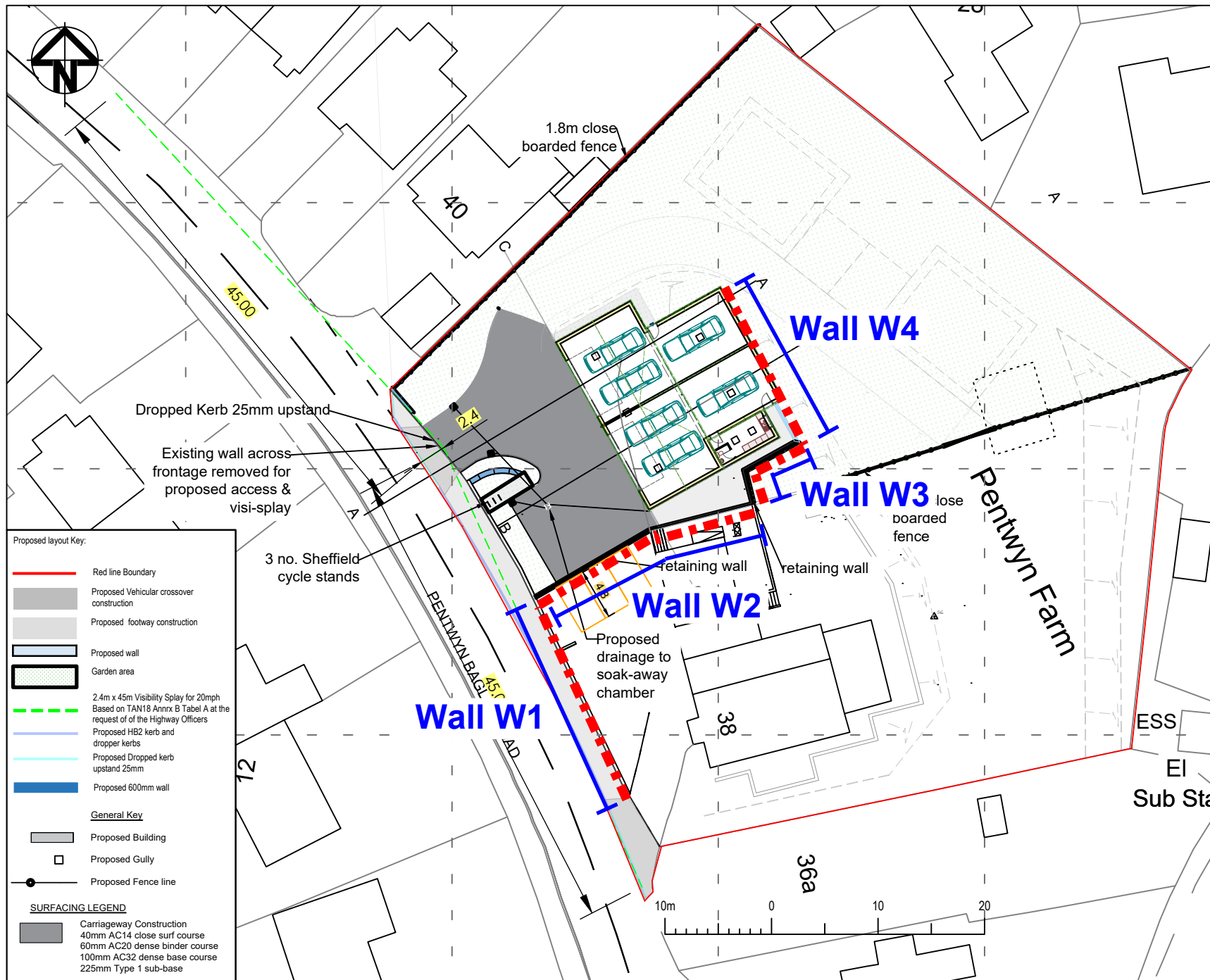


WALL CROSS SECTION

Project 38-40 Pentwyn, Baglan				Title WALL 4 SCHEDULE FOR 1m RUN ONLY			Drg No. GC-642 Drg No. RX3(S)		GRADE CONSULTING Ltd. Tel: 01554 707045 info@gradeconsulting.co.uk www.gradeconsulting.co.uk			
member	bar mark	type and size	no. of mbrs.	no. in each	total no.	length of each bar mm *	shape code	A mm**	B mm **	C mm**	D mm**	E/r mm**
	01	H12			5	2200	51	250	750			
	02	H12			15	1000	00	1000				
	03	H12			5	1850	31	510	250	240		
	04	H12			5	1500	00	1500				
	1 No. 4.8m x 2.4m SHEET OF A142 SMF REQUIRED PER 1m RUN											
All bending details are in accordance with BS 8666						* Specified to the nearest 25mm		** Specified to the nearest 25mm				

Rev A - 12/9/24 -minor dimensional amendments

GRADE CONSULTING Ltd. Tel: 01554 707045 info@gradeconsulting.co.uk www.gradeconsulting.co.uk		
<i>Project</i> 38-40 Pentwyn, Baglan		
<i>Title</i> PROPOSED RETAINING WALL CROSS SECTION - WALL 4		
<i>Dwg No.</i> GC-642 RX3A	<i>Drawn</i> LD	<i>date</i> 04/24
	<i>Checked</i> LD	<i>Scale</i> 1/20



General Notes

- ALL DIMENSIONS ARE INDICATIVE AND IN METRES UNLESS NOTED OTHERWISE.
- DO NOT SCALE THIS DRAWING, USE FIGURED DIMENSIONS ONLY.
- ALL LEVELS ARE IN METRES ABOVE ORDNANCE DATUM (AOD) BASED ON THE TOPOGRAPHICAL SURVEY DRAWING SUPPLIED BY THE CLIENT.
- ANY DISCREPANCIES TO BE REPORTED TO THE ENGINEER.
- THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS.
- THE SPECIFICATION IN ALL ASPECTS SHALL BE IN ACCORDANCE WITH THE CURRENT RESIDENTIAL DESIGN GUIDE AND SPECIFICATION IN FORCE WITHIN THE COUNTY AT THE TIME OF CONSTRUCTION.
- COPYRIGHT OF THIS DRAWING IS RETAINED BY THE ENGINEER AND IT MUST NOT BE REPRODUCED IN WHOLE OR PART WITHOUT WRITTEN CONSENT.

F	Amendments requested by LHA	20.12.2003
E	Amendments requested by LHA	15.12.2003
D	Red line amended	25.08.2003
C	For Planning	15.08.2003
B	Not Issued	10.08.2003
A	For Discussion	08.08.2003
No.	Revision/Issue	Date

Firm Name and Address	LvW Highways Ltd The Park Fennyngton, Lichfield Staffordshire B53 7PP Tel: 07769 226295
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Project Name and Address	Land between 38 & 40 Pentwyn Baglan Road, Baglan, NPTCBC. Site Layout General Arrangement
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Project	2023-798	Sheet	SK02
Date	20.12.2003		
Scale	1:500@A4L		