SY Homes

# Garth Owen, Newtown

## Structural Calculations for Building Regulations Submission

BR 74003-001

Issue 1

October 2023

CIVIL + STRUCTURAL ENGINEERS

## Document History

| Job Number: 74003 | | Document Reference: 74003-001 | | |
|---|---|---|---|---|
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| 1 | Building Regs | LM | JP | 20.10.2023 |
| Revision | Purpose Description | Originated | Authorised | Date |

# Contents

# 1 Introduction

## 1.1 Location

Garth Owen

Newtown

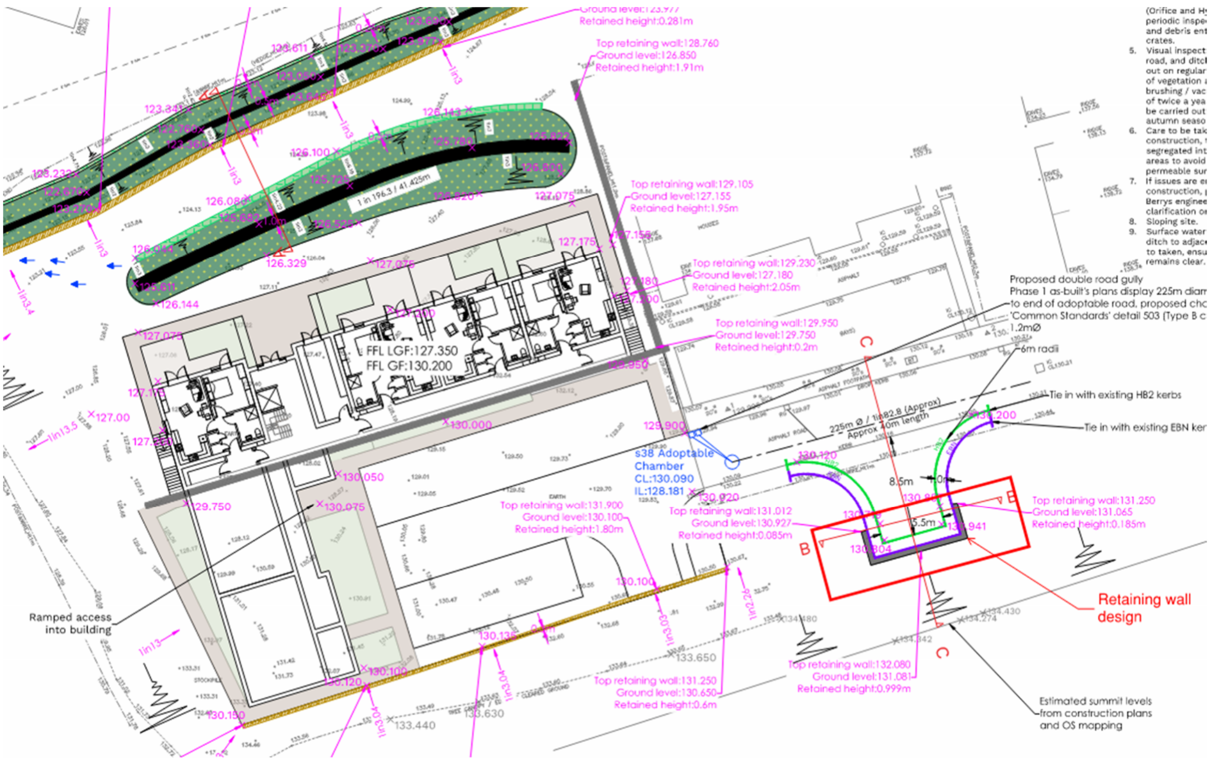
Powys

SY16 1AZ

## 1.2 The Proposed Works

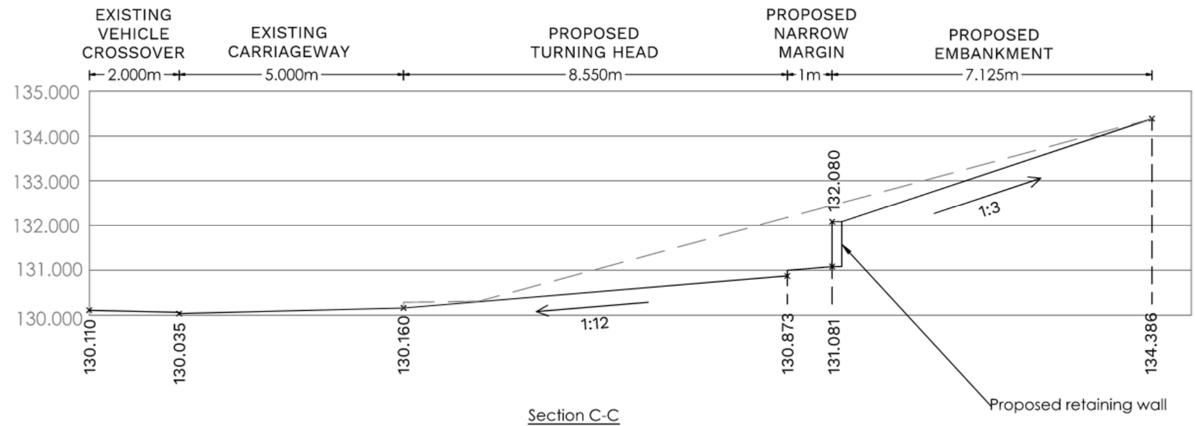
The proposed works comprise the construction of a retaining wall to enable the construction of a turning head in the highway as part of the new housing development.

## 1.3 Proposed Arrangement




Proposed Site Layout

| Calculation Sheet | | |
|---|---|---|
| Job Title<br>Garth Owen, Newtown | Job Number<br>74003 | Sheet Number<br>2 |




Section C-C

<u>Section Through Retaining Wall</u>

# 2 Design Standards & Sources of Reference

## 2.1 Statutory Regulations/Bye-Laws

The current edition of the Building Regulations Part A

## 2.2 Codes of Practice and Standards

- *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings EN1992-1-1:2004*
- *Eurocode 6: Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures EN1996-1-1:2005 + A1:2012*
- *Eurocode 7: Geotechnical design - Part 1: General rules EN1997-1:*
- *UK National Annex* *NA to BS EN 1992-1-1:2004 incorporating National Amendment No.1*
  *NA to BS EN 1996-1-1:2005 + A1:2012*
  *NA to BS EN 1997-1:2004 incorporating Corrigendum No.1*

# 3 Structural Calculations

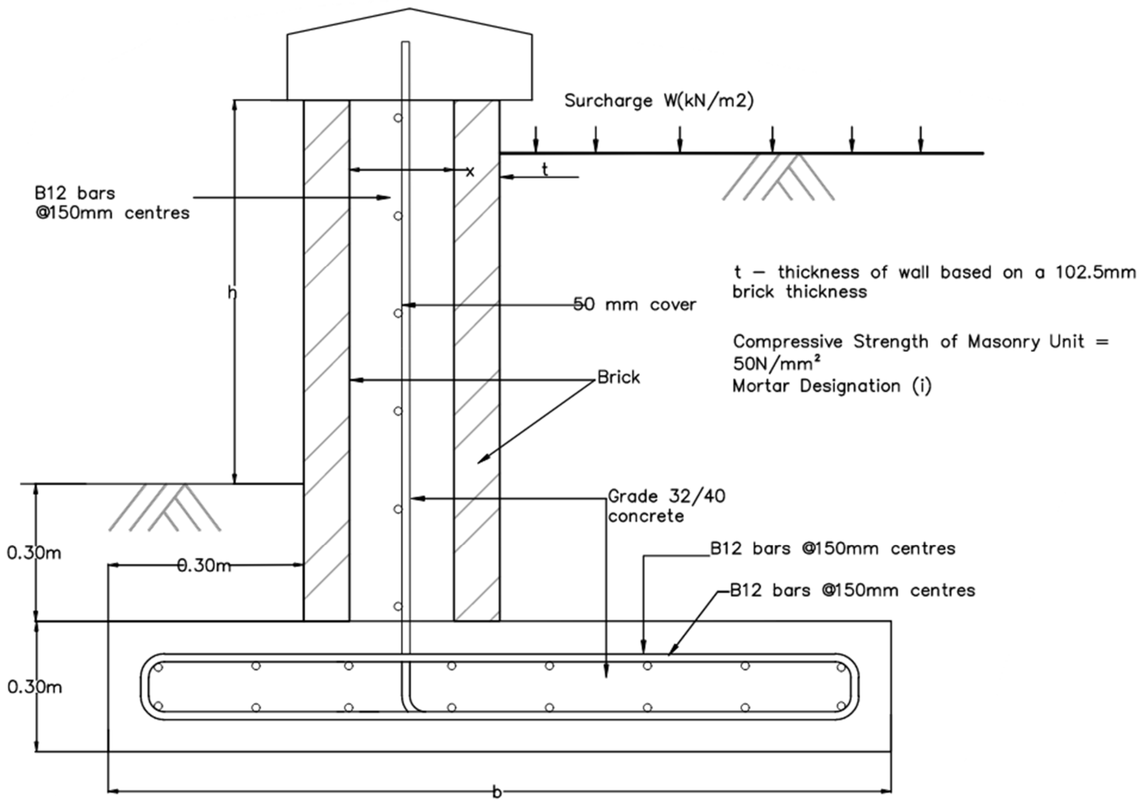
Calculations required for:

- Loading assessment;
- Retaining wall

**Loading:**

- 5.0 kN/m² surcharge to back of retaining wall

- Adopt Reinforced Grouted Masonry Wall Detail from 'Common Standards for Wales Highway Design Guide:



# Retaining Wall Design

Height Retained = 1000mm

## 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; | $h_{stem}$ = **1500** mm |
| Stem thickness; | $t_{stem}$ = **320** mm |
| Angle to rear face of stem; | $\alpha$ = **90** deg |
| Stem density; | $\gamma_{stem}$ = **25** kN/m$^3$ |
| Toe length; | $l_{toe}$ = **300** mm |
| Heel length; | $l_{heel}$ = **680** mm |
| Base thickness; | $t_{base}$ = **300** mm |
| Base density; | $\gamma_{base}$ = **25** kN/m$^3$ |
| Height of retained soil; | $h_{ret}$ = **1000** mm |
| Angle of soil surface; | $\beta$ = **18.5** deg |
| Depth of cover; | $d_{cover}$ = **300** mm |

### Retained soil properties

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

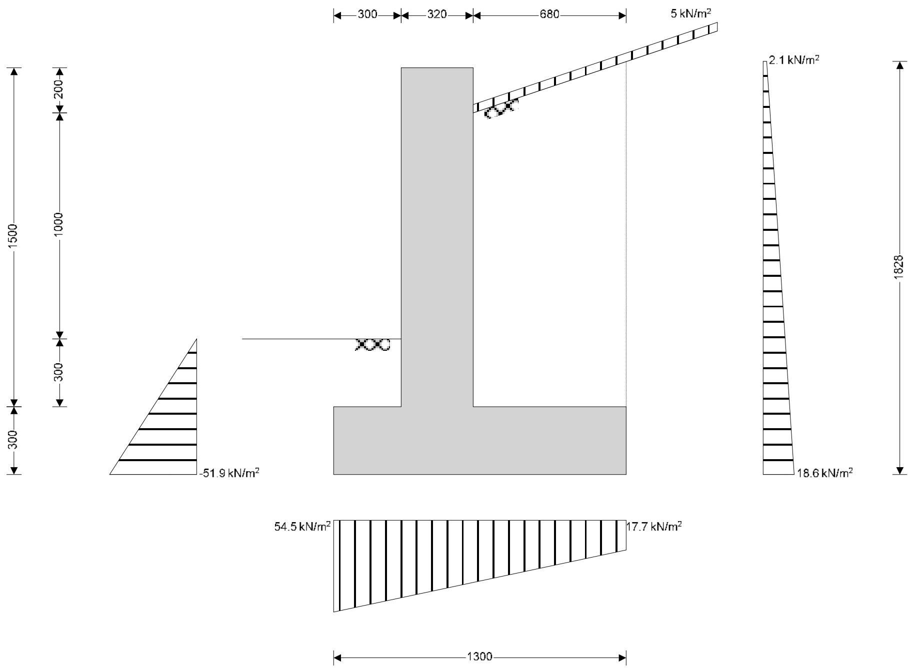
### Base soil properties

| | |
|---|---|
| Soil type; | Medium dense well graded sand |
| Soil density; | $\gamma_b$ = **18** kN/m$^3$ |
| Characteristic effective shear resistance angle; | $\phi'_{b.k}$ = **30** deg |
| Characteristic wall friction angle; | $\delta_{b.k}$ = **15** deg |
| Characteristic base friction angle; | $\delta_{bb.k}$ = **30** deg |
| Presumed bearing capacity; | $P_{bearing}$ = **100** kN/m$^2$ |

### Loading details

| | |
|---|---|
| Variable surcharge load; | $Surcharge_Q$ = **5** kN/m$^2$ |

| Calculation Sheet | | JPS CIVIL + STRUCTURAL ENGINEERS |
|---|---|---|
| Job Title<br>Garth Owen, Newtown | Job Number<br>74003 | Sheet Number<br>6 |




**General arrangement - sketch pressures relate to bearing check**

**Calculate retaining wall geometry**

| | |
|---|---|
| Base length; | $l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **1300** mm |
| Moist soil height; | $h_{moist} = h_{soil}$ = **1300** mm |
| Length of surcharge load; | $l_{sur} = l_{heel}$ = **680** mm |
| - Distance to vertical component; | $x_{sur\_v} = l_{base} - l_{heel} / 2$ = **960** mm |
| Effective height of wall; | $h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta)$ = **1828** mm |
| - Distance to horizontal component; | $x_{sur\_h} = h_{eff} / 2$ = **914** mm |
| Area of wall stem; | $A_{stem} = h_{stem} \times t_{stem}$ = **0.48** $m^2$ |
| - Distance to vertical component; | $x_{stem} = l_{toe} + t_{stem} / 2$ = **460** mm |
| Area of wall base; | $A_{base} = l_{base} \times t_{base}$ = **0.39** $m^2$ |
| - Distance to vertical component; | $x_{base} = l_{base} / 2$ = **650** mm |
| Area of moist soil; | $A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2$ = **0.961** $m^2$ |
| - Distance to vertical component; | $x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist}$ = **969** mm |
| - Distance to horizontal component; | $x_{moist\_h} = h_{eff} / 3$ = **609** mm |
| Area of base soil; | $A_{pass} = d_{cover} \times l_{toe}$ = **0.09** $m^2$ |
| - Distance to vertical component; | $x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass}$ = **150** mm |
| - Distance to horizontal component; | $x_{pass\_h} = (d_{cover} + h_{base}) / 3$ = **200** mm |
| Area of excavated base soil; | $A_{exc} = h_{pass} \times l_{toe}$ = **0.09** $m^2$ |

- Distance to vertical component; $x_{exc\_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc}$ = **150** mm

- Distance to horizontal component; $x_{exc\_h} = (h_{pass} + h_{base}) / 3$ = **200** mm

**Using Coulomb theory**

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2)$ = **0.428**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2)$ = **4.977**

**Bearing pressure check**

**Vertical forces on wall**

Wall stem; $F_{stem} = A_{stem} \times \gamma_{stem}$ = **12** kN/m

Wall base; $F_{base} = A_{base} \times \gamma_{base}$ = **9.8** kN/m

Surcharge load; $F_{sur\_v} = Surcharge_Q \times l_{heel}$ = **3.4** kN/m

Moist retained soil; $F_{moist\_v} = A_{moist} \times \gamma_{mr}$ = **20.2** kN/m

Base soil; $F_{pass\_v} = A_{pass} \times \gamma_b$ = **1.6** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{moist\_v} + F_{pass\_v}$ = **47** kN/m

**Horizontal forces on wall**

Surcharge load; $F_{sur\_h} = K_A \times Surcharge_Q \times h_{eff}$ = **3.9** kN/m

Moist retained soil; $F_{moist\_h} = K_A \times \gamma_{mr} \times h_{eff}^2 / 2$ = **15** kN/m

Base soil; $F_{pass\_h} = -K_P \times \cos(\delta_{b.k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2$ = **-15.6** kN/m

Total; $F_{total\_h} = \max(F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{total\_v} \times \tan(\delta_{bb.k}), 0 \text{ kN/m})$ = **0** kN/m

**Moments on wall**

Wall stem; $M_{stem} = F_{stem} \times x_{stem}$ = **5.5** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base}$ = **6.3** kNm/m

Surcharge load; $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h}$ = **-0.3** kNm/m

Moist retained soil; $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h}$ = **10.4** kNm/m

Base soil; $M_{pass} = F_{pass\_v} \times x_{pass\_v} - F_{pass\_h} \times x_{pass\_h}$ = **3.4** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass}$ = **25.3** kNm/m

**Check bearing pressure**

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v}$ = **540** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2$ = **-110** mm

Loaded length of base; $l_{load} = l_{base}$ = **1300** mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base})$ = **54.5** kN/m²

Bearing pressure at heel; $q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base})$ = **17.7** kN/m²

Factor of safety; $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **1.834**

***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; | $\gamma_G$ = **1.350** |
| Permanent favourable action; | $\gamma_{Gf}$ = **1.000** |
| Variable unfavourable action; | $\gamma_Q$ = **1.500** |
| Variable favourable action; | $\gamma_{Qf}$ = **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; | $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **21** kN/m$^3$ |
| Design saturated density; | $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **23** kN/m$^3$ |
| Design effective shear resistance angle; | $\phi'_{r.d} = atan(tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **30** deg |
| Design wall friction angle; | $\delta_{r.d} = atan(tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg |

**Base soil properties**

| | |
|---|---|
| Design soil density; | $\gamma_b' = \gamma_b / \gamma_\gamma$ = **18** kN/m$^3$ |
| Design effective shear resistance angle; | $\phi'_{b.d} = atan(tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **30** deg |
| Design wall friction angle; | $\delta_{b.d} = atan(tan(\delta_{b.k}) / \gamma_{\phi'})$ = **15** deg |
| Design base friction angle; | $\delta_{bb.d} = atan(tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30** deg |
| Design effective cohesion; | $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m$^2$ |

**Using Coulomb theory**

| | |
|---|---|
| Active pressure coefficient; | $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.428** |
| Passive pressure coefficient; | $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **4.977** |

**Sliding check**

**Vertical forces on wall**

| | |
|---|---|
| Wall stem; | $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12** kN/m |
| Wall base; | $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **9.8** kN/m |
| Moist retained soil; | $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **20.2** kN/m |
| Base soil; | $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **1.6** kN/m |
| Total; | $F_{total\_v} = F_{stem} + F_{base} + F_{moist\_v} + F_{exc\_v}$ = **43.6** kN/m |

**Horizontal forces on wall**

| | |
|---|---|
| Surcharge load; | $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **5.9** kN/m |
| Moist retained soil; | $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **20.2** kN/m |
| Total; | $F_{total\_h} = F_{sur\_h} + F_{moist\_h}$ = **26.1** kN/m |

**Check stability against sliding**

Base soil resistance; $F_{exc\_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$

= **15.6** kN/m

Base friction; $F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **25.1** kN/m

Resistance to sliding; $F_{rest} = F_{exc\_h} + F_{friction}$ = **40.7** kN/m

Factor of safety; $FoS_{sl} = F_{rest} / F_{total\_h}$ = **1.56**

***PASS - Resistance to sliding is greater than sliding force***

**Overturning check**

**Vertical forces on wall**

Wall stem; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12** kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **9.8** kN/m

Moist retained soil; $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **20.2** kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **1.6** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{moist\_v} + F_{exc\_v}$ = **43.6** kN/m

**Horizontal forces on wall**

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **5.9** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **20.2** kN/m

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

= **-15.6** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h}$ = **10.5** kN/m

**Overturning moments on wall**

Surcharge load; $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **5.4** kNm/m

Moist retained soil; $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **12.3** kNm/m

Total; $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT}$ = **17.7** kNm/m

**Restoring moments on wall**

Wall stem; $M_{stem\_R} = F_{stem} \times x_{stem}$ = **5.5** kNm/m

Wall base; $M_{base\_R} = F_{base} \times x_{base}$ = **6.3** kNm/m

Moist retained soil; $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **19.6** kNm/m

Base soil; $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v} - F_{exc\_h} \times x_{exc\_h}$ = **3.4** kNm/m

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{moist\_R} + M_{exc\_R}$ = **34.8** kNm/m

**Check stability against overturning**

Factor of safety; $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.966**

***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; $\gamma_G$ = **1.000**

Permanent favourable action; $\gamma_{Gf}$ = **1.000**

Variable unfavourable action; $\gamma_Q$ = **1.300**

Variable favourable action; $\gamma_{Qf}$ = **0.000**

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

| | |
|---|---|
| Soil parameter set; | M2 |
| Angle of shearing resistance; | $\gamma_{\phi'}$ = **1.25** |
| Effective cohesion; | $\gamma_{c'}$ = **1.25** |
| Weight density; | $\gamma_{\gamma}$ = **1.00** |

**Retained soil properties**

| | |
|---|---|
| Design moist density; | $\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma}$ = **21** kN/m$^3$ |
| Design saturated density; | $\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma}$ = **23** kN/m$^3$ |
| Design effective shear resistance angle; | $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **24.8** deg |
| Design wall friction angle; | $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg |

**Base soil properties**

| | |
|---|---|
| Design soil density; | $\gamma_b' = \gamma_b / \gamma_{\gamma}$ = **18** kN/m$^3$ |
| Design effective shear resistance angle; | $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **24.8** deg |
| Design wall friction angle; | $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **12.1** deg |
| Design base friction angle; | $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **24.8** deg |
| Design effective cohesion; | $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m$^2$ |

**Using Coulomb theory**

| | |
|---|---|
| Active pressure coefficient; | $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.554** |
| Passive pressure coefficient; | $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **3.473** |

**Sliding check**

**Vertical forces on wall**

| | |
|---|---|
| Wall stem; | $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12** kN/m |
| Wall base; | $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **9.8** kN/m |
| Moist retained soil; | $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **20.2** kN/m |
| Base soil; | $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **1.6** kN/m |
| Total; | $F_{total\_v} = F_{stem} + F_{base} + F_{moist\_v} + F_{exc\_v}$ = **43.6** kN/m |

**Horizontal forces on wall**

| | |
|---|---|
| Surcharge load; | $F_{sur\_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **6.6** kN/m |
| Moist retained soil; | $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **19.4** kN/m |
| Total; | $F_{total\_h} = F_{sur\_h} + F_{moist\_h}$ = **26** kN/m |

**Check stability against sliding**

| | |
|---|---|
| Base soil resistance; | $F_{exc\_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ |
| = **11** kN/m | |
| Base friction; | $F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **20.1** kN/m |
| Resistance to sliding; | $F_{rest} = F_{exc\_h} + F_{friction}$ = **31.1** kN/m |
| Factor of safety; | $FoS_{sl} = F_{rest} / F_{total\_h}$ = **1.197** |

***PASS - Resistance to sliding is greater than sliding force***

### Overturning check

**Vertical forces on wall**

Wall stem; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12** kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **9.8** kN/m

Moist retained soil; $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **20.2** kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_{b}'$ = **1.6** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{moist\_v} + F_{exc\_v}$ = **43.6** kN/m

**Horizontal forces on wall**

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **6.6** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **19.4** kN/m

Base soil; $F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **-11** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h}$ = **15** kN/m

**Overturning moments on wall**

Surcharge load; $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **6** kNm/m

Moist retained soil; $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **11.8** kNm/m

Total; $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT}$ = **17.8** kNm/m

**Restoring moments on wall**

Wall stem; $M_{stem\_R} = F_{stem} \times x_{stem}$ = **5.5** kNm/m

Wall base; $M_{base\_R} = F_{base} \times x_{base}$ = **6.3** kNm/m

Moist retained soil; $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **19.6** kNm/m

Base soil; $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v} - F_{exc\_h} \times x_{exc\_h}$ = **2.4** kNm/m

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{moist\_R} + M_{exc\_R}$ = **33.9** kNm/m

**Check stability against overturning**

Factor of safety; $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.899**

***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; C32/40

Characteristic compressive cylinder strength; $f_{ck}$ = **32** N/mm$^2$

Characteristic compressive cube strength; $f_{ck,cube}$ = **40** N/mm$^2$

Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8\ N/mm^2$ = **40** N/mm$^2$

Mean value of axial tensile strength; $f_{ctm} = 0.3\ N/mm^2 \times (f_{ck} / 1\ N/mm^2)^{2/3}$ = **3.0** N/mm$^2$

5% fractile of axial tensile strength; $f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.1** N/mm$^2$

Secant modulus of elasticity of concrete; $E_{cm} = 22\ kN/mm^2 \times (f_{cm} / 10\ N/mm^2)^{0.3}$ = **33346** N/mm$^2$

Partial factor for concrete - Table 2.1N; $\gamma_C$ = **1.50**

Compressive strength coefficient - cl.3.1.6(1); $\alpha_{cc}$ = **0.85**

Design compressive concrete strength - exp.3.15; $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **18.1** N/mm$^2$

Maximum aggregate size; $h_{agg}$ = **20** mm

Ultimate strain - Table 3.1; $\varepsilon_{cu2}$ = **0.0035**

Shortening strain - Table 3.1; $\varepsilon_{cu3}$ = **0.0035**

Effective compression zone height factor; $\lambda$ = **0.80**

Effective strength factor; $\eta$ = **1.00**

Bending coefficient $k_1$; $K_1$ = **0.40**

Bending coefficient $k_2$; $K_2$ = 1.00 ´ $(0.6 + 0.0014/\varepsilon_{cu2})$ = **1.00**

Bending coefficient $k_3$; $K_3$ =**0.40**

Bending coefficient $k_4$; $K_4$ = 1.00 ´ $(0.6 + 0.0014/\varepsilon_{cu2})$ =**1.00**

**Reinforcement details**

Characteristic yield strength of reinforcement; $f_{yk}$ = **500** N/mm$^2$

Modulus of elasticity of reinforcement; $E_s$ = **200000** N/mm$^2$

Partial factor for reinforcing steel - Table 2.1N; $\gamma_S$ = **1.15**

Design yield strength of reinforcement; $f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm$^2$

**Cover to reinforcement**

Top face of base; $c_{bt}$ = **50** mm

Bottom face of base; $c_{bb}$ = **75** mm

**Masonry details - Section 3.1**

Masonry type; Calcium silicate - Group 1

Normalised mean compressive strength; $f_b$ = **15** N/mm$^2$

Characteristic flexural strength - cl.6.3.4(1); $f_{xk}$ = **0** N/mm$^2$

Initial shear strength - Table NA.5; $f_{vko}$ = **0.15** N/mm$^2$

**Mortar details - Section 3.2**

Mortar type; General purpose - M6, prescribed mix

Compressive strength of mortar; $f_m$ = **6** 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; C32/40

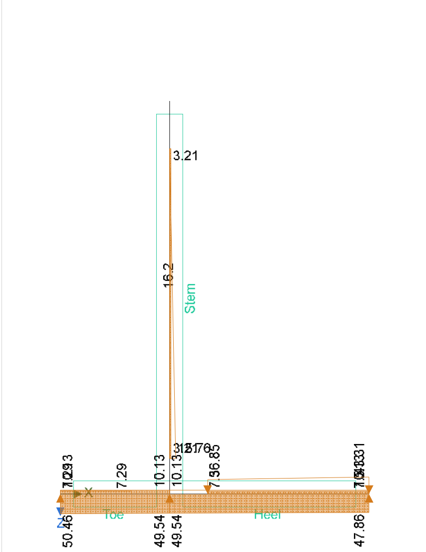
Characteristic compressive strength; $f_{ck,infill}$ = **25** N/mm$^2$

Characteristic shear strength; $f_{cvk,infill}$ = **0.45** N/mm$^2$

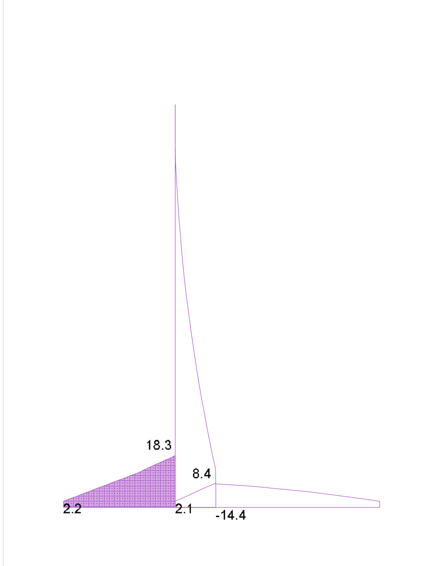
Design shear strength; $f_{cvd,infill} = f_{cvk,infill} / \gamma_{Mv}$ = **0.225** N/mm$^2$

| Calculation Sheet | | |
|---|---|---|
| Job Title<br>Garth Owen, Newtown | Job Number<br>74003 | Sheet Number<br>13 |

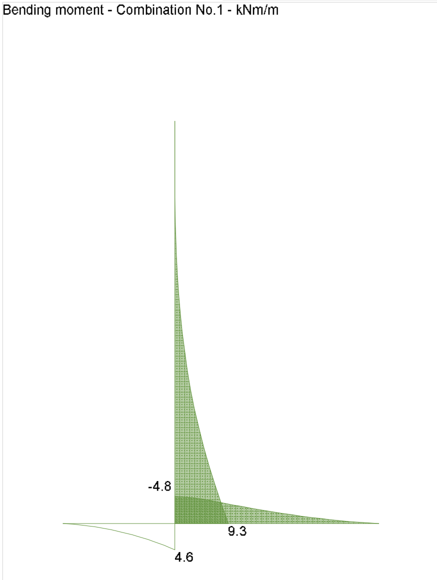
Loading details - Combination No.1 - kN/m$^2$




Shear force - Combination No.1 - kN/m

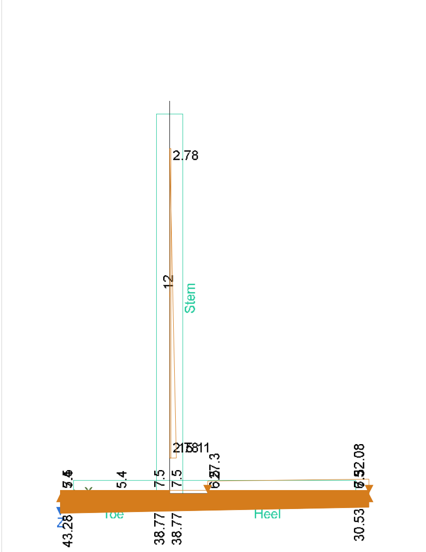



Bending moment - Combination No.1 - kNm/m

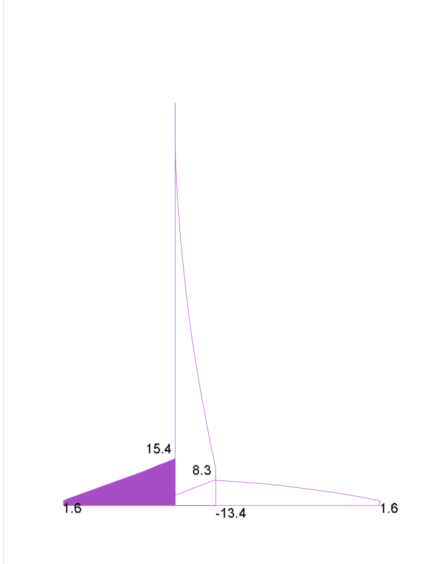


| Calculation Sheet | | |
|---|---|---|
| Job Title<br>Garth Owen, Newtown | Job Number<br>74003 | Sheet Number<br>14 |

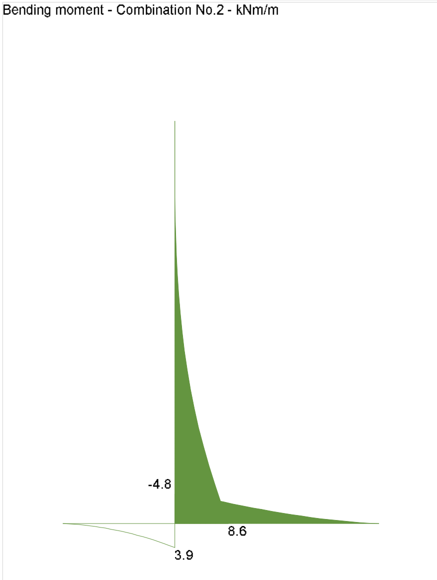
Loading details - Combination No.2 - kN/m$^2$




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 = **320** mm |

**Cavity wall details**

| | |
|---|---|
| Front leaf thickness; | $t_f$ = **100** mm |
| Rear leaf thickness; | $t_r$ = **100** mm |

**Masonry characteristics**

| | |
|---|---|
| Compressive strength constants - Table NA.4 | K = 0.500 |
| Characteristic compressive strength - cl.3.6.1.2(1) | $f_k = K \times f_b^{0.7} \times f_m^{0.3}$ = **5.697** N/mm$^2$ |
| Design compressive strength | $f_d = \min(f_k, f_{ck,infill}) / \gamma_{Mc}$ = **2.849** N/mm$^2$ |
| Design flexural strength | $f_{xd} = f_{xk} / \gamma_{Mt}$ = **0** N/mm$^2$ |
| Height of masonry | $h_{wt} = h_{stem}$ = **1500** mm |
| Compressive axial force combination 0 | $F_x = \gamma_{Gf} \times \gamma_{stem} \times h_{wt} \times t$ = **12** kN/m |

Moment combination 0 — $M_x = \gamma_{Gf} \times \gamma_{stem} \times h_{wt} \times t^2 / 2 =$ **1.9** kNm/m

Eccentricity of axial load — $e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) =$ **16** mm

Capacity reduction factor - exp.6.4 — $\Phi = 1 - 2 \times e / t =$ **0.9**

Design vertical resistance - exp.6.2 — $N_{Rd} = \Phi \times t \times f_d =$ **820.4** kN/m

Design vertical compressive stress — $\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) =$ **0.038** N/mm$^2$

Apparent design flexural strength - exp.6.16 — $f_{xd,app} = f_{xd} + \sigma_d =$ **0.038** N/mm$^2$

Limit of charact. shear strength - exp. 3.1; — $f_{vk,lim} = 0.065 \times f_b =$ **0.975** N/mm$^2$

Characteristic shear strength - exp.3.5 — $f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) =$ **0.165** N/mm$^2$

Design shear strength — $f_{vd} = f_{vk} / \gamma_{Mv} =$ **0.083** 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 = **7.2** kNm/m

Tension reinforcement provided; — 16 dia.bars @ 150 c/c

Area of tension reinforcement provided; — $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) =$ **1340** mm$^2$/m

Depth to tension reinforcement; — d = **158** mm

Minimum area of reinforcement - cl.8.2.3(1); — $A_{sr.min} = 0.0005 \times d =$ **79** mm$^2$/m

Lever arm - exp.6.23; — $z = d \times \min(1 - 0.5 \times A_{sr.prov} \times f_{yd} / (d \times f_d), 0.95) =$ **55** mm

Moment of resistance - exp.6.22 and exp.6.24a; — $M_{Rd} = \min(A_{sr.prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2) =$ **28.3** kNm/m

$M / M_{Rd} =$ **0.253**

***PASS - Moment of resistance exceeds applied design moment***

**Reinforced masonry members subjected to shear loading - Section 6.7**

Design shear force — V = **14.416** kN/m

Design shear resistance - exp.6.40; — $V_{Rd} = \min(f_{vd}, f_{cvd,infill}) \times d =$ **12.994** kN/m

$V / V_{Rd} =$ **1.109**

***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; — $d = d_{stem} - t_f =$ **57** mm

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

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

Longitudinal reinforcement ratio; — $\rho_l = \min(A_{sr.prov} / d, 0.02) =$ **0.020**

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

Design shear resistance - exp.6.2a & 6.2b; — $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck,infill})^{1/3}, v_{min}) \times d$

$V_{Rd.c} =$ **50.8** kN/m

$V / V_{Rd.c} =$ **0.284**

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

**Check stem design at 300 mm**

Depth of section; — t = **320** mm

**Cavity wall details**

Front leaf thickness; — $t_f =$ **100** mm

Rear leaf thickness; $t_r$ = **100** mm

**Masonry characteristics**

Compressive strength constants - Table NA.4 K = 0.500

Characteristic compressive strength - cl.3.6.1.2(1) $f_k = K ´ f_b^{0.7} ´ f_m^{0.3}$ = **5.697** N/mm$^2$

Design compressive strength $f_d = \min(f_k, f_{ck,infill}) / \gamma_{Mc}$ = **2.849** N/mm$^2$

Design flexural strength $f_{xd} = f_{xk} / \gamma_{Mt}$ = **0** N/mm$^2$

Height of masonry $h_{wt} = h_{stem}$ - 300 mm = **1200** mm

Compressive axial force combination 0 $F_x = \gamma_{Gf} ´ \gamma_{stem} ´ h_{wt} ´ t$ = **9.6** kN/m

Moment combination 0 $M_x = \gamma_{Gf} ´ \gamma_{stem} ´ h_{wt} ´ t^2 / 2$ = **1.5** kNm/m

Eccentricity of axial load e = max(abs(t / 2 - $M_x$ / $F_x$), 0.05 ´ t) = **16** mm

Capacity reduction factor - exp.6.4 $\Phi = 1 - 2 \times e / t$ = **0.9**

Design vertical resistance - exp.6.2 $N_{Rd} = \Phi \times t \times f_d$ = **820.4** kN/m

Design vertical compressive stress $\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t)$ = **0.03** N/mm$^2$

Apparent design flexural strength - exp.6.16 $f_{xd,app} = f_{xd} + \sigma_d$ = **0.03** N/mm$^2$

Limit of charact. shear strength - exp. 3.1; $f_{vk,lim} = 0.065 ´ f_b$ = **0.975** N/mm$^2$

Characteristic shear strength - exp.3.5 $f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim})$ = **0.162** N/mm$^2$

Design shear strength $f_{vd} = f_{vk} / \gamma_{Mv}$ = **0.081** 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 = **3.6** kNm/m

Tension reinforcement provided; 12 dia.bars @ 150 c/c

Area of tension reinforcement provided; $A_{sr1.prov} = \pi ´ \phi_{sr1}^2 / (4 ´ s_{sr1})$ = **754** mm$^2$/m

Depth to tension reinforcement; d = **158** mm

Minimum area of reinforcement - cl.8.2.3(1); $A_{sr.min} = 0.0005 \times d$ = **79** mm$^2$/m

Lever arm - exp.6.23; $z = d ´ \min(1 - 0.5 ´ A_{sr1.prov} ´ f_{yd} / (d ´ f_d), 0.95)$ = **100** mm

Moment of resistance - exp.6.22 and exp.6.24a; $M_{Rd} = \min(A_{sr1.prov} ´ f_{yd} ´ z, 0.4 ´ f_d ´ d^2)$ = **28.3** kNm/m

$M / M_{Rd}$ = **0.128**

***PASS - Moment of resistance exceeds applied design moment***

**Reinforced masonry members subjected to shear loading - Section 6.7**

Design shear force V = **9.27** kN/m

Design shear resistance - exp.6.40; $V_{Rd} = \min(f_{vd}, f_{cvd,infill}) ´ d$ = **12.758** kN/m

$V / V_{Rd}$ = **0.727**

***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); $A_{sx.req} = 0.0005 \times d$ = **79** mm$^2$/m

Transverse reinforcement provided; 12 dia.bars @ 150 c/c

Area of transverse reinforcement provided; $A_{sx.prov} = \pi ´ \phi_{sx}^2 / (4 ´ s_{sx})$ = **754** mm$^2$/m

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

**Check base design at toe**

Depth of section; h = **300** mm

**Rectangular section in flexure - Section 6.1**

Design bending moment combination 1; $M$ = **2.1** kNm/m

Depth to tension reinforcement; $d = h - c_{bb} - \phi_{bb} / 2$ = **219** 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; $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **208** mm

Depth of neutral axis; $x = 2.5 \times (d – z)$ = **27** mm

Area of tension reinforcement required; $A_{bb.req} = M / (f_{yd} \times z)$ = **24** mm²/m

Tension reinforcement provided; 12 dia.bars @ 150 c/c

Area of tension reinforcement provided; $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **754** mm²/m

Minimum area of reinforcement - exp.9.1N; $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **344** mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{bb.max} = 0.04 \times h$ = **12000** mm²/m

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.457**

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

Library item: Rectangular single output

**Rectangular section in shear - Section 6.2**

Design shear force; $V$ = **12** kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.956**

Longitudinal reinforcement ratio; $\rho_l = \min(A_{bb.prov} / d, 0.02)$ = **0.003**

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.541** N/mm²

Design shear resistance - exp.6.2a & 6.2b; $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c}$ = **118.6** kN/m

$V / V_{Rd.c}$ = **0.101**

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

**Check base design at heel**

Depth of section; $h$ = **300** mm

**Rectangular section in flexure - Section 6.1**

Design bending moment combination 1; $M$ = **3.9** kNm/m

Depth to tension reinforcement; $d = h - c_{bt} - \phi_{bt} / 2$ = **244** 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; $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **232** mm

| | |
|---|---|
| Depth of neutral axis; | $x = 2.5 \times (d - z) =$ **31** mm |
| Area of tension reinforcement required; | $A_{bt.req} = M / (f_{yd} \times z) =$ **39** $mm^2/m$ |
| Tension reinforcement provided; | 12 dia.bars @ 150 c/c |
| Area of tension reinforcement provided; | $A_{bt.prov} = \pi$ ´ $\phi_{bt}^2$ / (4 ´ $s_{bt}$) = **754** $mm^2/m$ |
| Minimum area of reinforcement - exp.9.1N; | $A_{bt.min}$ = max(0.26 ´ $f_{ctm}$ / $f_{yk}$, 0.0013) ´ d = **384** $mm^2/m$ |
| Maximum area of reinforcement - cl.9.2.1.1(3); | $A_{bt.max}$ = 0.04 ´ h = **12000** $mm^2/m$ |
| | max($A_{bt.req}$, $A_{bt.min}$) / $A_{bt.prov}$ = **0.509** |

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

Library item: Rectangular single output

**Rectangular section in shear - Section 6.2**

| | |
|---|---|
| Design shear force; | V = **8.4** kN/m |
| | $C_{Rd,c} = 0.18 / \gamma_C$ = **0.120** |
| | k = min(1 + √(200 mm / d), 2) = **1.905** |
| Longitudinal reinforcement ratio; | $\rho_l$ = min($A_{bt.prov}$ / d, 0.02) = **0.003** |
| | $v_{min}$ = 0.035 $N^{1/2}/mm$ ´ $k^{3/2}$ ´ $f_{ck}^{0.5}$ = **0.521** $N/mm^2$ |
| Design shear resistance - exp.6.2a & 6.2b; | $V_{Rd.c}$ = max($C_{Rd.c}$ ´ k ´ (100 $N^2/mm^4$ ´ $\rho_l$ ´ $f_{ck})^{1/3}$, |

$v_{min}$) ´ d

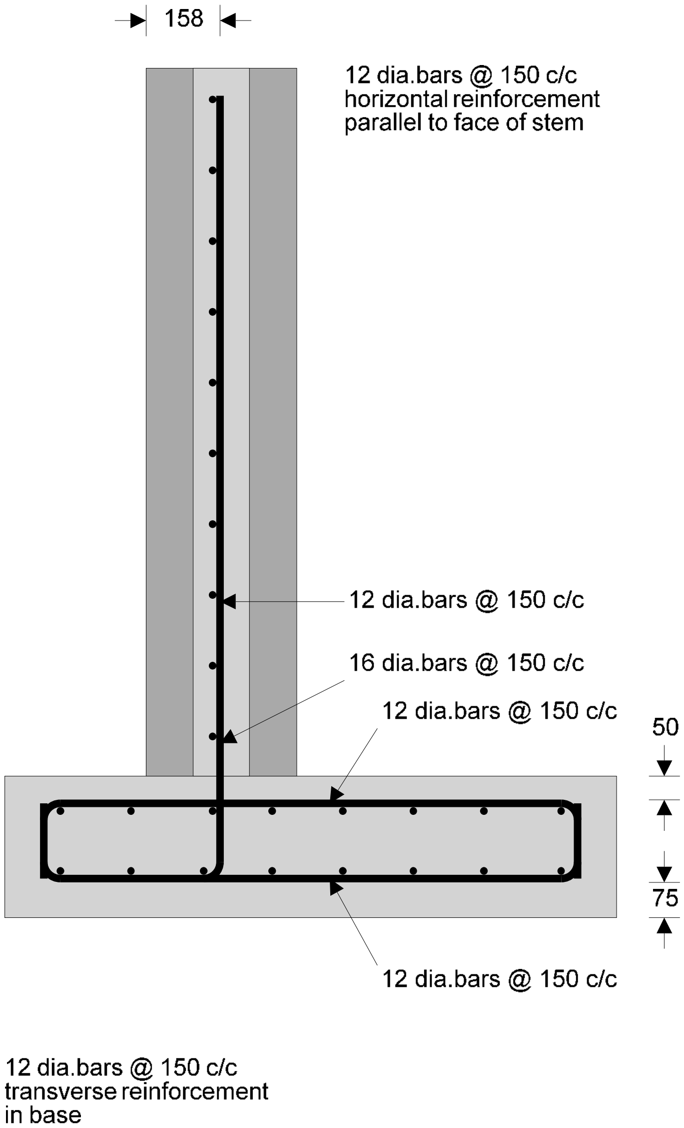
| | |
|---|---|
| | $V_{Rd.c}$ = **127.1** kN/m |
| | V / $V_{Rd.c}$ = **0.066** |

***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 ´ $A_{bb.prov}$ = **151** $mm^2/m$ |
| Maximum spacing of reinforcement – cl.9.3.1.1(3); | $s_{bx\_max}$ = **450** mm |
| Transverse reinforcement provided; | 12 dia.bars @ 150 c/c |
| Area of transverse reinforcement provided; | $A_{bx.prov} = \pi$ ´ $\phi_{bx}^2$ / (4 ´ $s_{bx}$) = **754** $mm^2/m$ |

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




**Reinforcement details**

***Therefore provide 320 wide brickwork cavity wall stem with 300thk Grade 32/40 concrete base, 1300 wide.***

# 4 Summary

**Structural Requirements:**