Architecture
For London
82—84
Clerkenwell Rd
London
EC1M 5RF
020 3637 4236
architecture
forlondon.com

Structural Calculations: 23 Dartmouth Park Hill, NW5

22nd January 2020

Introduction

Architecture for London were instructed by the client Ms. Philippa Huckle.

The structural works consist of creating a basement beneath existing section of the property and the proposed new rear extension extending into the garden area.

Design Codes

The following design codes / guidance were used to carry out the design:

- BS 648: 1964 - Weight of Building Materials
- BS 5268: Pt 2: 1991 - Structural Timber
- BS 5628: Pt 1: 1992 - Masonry
- BS 5950: Pt 1: 1990 - Structural Steel
- BS 6399: Pt 1: 1984 - Design Loads
- BS 8110: Pt 1: 1997 - Structural Use of Concrete

Ground Conditions

Trial holes and ground investigation carried out by LMB GeoSolutions have confirmed the underlying ground is London clay. For the purposes of these calculations an allowable safe bearing pressure of 110kN/m^2 has been used.

Substructure Design

Designing new structural retaining walls and underpins forming the new basement.

Superstructure Design

N/A

The Contractor will be responsible for all temporary supports and will be responsible for the stability of the structure during the works.

E mail@architectureforlondon.com **W** architectureforlondon.com **A** 82 Clerkenwell Road EC1M 5RF **T** 020 3637 4236

Loading

The loadings used throughtout the design are shown in the table below:

Item	**DL (kPa)**	**LL (kPa)**
Existing Timber Floor		
Boards	0.15	
Joists	0.2	
Plasterboard & Skim	0.15	
	0.5	
Domestic Floor		1.5
Solid Masonry		
100mm Thick	1.9	
15mm Plaster	0.3	
	2.2	
215mm Thick	4.0	
15mm Plaster	0.3	
	4.3	
330mm Thick	6.14	
15mm Plaster	0.3	
	6.44	
New Cavity		
102mm Brick	2.1	
100mm Block	0.8	
Plasterboard & Skim	0.24	
	3.14	

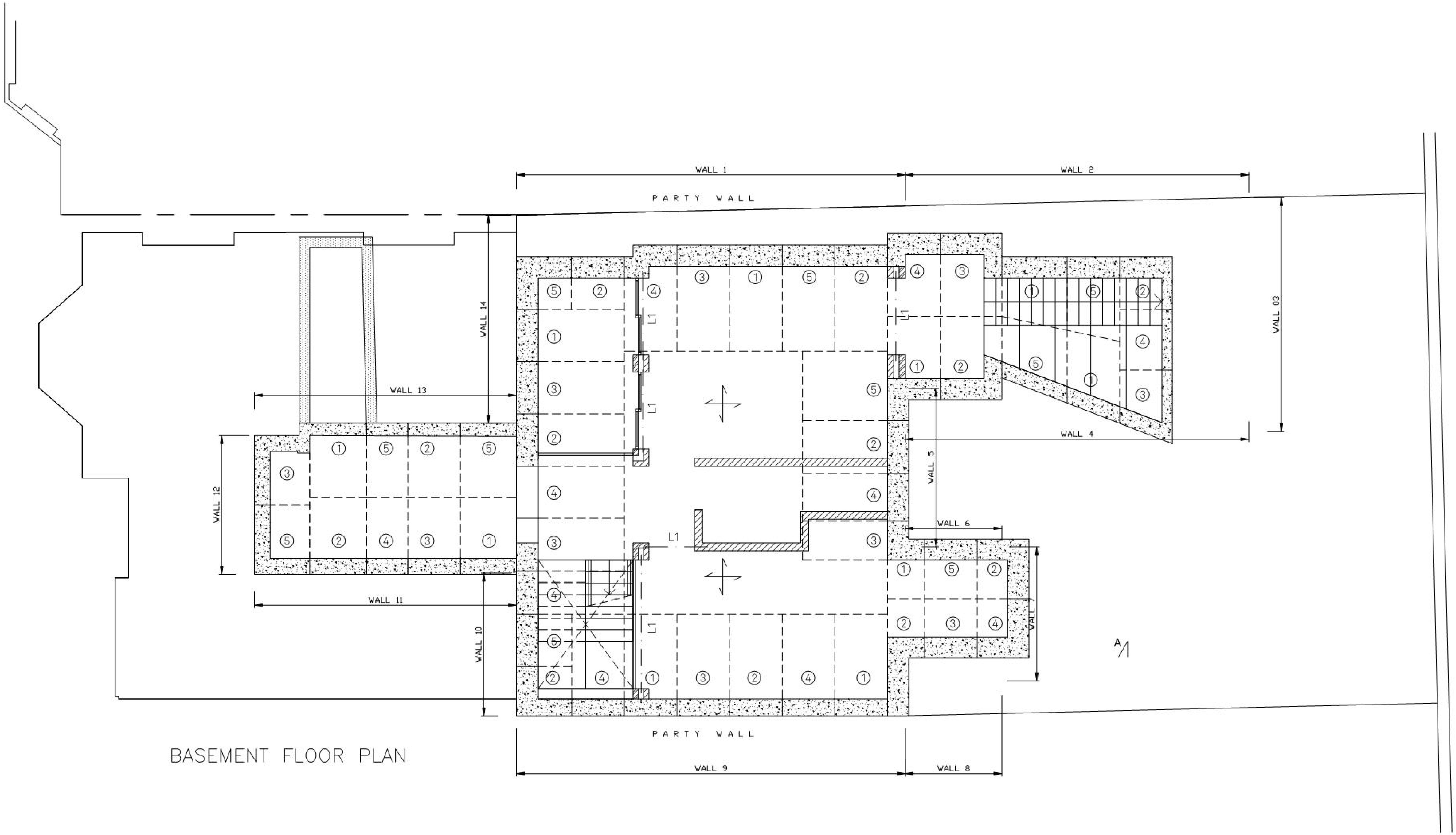
E mail@architectureforlondon.com **W** architectureforlondon.com **A** 82 Clerkenwell Road EC1M 5RF **T** 020 3637 4236

Timber Stud Walls		
Plasterboards	0.20	
Skim Coats	0.15	
Studs (75x50 @400mm c/c)	0.15	
	0.5	
Flat Roof		
Felt & Chippings	0.20	
Decking & Insulations	0.13	
Joists & Firrings	0.20	
Plasterboard & Skim	0.15	
	0.68	
No Access		0.75
Access		1.5
Glazed Window		
Triple Glazing	0.8	
	0.8	
Snow		0.8
Glazed Skylight		
15mm plater	0.92	
	0.92	
No Access		0.75
Public Highway		10.00
Garden		2.50

E mail@architectureforlondon.com W architectureforlondon.com A 82 Clerkenwell Road EC1M 5RF T 020 3637 4236

Tiled Roof		
Tiles	0.75	
Felt & Battens	0.06	
Rafters	0.06	
	0.87	
Plan Load		
20º	0.92	0.75
30º	0.95	0.75
35º	1.06	0.67
40º	1.13	0.58
45º	1.23	0.5
50º	1.35	0.42

E mail@architectureforlondon.com W architectureforlondon.com A 82 Clerkenwell Road EC1M 5RF T 020 3637 4236



Above:
Basement Wall Plan

E mail@architectureforlondon.com **W** architectureforlondon.com **A** 82 Clerkenwell Road EC1M 5RF **T** 020 3637 4236

E mail@architectureforlondon.com **W** architectureforlondon.com **A** 82 Clerkenwell Road EC1M 5RF **T** 020 3637 4236

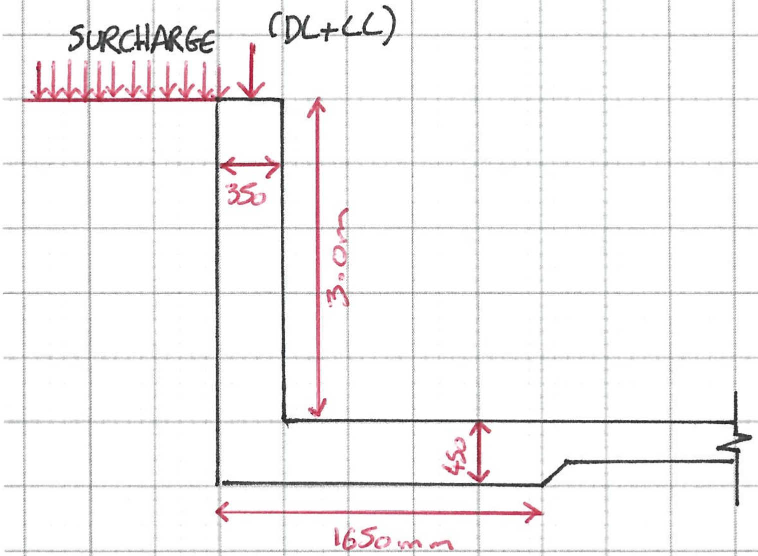
Basement Design

Architecture for London.	Project: 23 Dartmouth Park Hill	Job no.: 1967
	Calcs for: Retaining Wall Design	Start page no./Revision:
	Client:	Calcs by: BS / Calcs date:

* Wall 1

Load:-	Dead	Live
- Masonry wall (h = 4.0m) (3.14)	12.56	–
- Roof load (5.0m/2)(1.0, 0.75)	2.5	1.875
- Beam & Block Floor (9.1/2)(5.85, 1.5)	26.62	6.83
Total	41.68	8.71

* Garden Surcharge = 2.5kN/m²
* Water level (B.G.L) = 1.0m (Assumed)

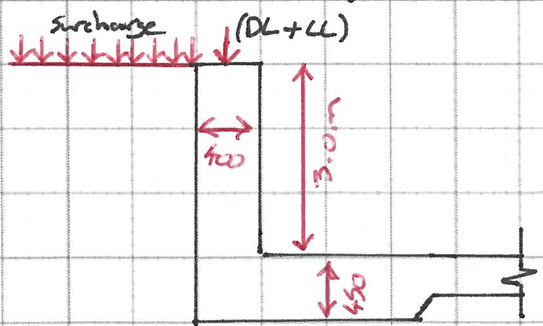


∴ Refer to Tedds Calcs

* Wall 2 & 4

Load:-	Dead	Live
- RC staircase (4.5/2)(5.5, 1.5)	12.4	3.40

* Garden surcharge = 2.5kN/m²
* Water level (B.G.L) = 1.0m (Assumed)

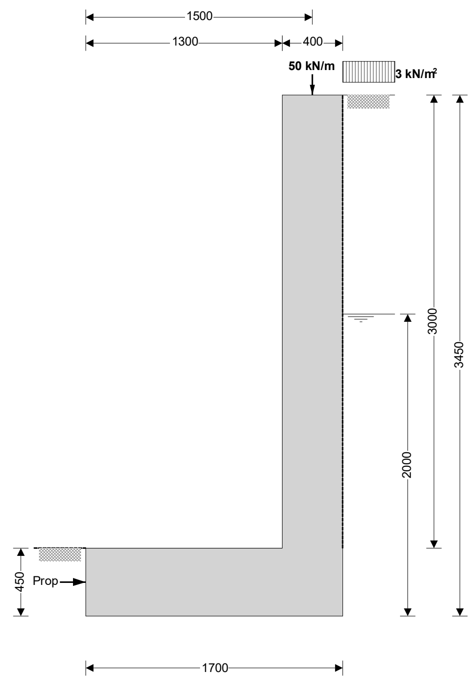


∴ Refer to Tedds Calcs

Architecture for London.	Project 23 Dartmouth Park Hill			Job Ref. 19047	
	Section Wall 1			Sheet no./rev. 1	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **400** mm
Length of toe	l_{toe} = **1300** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1700** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1200** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

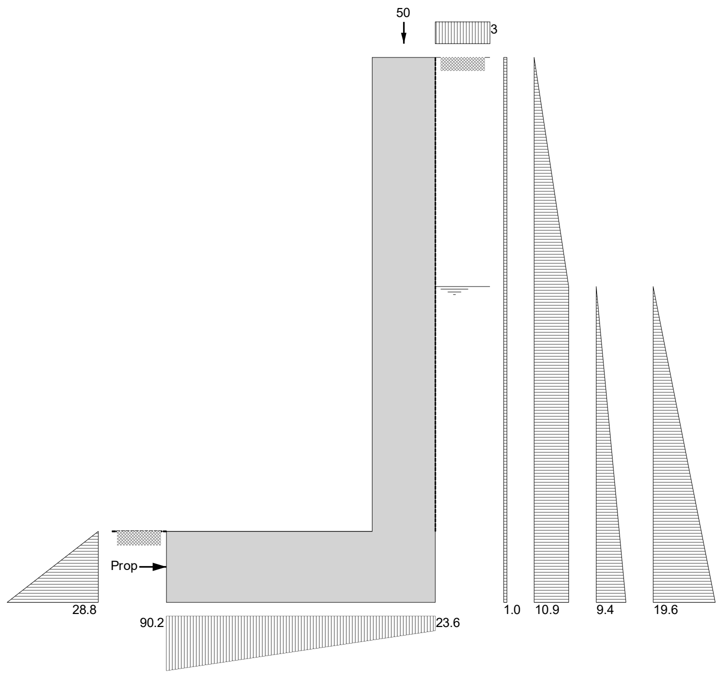
Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **2.5** kN/m^2
Applied vertical dead load on wall	W_{dead} = **41.7** kN/m
Applied vertical live load on wall	W_{live} = **8.7** kN/m
Position of applied vertical load on wall	l_{load} = **1500** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.3** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **18.1** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **50.4** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **96.8** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **3.6** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **62.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop} = **26.3** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.2** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **67.2** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **42.5** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2 =$ **15.3** kNm/m

Design vertical load $M_v = W_v \times l_{load} =$ **75.6** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_v =$ **133.4** kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot} =$ **66.2** kNm/m

Total vertical reaction $R = W_{total} =$ **96.8** kN/m

Distance to reaction $x_{bar} = M_{total} / R =$ **684** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) =$ **166** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) =$ **90.2** kN/m^2

Bearing pressure at heel $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) =$ **23.6** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **39.6** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **25.3** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **72.3** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **137.2** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **8.1** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **112.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **62.3** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **126.6** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **59.5** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **21.5** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **108.4** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **189.4** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **62.7** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **137.2** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **457** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **393** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **200** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction rate = p_{toe_f} / (3 × x_{bar_f}) = **145.77** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f}$ = max(p_{toe_f} - (rate × l_{toe}), 0 kN/m^2) = **10.5** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall} / 2)), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall})), 0 kN/m^2) = **0** kN/m^2

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure V_{toe_bear} = (p_{toe_f} + $p_{stem\_toe\_f}$) × l_{toe} / 2 = **136.8** kN/m

Shear from weight of base $V_{toe\_wt\_base}$ = γ_{f_d} × γ_{base} × l_{toe} × t_{base} = **19.3** kN/m

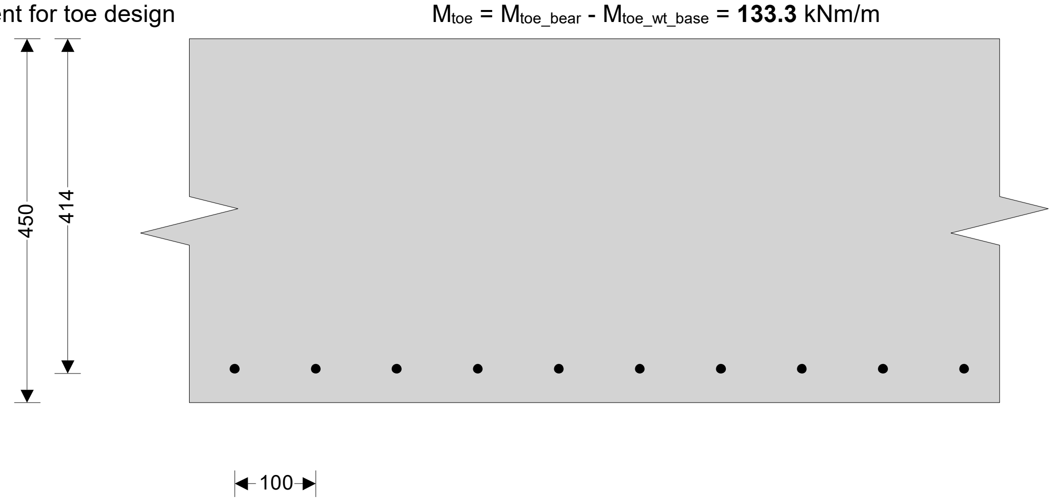
Total shear for toe design V_{toe} = V_{toe_bear} - $V_{toe\_wt\_base}$ = **117.5** kN/m

Calculate moment for toe design

Moment from bearing pressure M_{toe_bear} = (2 × p_{toe_f} + $p_{stem\_mid\_f}$) × (l_{toe} + t_{wall} / 2)^2 / 6 = **150** kNm/m

Moment from weight of base $M_{toe\_wt\_base}$ = (γ_{f_d} × γ_{base} × t_{base} × (l_{toe} + t_{wall} / 2)^2 / 2) = **16.7** kNm/m

Total moment for toe design M_{toe} = M_{toe_bear} - $M_{toe\_wt\_base}$ = **133.3** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement d_{toe} = t_{base} – c_{toe} – (ϕ_{toe} / 2) = **414.0** mm

Constant K_{toe} = M_{toe} / (b × d_{toe}^2 × f_{cu}) = **0.019**

Compression reinforcement is not required

Lever arm z_{toe} = min(0.5 + √(0.25 - (min(K_{toe}, 0.225) / 0.9)),0.95) × d_{toe}

z_{toe} = **393** mm

Area of tension reinforcement required $A_{s\_toe\_des}$ = M_{toe} / (0.87 × f_y × z_{toe}) = **779** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min}$ = k × b × t_{base} = **585** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req}$ = Max($A_{s\_toe\_des}$, $A_{s\_toe\_min}$) = **779** mm²/m

Reinforcement provided — **12 mm dia.bars @ 100 mm centres**

Area of reinforcement provided — $A_{s\_toe\_prov}$ = **1131** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.284** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_toe} = **0.480** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm²

Characteristic strength of reinforcement — f_y = **500** N/mm²

Wall details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in stem — c_{stem} = **40** mm

Cover to reinforcement in wall — c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge — $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **7.1** kN/m

Moist backfill above water table — $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m

Moist backfill below water table — $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m

Saturated backfill — $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m

Water — $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem — $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **21.4** kN/m

Calculate moment for stem design

Surcharge — $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **12.2** kNm/m

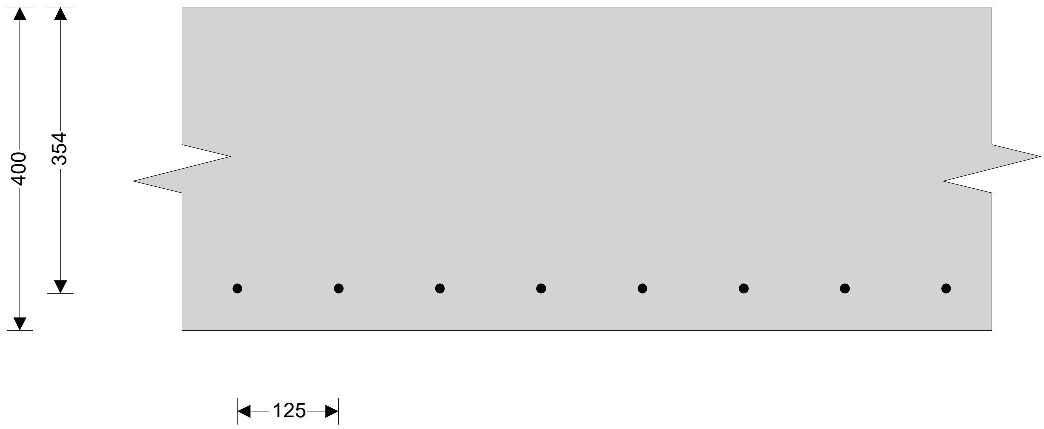
Moist backfill above water table — $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m

Moist backfill below water table — $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m

Saturated backfill — $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m

Water — $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **87.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) =$ **354.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) =$ **0.017**

Compression reinforcement is not required

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

$z_{stem} =$ **336** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) =$ **599** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall} =$ **520** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) =$ **599** mm²/m

Reinforcement provided — **12 mm dia.bars @ 125 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov} =$ **905** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem}) =$ **0.061** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 =$ **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — $v_{c\_stem} =$ **0.484** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas} =$ **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov}) =$ **220.8** N/mm²

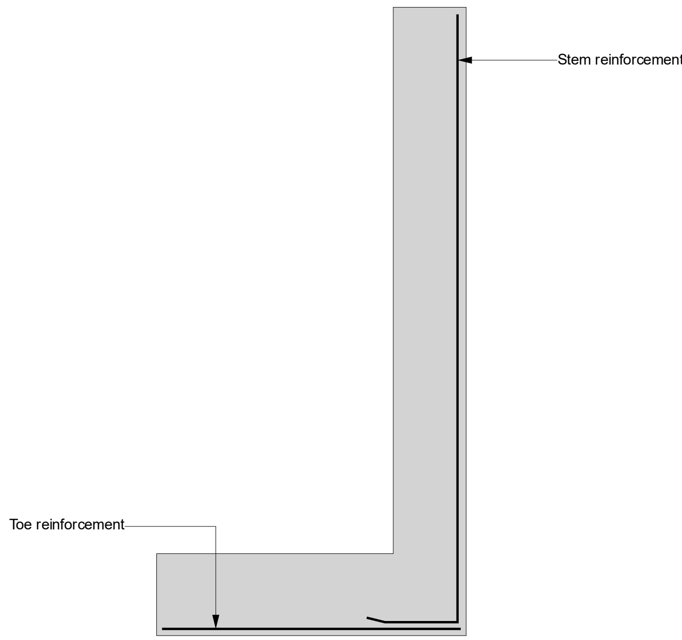
Modification factor — $factor_{tens} = \min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2) =$ **1.88**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens} =$ **13.19**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem} =$ **8.47**

PASS - Span to depth ratio is acceptable

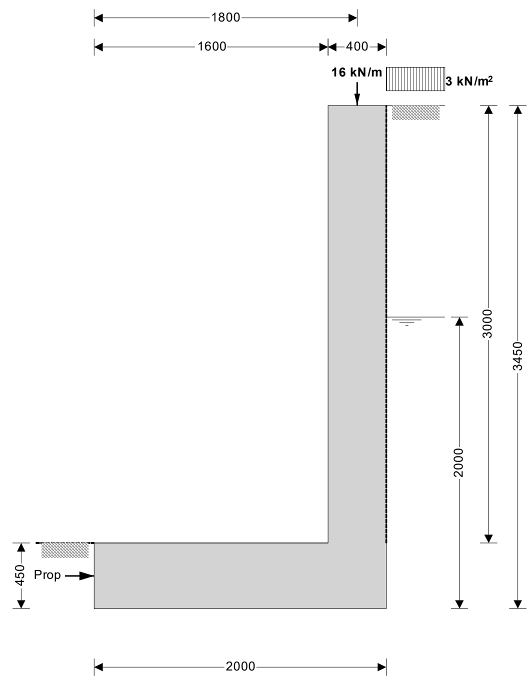
Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 100 mm centres - (1131 mm^2/m)
Stem bars - 12 mm dia.@ 125 mm centres - (905 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **400** mm
Length of toe	l_{toe} = **1600** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **2000** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

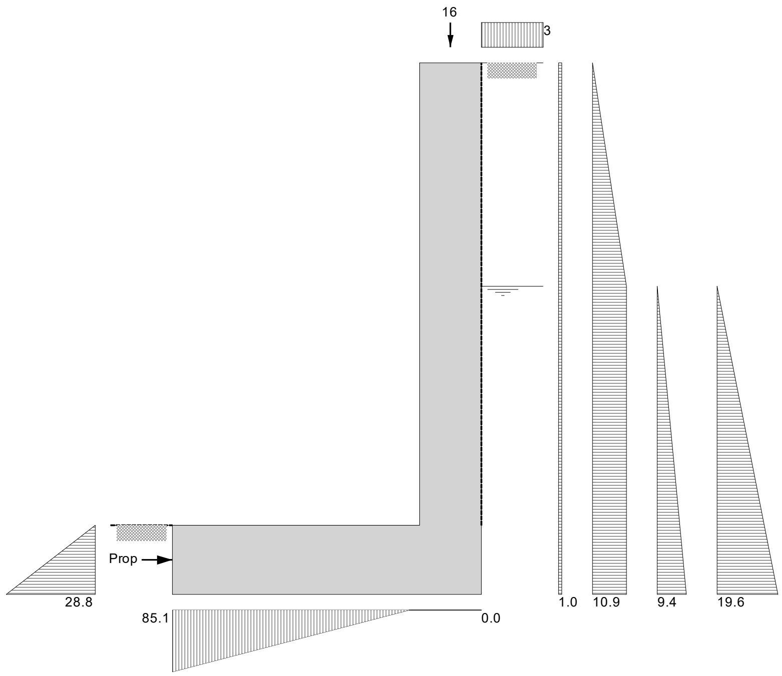
At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **2.5** kN/m^2
Applied vertical dead load on wall	W_{dead} = **12.4** kN/m
Applied vertical live load on wall	W_{live} = **3.4** kN/m
Position of applied vertical load on wall	l_{load} = **1800** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm

Architecture for London.	Project 23 Dartmouth Park Hill			Job Ref. 19047	
	Section Wall 2 & 4			Sheet no./rev. 3	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.3** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **21.2** kN/m

Applied vertical load — $W_v = W_{dead} + W_{live}$ = **15.8** kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v$ = **65.3** kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **3.6** kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m

Moist backfill below water table — $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **62.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m

Propping force — $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop} = **35.1** kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.2** kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m

Moist backfill below water table — $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **67.2** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **51** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2$ = **21.2** kNm/m

Design vertical load — $M_v = W_v \times l_{load}$ = **28.4** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_v$ = **100.6** kNm/m

Check bearing pressure

Total moment for bearing — $M_{total} = M_{rest} - M_{ot}$ = **33.4** kNm/m

Total vertical reaction — $R = W_{total}$ = **65.3** kN/m

Distance to reaction — $x_{bar} = M_{total} / R$ = **512** mm

Eccentricity of reaction — $e = abs((l_{base} / 2) - x_{bar})$ = **488** mm

Reaction acts outside middle third of base

Bearing pressure at toe — $p_{toe} = R / (1.5 \times x_{bar})$ = **85.1** kN/m^2

Bearing pressure at heel — p_{heel} = 0 kN/m^2 = **0** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	γ_{f_d} = **1.4**
Live load factor	γ_{f_l} = **1.6**
Earth and water pressure factor	γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **39.6** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **29.7** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **22.8** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **92.1** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **8.1** kN/m
Moist backfill above water table	$F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m
Moist backfill below water table	$F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m
Water	$F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m
Total horizontal load	$F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **112.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m
Propping force	$F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop_f} = **74.6** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14** kNm/m
Moist backfill above water table	$M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m
Moist backfill below water table	$M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m
Saturated backfill	$M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m
Water	$M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m
Total overturning moment	$M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **126.6** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **71.4** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **29.7** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **41** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **142.1** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **15.4** kNm/m
Total vertical reaction	$R_f = W_{total\_f}$ = **92.1** kN/m
Distance to reaction	$x_{bar\_f} = M_{total\_f} / R_f$ = **168** mm
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **832** mm
	Reaction acts outside middle third of base
Bearing pressure at toe	$p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **366.5** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction rate = p_{toe_f} / (3 × x_{bar_f}) = **728.93** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f}$ = max(p_{toe_f} - (rate × l_{toe}), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall} / 2)), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall})), 0 kN/m^2) = **0** kN/m^2

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure V_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} / 2 = **92.1** kN/m

Shear from weight of base $V_{toe\_wt\_base}$ = γ_{f_d} × γ_{base} × l_{toe} × t_{base} = **23.8** kN/m

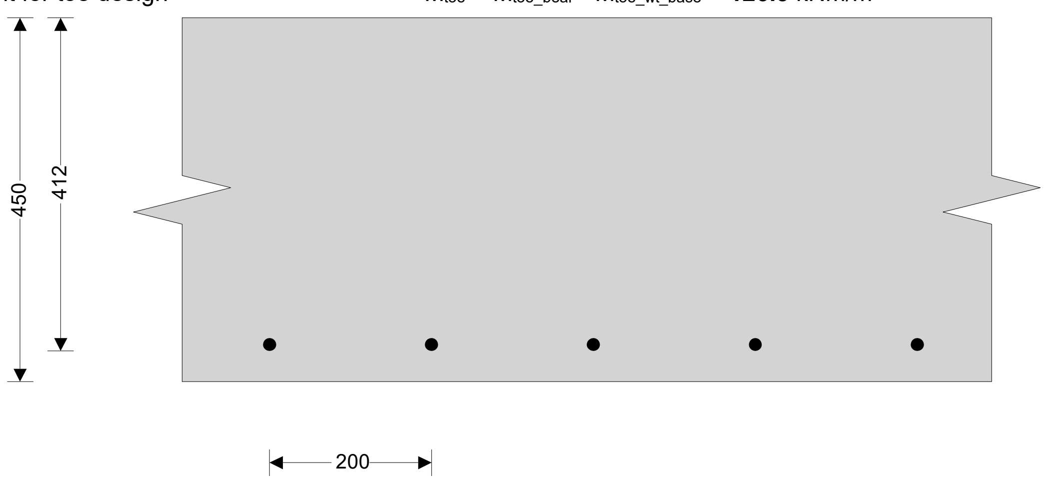
Total shear for toe design V_{toe} = V_{toe_bear} - $V_{toe\_wt\_base}$ = **68.4** kN/m

Calculate moment for toe design

Moment from bearing pressure M_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} × (l_{toe} - x_{bar_f} + t_{wall} / 2) / 2 = **150.4** kNm/m

Moment from weight of base $M_{toe\_wt\_base}$ = (γ_{f_d} × γ_{base} × t_{base} × (l_{toe} + t_{wall} / 2)^2 / 2) = **24.1** kNm/m

Total moment for toe design M_{toe} = M_{toe_bear} - $M_{toe\_wt\_base}$ = **126.3** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement d_{toe} = t_{base} – c_{toe} – (ϕ_{toe} / 2) = **412.0** mm

Constant K_{toe} = M_{toe} / (b × d_{toe}^2 × f_{cu}) = **0.019**

Compression reinforcement is not required

Lever arm z_{toe} = min(0.5 + √(0.25 - (min(K_{toe}, 0.225) / 0.9)),0.95) × d_{toe}

z_{toe} = **391** mm

Area of tension reinforcement required $A_{s\_toe\_des}$ = M_{toe} / (0.87 × f_y × z_{toe}) = **742** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min}$ = k × b × t_{base} = **585** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req} = Max(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **742** mm²/m

Reinforcement provided — **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_toe\_prov}$ = **1005** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.166** N/mm²

Allowable shear stress — $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5) \times 1 N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_toe} = **0.462** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm²

Characteristic strength of reinforcement — f_y = **500** N/mm²

Wall details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in stem — c_{stem} = **40** mm

Cover to reinforcement in wall — c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge — $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **7.1** kN/m

Moist backfill above water table — $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m

Moist backfill below water table — $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m

Saturated backfill — $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m

Water — $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem — $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **9.2** kN/m

Calculate moment for stem design

Surcharge — $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **12.2** kNm/m

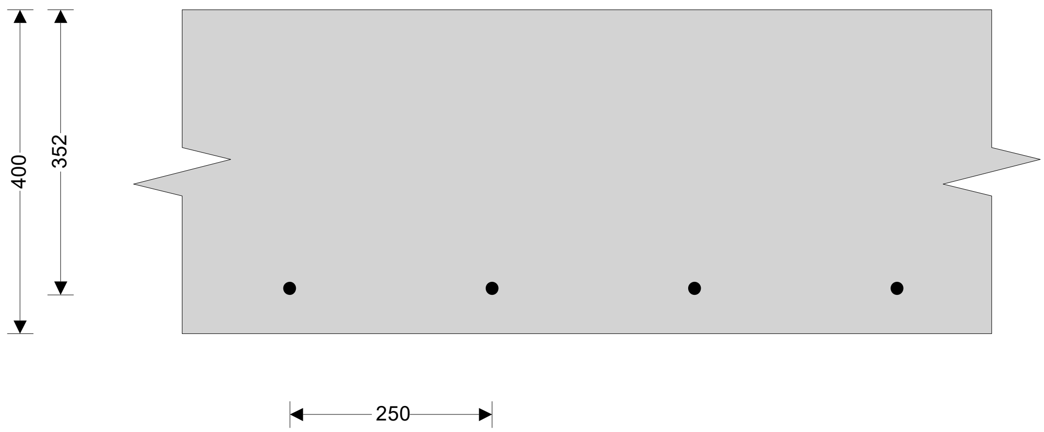
Moist backfill above water table — $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m

Moist backfill below water table — $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m

Saturated backfill — $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m

Water — $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **87.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **352.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.018**

Compression reinforcement is not required

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

z_{stem} = **334** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **603** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **520** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **603** mm²/m

Reinforcement provided — **16 mm dia.bars @ 250 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **804** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.026** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.467** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **249.8** N/mm²

Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.73**

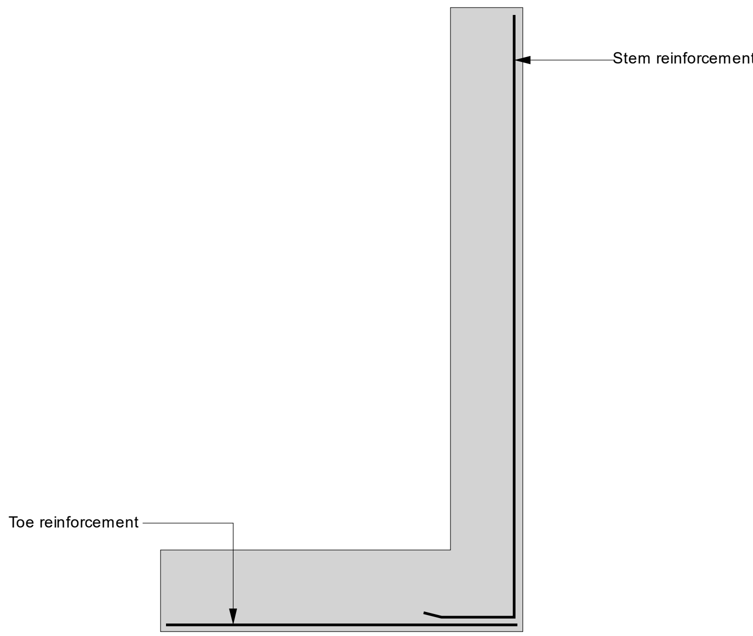
Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **12.09**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **8.52**

PASS - Span to depth ratio is acceptable

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 2 & 4				Sheet no./rev. 9	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)
Stem bars - 16 mm dia.@ 250 mm centres - (804 mm^2/m)

* Wall 3

Load:-

	Dead	Live
- RC Staircase (5.1/2) (5.5/2.5)	14.03	3.83

* Garden Surcharge = 2.5kN/m^2
* Water level (B.G.L) = 1.0m (Assumed)

* Wall 5

Load:-

	Dead	Live
- Beam & Block floor (7.4/2) (5.85, 1.5)	21.65	5.55
- Masonry wall (h = 4.0m) (3.14)	12.56	–
- Roof load (5.0m/2) (1.0, 0.75)	2.5	1.875
Total load	36.71	7.38

* Garden surcharge = 2.5kN/m^2
* Water level (B.G.L) = 1.0m (Assumed)

* Wall 6, 7, & 8

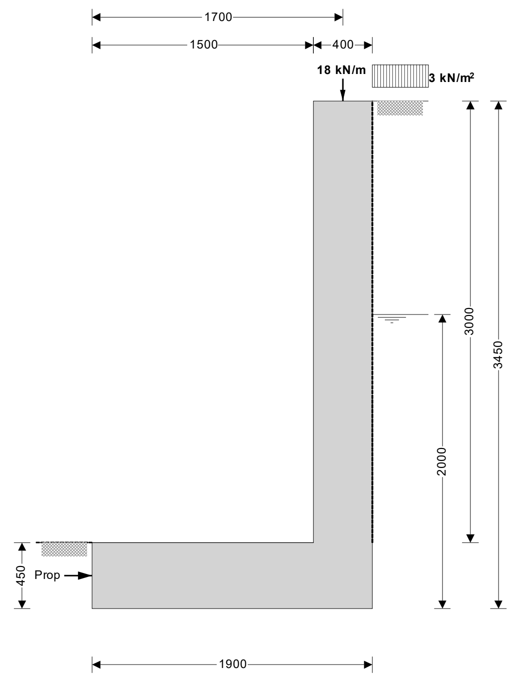
Load:-

	Dead	Live
- Glazing (h = 2.0m) (1.0)	2.0	–
- Masonry wall (h = 4.0m) (3.14)	12.56	–
- Roof (5.0m/2) (1.0, 0.75)	2.5	1.875

* Garden Surcharge = 2.5kN/m^2
* Water level = 1.0m (Assumed)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **400** mm
Length of toe	l_{toe} = **1500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1900** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **0** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **0.0** deg

Base material details

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio $r_a = \beta / \phi'$ = **0.00**

Wall friction ratio $r_b = \delta / \phi'$ = **0.00**

Active pressure coefficient for retained material K_a = **0.419**

Passive pressure coefficient for base material

Slope angle ratio r_a = 0 deg / ϕ'_b = **0.00**

Wall friction ratio $r_b = \delta_b / \phi'_b$ = **0.77**

Passive pressure coefficient for base material K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan Surcharge = **2.5** kN/m^2

Applied vertical dead load on wall W_{dead} = **14.0** kN/m

Applied vertical live load on wall W_{live} = **3.8** kN/m

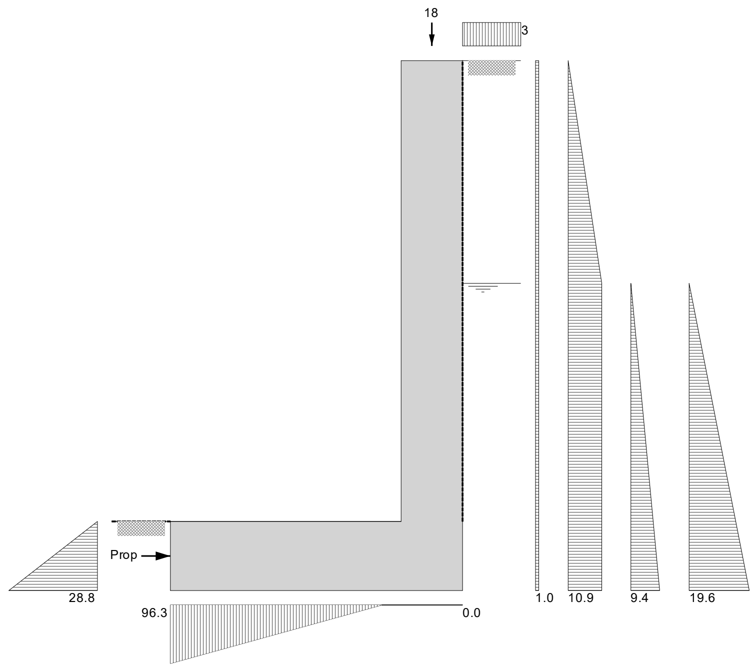
Position of applied vertical load on wall l_{load} = **1700** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 3				Sheet no./rev. 3	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.3** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **20.2** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **17.9** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **66.4** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **3.6** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **62.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop} = **34.9** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.2** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **67.2** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **48.1** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2 =$ **19.2** kNm/m

Design vertical load — $M_v = W_v \times l_{load} =$ **30.4** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_v =$ **97.7** kNm/m

Check bearing pressure

Total moment for bearing — $M_{total} = M_{rest} - M_{ot} =$ **30.5** kNm/m

Total vertical reaction — $R = W_{total} =$ **66.4** kN/m

Distance to reaction — $x_{bar} = M_{total} / R =$ **460** mm

Eccentricity of reaction — $e = abs((l_{base} / 2) - x_{bar}) =$ **490** mm

Reaction acts outside middle third of base

Bearing pressure at toe — $p_{toe} = R / (1.5 \times x_{bar}) =$ **96.3** kN/m^2

Bearing pressure at heel — $p_{heel} = 0$ kN/m^2 = **0** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **39.6** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **28.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **25.8** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **93.7** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **8.1** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **112.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0\text{ kN/m})$

F_{prop_f} = **74.3** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **126.6** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **67.4** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **26.8** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **43.8** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **138** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **11.4** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **93.7** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **122** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **828** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **512.1** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction rate = p_{toe_f} / (3 × x_{bar_f}) = **1400.12** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f}$ = max(p_{toe_f} - (rate × l_{toe}), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall} / 2)), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall})), 0 kN/m^2) = **0** kN/m^2

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure V_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} / 2 = **93.7** kN/m

Shear from weight of base $V_{toe\_wt\_base}$ = γ_{f_d} × γ_{base} × l_{toe} × t_{base} = **22.3** kN/m

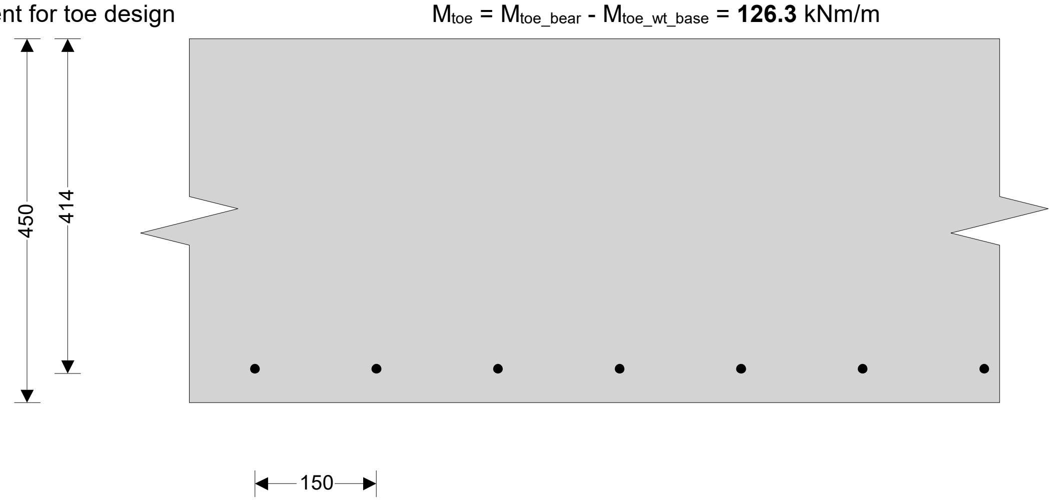
Total shear for toe design V_{toe} = V_{toe_bear} - $V_{toe\_wt\_base}$ = **71.4** kN/m

Calculate moment for toe design

Moment from bearing pressure M_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} × (l_{toe} - x_{bar_f} + t_{wall} / 2) / 2 = **147.8** kNm/m

Moment from weight of base $M_{toe\_wt\_base}$ = (γ_{f_d} × γ_{base} × t_{base} × (l_{toe} + t_{wall} / 2)^2 / 2) = **21.5** kNm/m

Total moment for toe design M_{toe} = M_{toe_bear} - $M_{toe\_wt\_base}$ = **126.3** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement d_{toe} = t_{base} – c_{toe} – (ϕ_{toe} / 2) = **414.0** mm

Constant K_{toe} = M_{toe} / (b × d_{toe}^2 × f_{cu}) = **0.018**

Compression reinforcement is not required

Lever arm z_{toe} = min(0.5 + √(0.25 - (min(K_{toe}, 0.225) / 0.9)),0.95) × d_{toe}

z_{toe} = **393** mm

Area of tension reinforcement required $A_{s\_toe\_des}$ = M_{toe} / (0.87 × f_y × z_{toe}) = **738** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min}$ = k × b × t_{base} = **585** mm^2/m

Area of tension reinforcement required	$A_{s\_toe\_req} = Max(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **738** mm²/m
Reinforcement provided	**12 mm dia.bars @ 150 mm centres**
Area of reinforcement provided	$A_{s\_toe\_prov}$ = **754** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress	$v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.172** N/mm²
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress	v_{c_toe} = **0.419** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete	f_{cu} = **40** N/mm²
Characteristic strength of reinforcement	f_y = **500** N/mm²

Wall details

Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in stem	c_{stem} = **40** mm
Cover to reinforcement in wall	c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

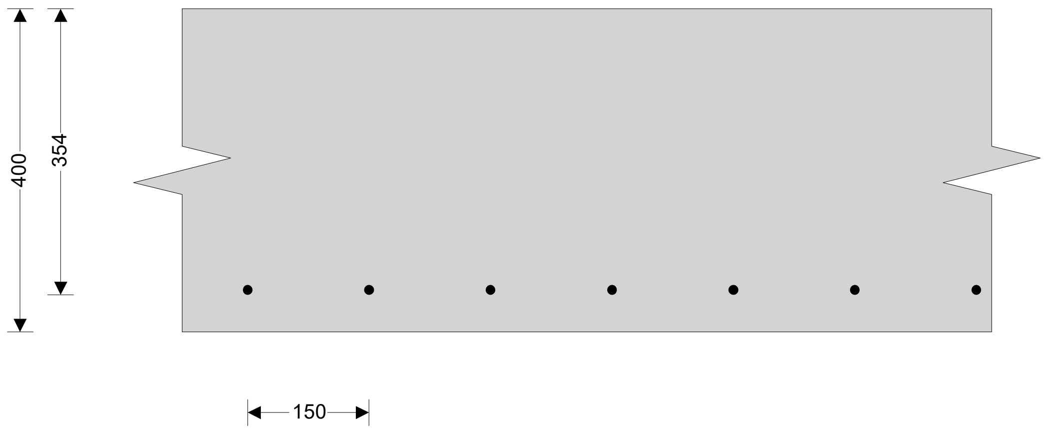
Surcharge	$F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **7.1** kN/m
Moist backfill above water table	$F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m
Moist backfill below water table	$F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m
Saturated backfill	$F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m
Water	$F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem	$V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **9.4** kN/m

Calculate moment for stem design

Surcharge	$M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **12.2** kNm/m
Moist backfill above water table	$M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m
Moist backfill below water table	$M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m
Saturated backfill	$M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m
Water	$M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m
Total moment for stem design	$M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **87.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) =$ **354.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) =$ **0.017**

Compression reinforcement is not required

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

$z_{stem} =$ **336** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) =$ **599** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall} =$ **520** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) =$ **599** mm²/m

Reinforcement provided — **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov} =$ **754** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem}) =$ **0.027** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \text{N/mm}^2)}, 5) \times 1\ \text{N/mm}^2 =$ **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — $v_{c\_stem} =$ **0.455** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas} =$ **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov}) =$ **265.0** N/mm²

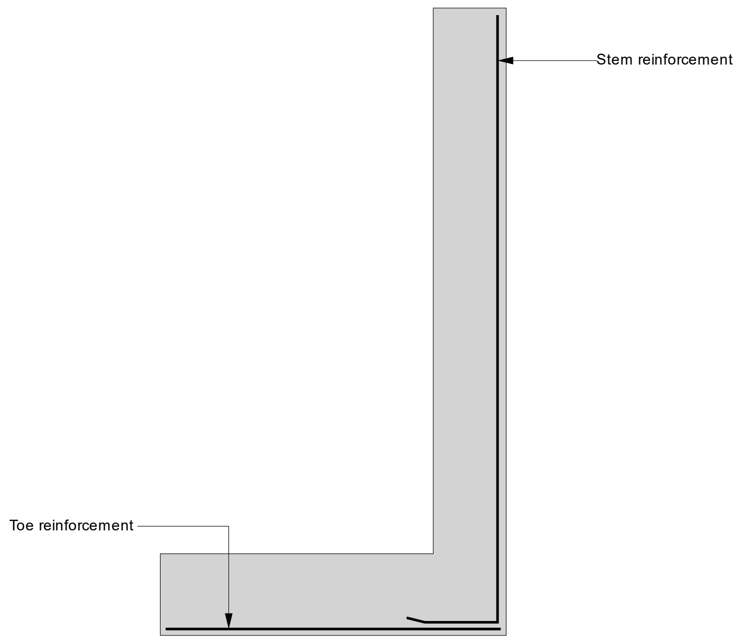
Modification factor — $factor_{tens} = \min(0.55 + (477\ \text{N/mm}^2 - f_s)/(120 \times (0.9\ \text{N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2) =$ **1.65**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens} =$ **11.58**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem} =$ **8.47**

PASS - Span to depth ratio is acceptable

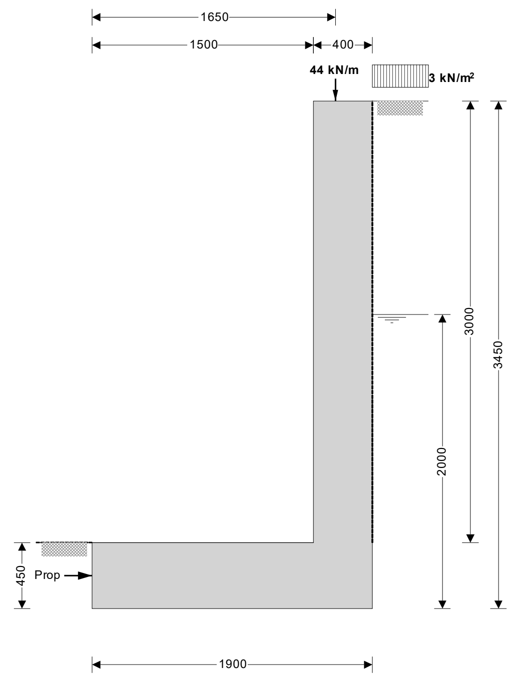
Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **400** mm
Length of toe	l_{toe} = **1500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1900** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1350** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

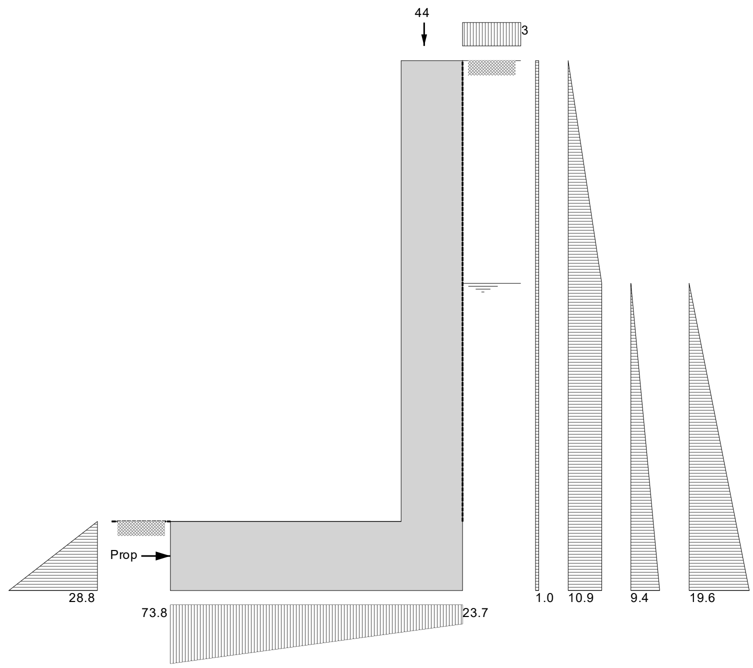
Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **2.5** kN/m^2
Applied vertical dead load on wall	W_{dead} = **36.7** kN/m
Applied vertical live load on wall	W_{live} = **7.4** kN/m
Position of applied vertical load on wall	l_{load} = **1650** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.3** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **20.2** kN/m

Applied vertical load — $W_v = W_{dead} + W_{live}$ = **44.1** kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v$ = **92.6** kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **3.6** kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m

Moist backfill below water table — $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **62.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m

Propping force — $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0\ \text{kN/m})$

F_{prop} = **27.3** kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.2** kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m

Moist backfill below water table — $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **67.2** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **48.1** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2 =$ **19.2** kNm/m

Design vertical load — $M_v = W_v \times l_{load} =$ **72.7** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_v =$ **140.1** kNm/m

Check bearing pressure

Total moment for bearing — $M_{total} = M_{rest} - M_{ot} =$ **72.9** kNm/m

Total vertical reaction — $R = W_{total} =$ **92.6** kN/m

Distance to reaction — $x_{bar} = M_{total} / R =$ **787** mm

Eccentricity of reaction — $e = abs((l_{base} / 2) - x_{bar}) =$ **163** mm

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) =$ **73.8** kN/m^2

Bearing pressure at heel — $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) =$ **23.7** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **39.6** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **28.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **63.2** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **131.1** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **8.1** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **112.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **63.6** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **126.6** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **67.4** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **26.8** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **104.3** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **198.5** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **71.9** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **131.1** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **548** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **402** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **159.4** kN/m^2

Bearing pressure at heel — p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction — rate = p_{toe_f} / (3 × x_{bar_f}) = **96.87** kN/m^2/m

Bearing pressure at stem / toe — $p_{stem\_toe\_f}$ = max(p_{toe_f} - (rate × l_{toe}), 0 kN/m^2) = **14.1** kN/m^2

Bearing pressure at mid stem — $p_{stem\_mid\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall} / 2)), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at stem / heel — $p_{stem\_heel\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall})), 0 kN/m^2) = **0** kN/m^2

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

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement — f_y = **500** N/mm^2

Base details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in toe — c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure — V_{toe_bear} = (p_{toe_f} + $p_{stem\_toe\_f}$) × l_{toe} / 2 = **130.1** kN/m

Shear from weight of base — $V_{toe\_wt\_base}$ = γ_{f_d} × γ_{base} × l_{toe} × t_{base} = **22.3** kN/m

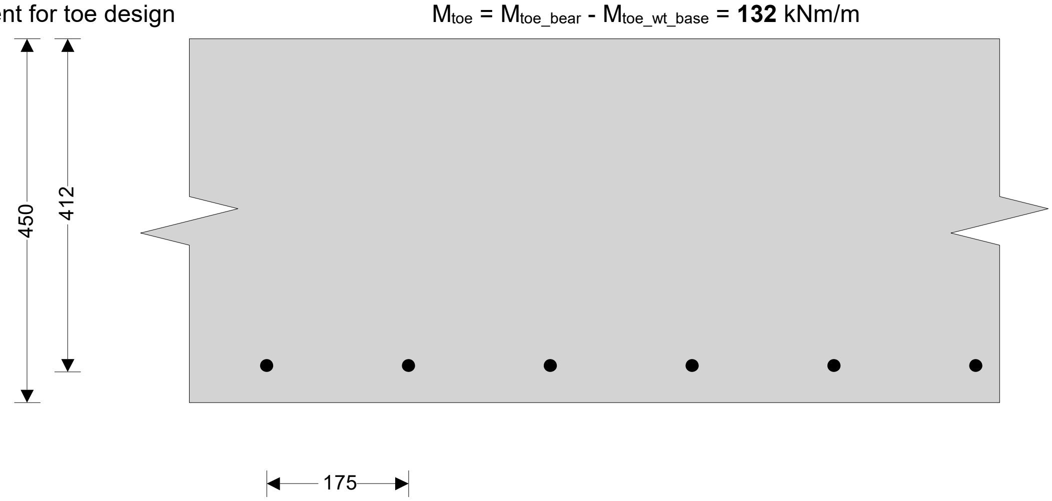
Total shear for toe design — V_{toe} = V_{toe_bear} - $V_{toe\_wt\_base}$ = **107.8** kN/m

Calculate moment for toe design

Moment from bearing pressure — M_{toe_bear} = (2 × p_{toe_f} + $p_{stem\_mid\_f}$) × (l_{toe} + t_{wall} / 2)^2 / 6 = **153.5** kNm/m

Moment from weight of base — $M_{toe\_wt\_base}$ = (γ_{f_d} × γ_{base} × t_{base} × (l_{toe} + t_{wall} / 2)^2 / 2) = **21.5** kNm/m

Total moment for toe design — M_{toe} = M_{toe_bear} - $M_{toe\_wt\_base}$ = **132** kNm/m



Check toe in bending

Width of toe — b = **1000** mm/m

Depth of reinforcement — d_{toe} = t_{base} – c_{toe} – (ϕ_{toe} / 2) = **412.0** mm

Constant — K_{toe} = M_{toe} / (b × d_{toe}^2 × f_{cu}) = **0.019**

Compression reinforcement is not required

Lever arm — z_{toe} = min(0.5 + √(0.25 - (min(K_{toe}, 0.225) / 0.9)),0.95) × d_{toe}

z_{toe} = **391** mm

Area of tension reinforcement required — $A_{s\_toe\_des}$ = M_{toe} / (0.87 × f_y × z_{toe}) = **776** mm^2/m

Minimum area of tension reinforcement — $A_{s\_toe\_min}$ = k × b × t_{base} = **585** mm^2/m

Area of tension reinforcement required	$A_{s\_toe\_req}$ = Max($A_{s\_toe\_des}$, $A_{s\_toe\_min}$) = **776** mm^2/m
Reinforcement provided	**16 mm dia.bars @ 175 mm centres**
Area of reinforcement provided	$A_{s\_toe\_prov}$ = **1149** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress	$v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.262** N/mm^2
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{}(f_{cu} / 1\ N/mm^2), 5) \times 1\ N/mm^2$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress	v_{c_toe} = **0.483** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

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

Wall details

Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in stem	c_{stem} = **40** mm
Cover to reinforcement in wall	c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

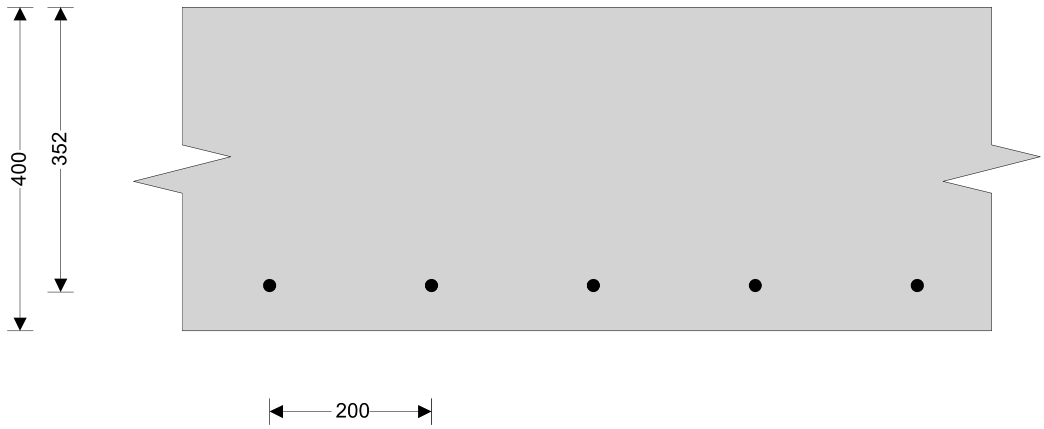
Surcharge	$F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **7.1** kN/m
Moist backfill above water table	$F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m
Moist backfill below water table	$F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m
Saturated backfill	$F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m
Water	$F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem	$V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **20.1** kN/m

Calculate moment for stem design

Surcharge	$M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **12.2** kNm/m
Moist backfill above water table	$M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m
Moist backfill below water table	$M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m
Saturated backfill	$M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m
Water	$M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m
Total moment for stem design	$M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **87.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **352.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.018**

Compression reinforcement is not required

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

z_{stem} = **334** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **603** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **520** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **603** mm²/m

Reinforcement provided — **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **1005** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.057** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.503** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **199.9** N/mm²

Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.99**

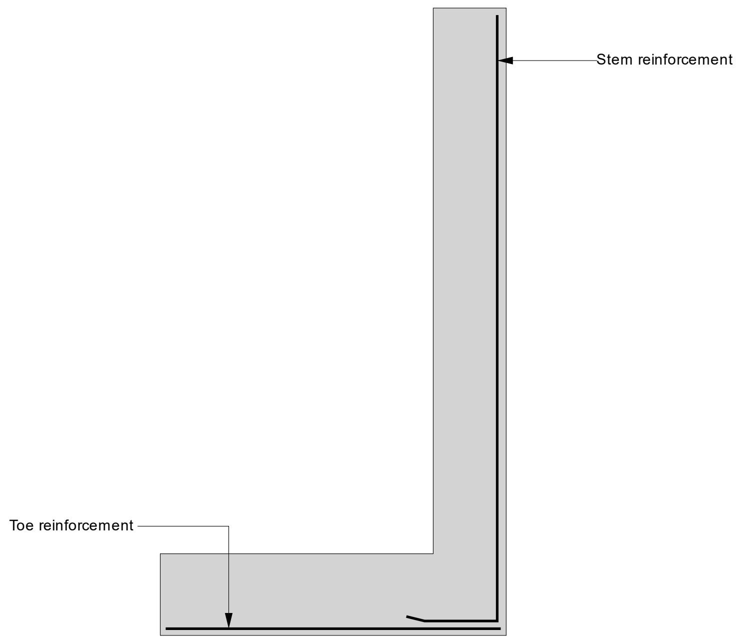
Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **13.91**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **8.52**

PASS - Span to depth ratio is acceptable

	Project			Job Ref.	
Architecture for London.	23 Dartmouth Park Hill			19047	
	Section			Sheet no./rev.	
	Wall 5			9	
	Calc. by	Date	Chk'd by	Date	App'd by	Date
	BS	23/01/2020				

Indicative retaining wall reinforcement diagram

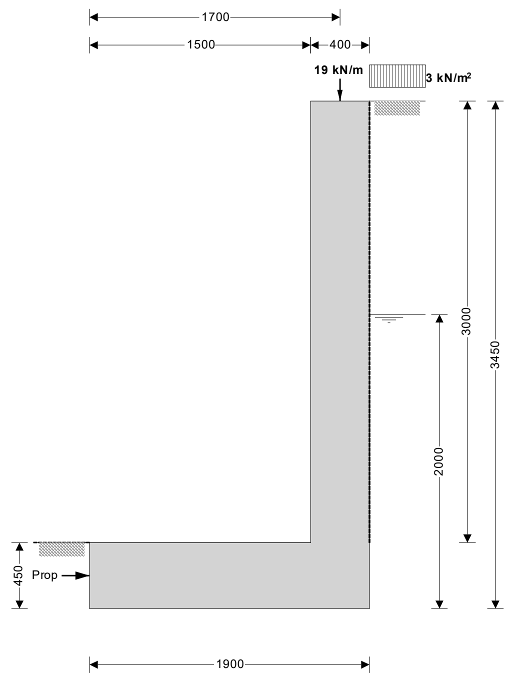


Toe bars - 16 mm dia.@ 175 mm centres - (1149 mm^2/m)
Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

Architecture for London.	Project 23 Dartmouth Park Hill			Job Ref. 19047	
	Section Wall 6,7 & 8			Sheet no./rev. 1	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **400** mm
Length of toe	l_{toe} = **1500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1900** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

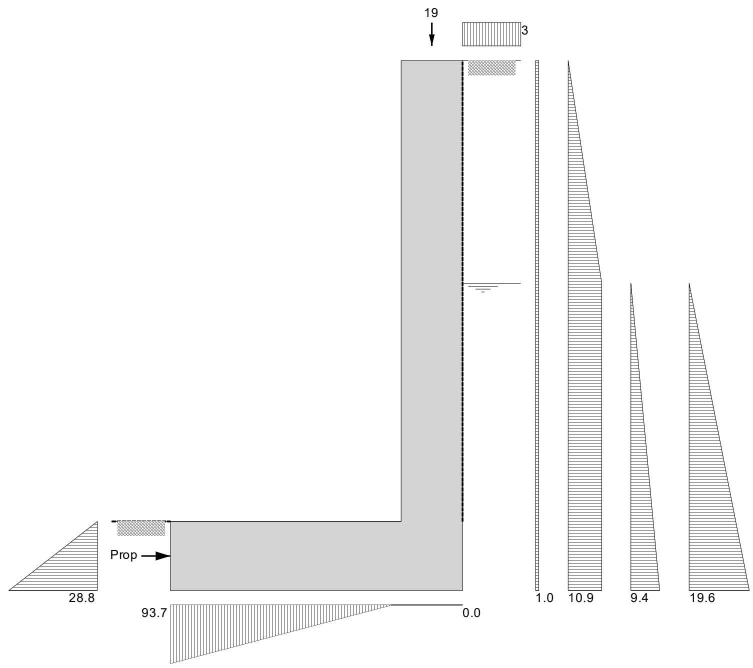
Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **2.5** kN/m^2
Applied vertical dead load on wall	W_{dead} = **17.1** kN/m
Applied vertical live load on wall	W_{live} = **1.9** kN/m
Position of applied vertical load on wall	l_{load} = **1700** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.3** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **20.2** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **19** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **67.5** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **3.6** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **62.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop} = **33.9** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.2** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **67.2** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \mathbf{48.1}$ kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2 = \mathbf{19.2}$ kNm/m

Design vertical load $M_v = W_v \times l_{load} = \mathbf{32.3}$ kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_v = \mathbf{99.6}$ kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot} = \mathbf{32.4}$ kNm/m

Total vertical reaction $R = W_{total} = \mathbf{67.5}$ kN/m

Distance to reaction $x_{bar} = M_{total} / R = \mathbf{480}$ mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) = \mathbf{470}$ mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe} = R / (1.5 \times x_{bar}) = \mathbf{93.7}$ kN/m^2

Bearing pressure at heel $p_{heel} = 0$ kN/m^2 $= \mathbf{0}$ kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **39.6** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **28.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **26.9** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **94.8** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **8.1** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **112.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **72.9** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **126.6** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **67.4** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **26.8** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **45.8** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **140** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **13.4** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **94.8** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **141** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **809** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **447.1** kN/m^2

Bearing pressure at heel	$p_{heel\_f} = 0 \text{ kN/m}^2 = \mathbf{0} \text{ kN/m}^2$
Rate of change of base reaction	$rate = p_{toe\_f} / (3 \times x_{bar\_f}) = \mathbf{1054.11} \text{ kN/m}^2\text{/m}$
Bearing pressure at stem / toe	$p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2) = \mathbf{0} \text{ kN/m}^2$
Bearing pressure at mid stem	$p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = \mathbf{0} \text{ kN/m}^2$
Bearing pressure at stem / heel	$p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = \mathbf{0} \text{ kN/m}^2$

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

Material properties

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

Base details

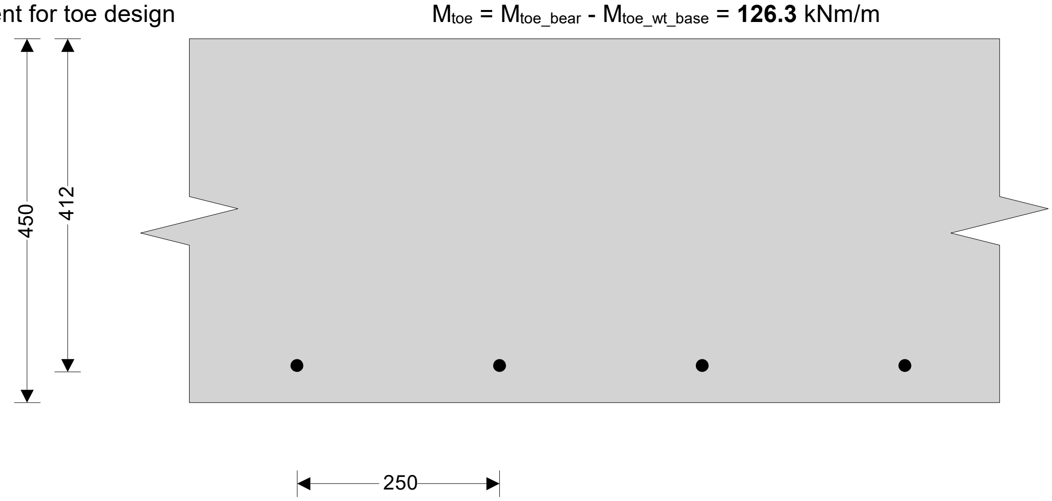
Minimum area of reinforcement	$k = \mathbf{0.13}$ %
Cover to reinforcement in toe	$c_{toe} = \mathbf{30}$ mm

Calculate shear for toe design

Shear from bearing pressure	$V_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} / 2 = \mathbf{94.8}$ kN/m
Shear from weight of base	$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{22.3}$ kN/m
Total shear for toe design	$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{72.5}$ kN/m

Calculate moment for toe design

Moment from bearing pressure	$M_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} \times (l_{toe} - x_{bar\_f} + t_{wall} / 2) / 2 = \mathbf{147.8}$ kNm/m
Moment from weight of base	$M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{21.5}$ kNm/m
Total moment for toe design	$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{126.3}$ kNm/m



Check toe in bending

Width of toe	$b = \mathbf{1000}$ mm/m
Depth of reinforcement	$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{412.0}$ mm
Constant	$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.019}$
	Compression reinforcement is not required
Lever arm	$z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
	$z_{toe} = \mathbf{391}$ mm
Area of tension reinforcement required	$A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{742} \text{ mm}^2\text{/m}$
Minimum area of tension reinforcement	$A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{585} \text{ mm}^2\text{/m}$

Area of tension reinforcement required — $A_{s\_toe\_req} = Max(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **742** mm²/m

Reinforcement provided — **16 mm dia.bars @ 250 mm centres**

Area of reinforcement provided — $A_{s\_toe\_prov}$ = **804** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.176** N/mm²

Allowable shear stress — $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5) \times 1 N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_toe} = **0.429** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm²

Characteristic strength of reinforcement — f_y = **500** N/mm²

Wall details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in stem — c_{stem} = **40** mm

Cover to reinforcement in wall — c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge — $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **7.1** kN/m

Moist backfill above water table — $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m

Moist backfill below water table — $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m

Saturated backfill — $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m

Water — $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem — $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **10.9** kN/m

Calculate moment for stem design

Surcharge — $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **12.2** kNm/m

Moist backfill above water table — $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m

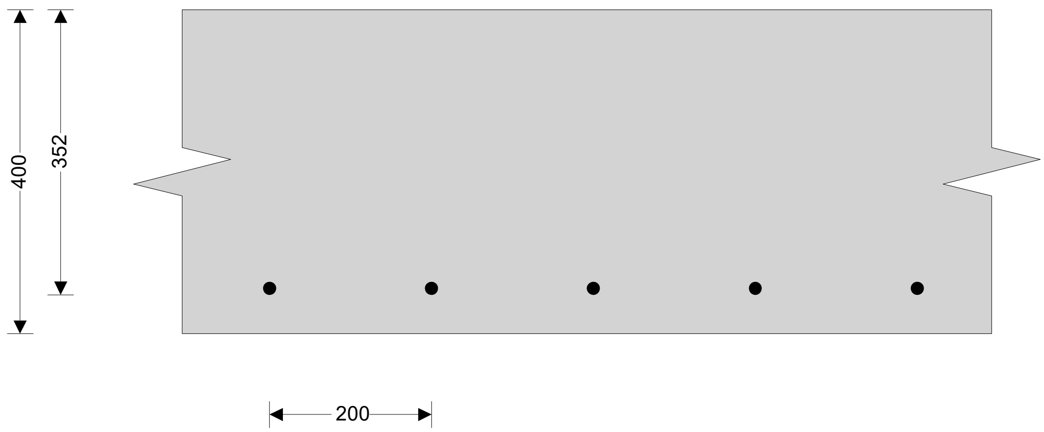
Moist backfill below water table — $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m

Saturated backfill — $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m

Water — $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **87.7** kNm/m

Architecture for London.	Project 23 Dartmouth Park Hill			Job Ref. 19047	
	Section Wall 6,7 & 8			Sheet no./rev. 8	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date



Check wall stem in bending

Width of wall stem: b = **1000** mm/m

Depth of reinforcement: $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **352.0** mm

Constant: $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.018**

Compression reinforcement is not required

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

z_{stem} = **334** mm

Area of tension reinforcement required: $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **603** mm^2/m

Minimum area of tension reinforcement: $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **520** mm^2/m

Area of tension reinforcement required: $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **603** mm^2/m

Reinforcement provided: **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided: $A_{s\_stem\_prov}$ = **1005** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress: $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.031** N/mm^2

Allowable shear stress: $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \mathrm{N/mm^2})}, 5) \times 1\ \mathrm{N/mm^2}$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress: v_{c_stem} = **0.503** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio: $ratio_{bas}$ = **7**

Design service stress: $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **199.9** N/mm^2

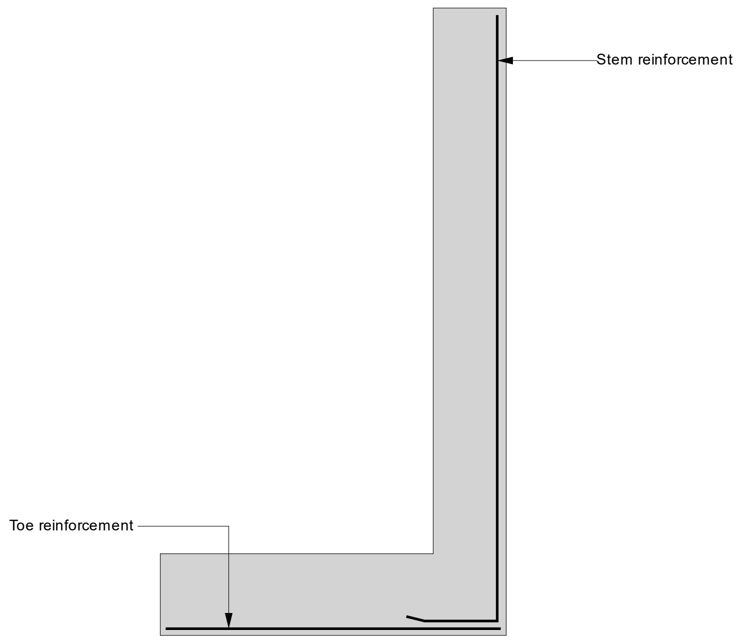
Modification factor: $factor_{tens} = \min(0.55 + (477\ \mathrm{N/mm^2} - f_s)/(120 \times (0.9\ \mathrm{N/mm^2} + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.99**

Maximum span/effective depth ratio: $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **13.91**

Actual span/effective depth ratio: $ratio_{act} = h_{stem} / d_{stem}$ = **8.52**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 250 mm centres - (804 mm^2/m)
Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

Architecture for London.	Project: Dartmouth Park Hill	Job no.: 9047
	Calcs for: Retaining wall Design	Start page no./Revision:
	Client:	Calcs by: BS / Calcs date:

* Wall 9

Load:-	Dead	Live
- Masonry wall (h=4.0m) (3.14)	12.56	–
- Roof load (5.0m/2) (1.0, 0.75)	2.5	1.88
- Beam & Block Floor (9.1/2) (5.85, 1.5)	26.62	6.83
Total	41.68	8.71

* Surcharge = 10kN/m²
* Water level = 1.0m (B.G.L) (Assumed)

* Wall 10

Load:-	Dead	Live
- Masonry wall (h= 3.5m) (3.14)	11.00	–
- Roof load (5.2/2) (1.0, 0.75)	2.6	1.95
- Glazing (2.3/2) (0.95, 0.75)	1.1	0.863
- Staircase (2.3/2) (5.85, 1.5)	6.73	1.73
Total load	21.42	4.543

* Surcharge =
* Water level = 1.0m (Assumed)

* Wall 11

* Surcharge =
* Water level = 1.0m

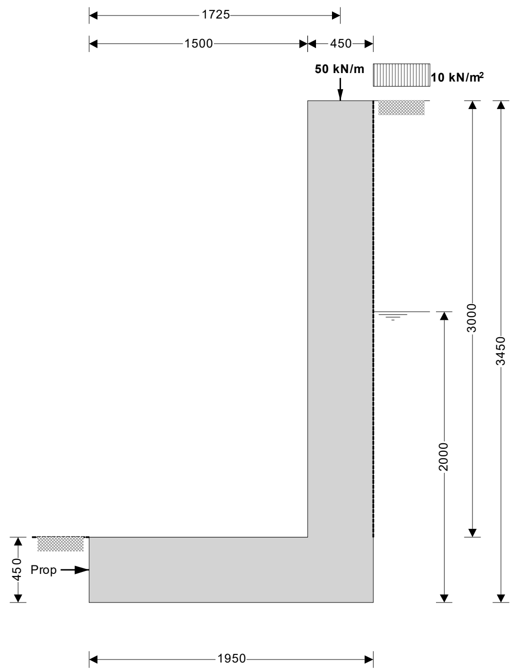
Load:-	Dead	Live
- Masonry wall (h= 9.5m) (4.3)	40.85	–
- Pitched Roof (5.3/2) (0.83, 0.75)	2.2	2.0
- Ground floor (2.8/2) (1.0, 1.5)	1.4	2.1
- First floor (2.8/2) (1.0, 1.5)	1.4	2.1
- Second floor (2.8/2) (1.0, 1.5)	1.4	2.1
- Loft (2.8/2) (1.0, 1.5)	1.4	2.1
- Flat Roof (2.8/2) (0.7, 0.75)	0.952	1.05

Total:-
Dead = 49.6kN/m
Live = 11.45 kN/m

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 9				Sheet no./rev. 1	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **450** mm
Length of toe	l_{toe} = **1500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1950** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

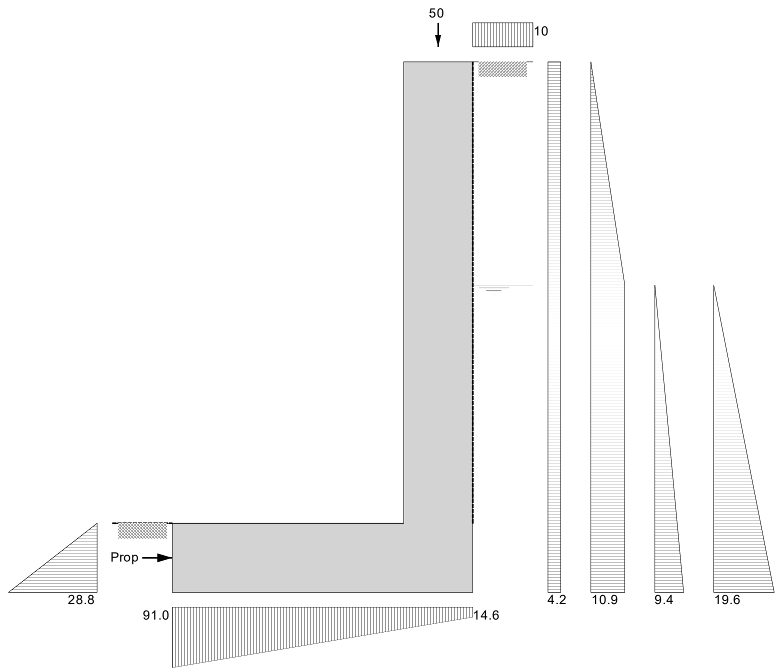
At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **10.0** kN/m^2
Applied vertical dead load on wall	W_{dead} = **41.7** kN/m
Applied vertical live load on wall	W_{live} = **8.7** kN/m
Position of applied vertical load on wall	l_{load} = **1725** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm

Architecture for London.	Project 23 Dartmouth Park Hill			Job Ref. 19047	
	Section Wall 9			Sheet no./rev. 3	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date



Loads shown in kN/m, pressures shown in kN/m[2]

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **31.9** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **20.7** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **50.4** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **103** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **14.5** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **73.3** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop} = **35.1** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **85.9** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **55** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2 =$ **20.2** kNm/m

Design vertical load $M_v = W_v \times l_{load} =$ **86.9** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_v =$ **162.1** kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot} =$ **76.2** kNm/m

Total vertical reaction $R = W_{total} =$ **103.0** kN/m

Distance to reaction $x_{bar} = M_{total} / R =$ **740** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) =$ **235** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) =$ **91** kN/m^2

Bearing pressure at heel $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) =$ **14.6** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **44.6** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **29** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **72.3** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **145.9** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **32.6** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **137.3** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **83.8** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **56.2** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **168.8** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **76.9** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **28.3** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **124.7** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **229.9** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **61.1** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **145.9** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **419** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **556** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **232.1** kN/m^2

Bearing pressure at heel	p_{heel_f} = 0 kN/m^2 = **0** kN/m^2
Rate of change of base reaction	rate = p_{toe_f} / (3 × x_{bar_f}) = **184.57** kN/m^2/m
Bearing pressure at stem / toe	$p_{stem\_toe\_f}$ = max(p_{toe_f} - (rate × l_{toe}), 0 kN/m^2) = **0** kN/m^2
Bearing pressure at mid stem	$p_{stem\_mid\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall} / 2)), 0 kN/m^2) = **0** kN/m^2
Bearing pressure at stem / heel	$p_{stem\_heel\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall})), 0 kN/m^2) = **0** kN/m^2

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

Material properties

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

Base details

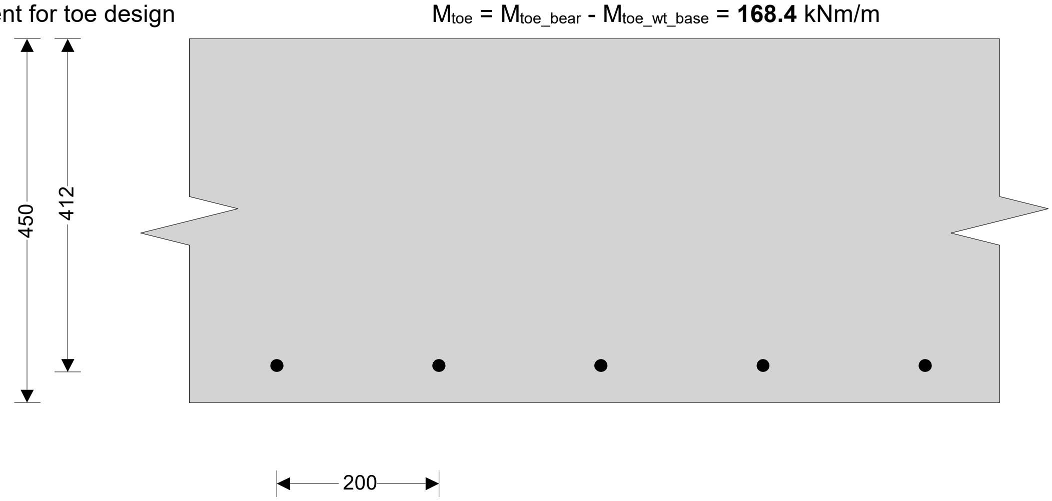
Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in toe	c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure	V_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} / 2 = **145.9** kN/m
Shear from weight of base	$V_{toe\_wt\_base}$ = γ_{f_d} × γ_{base} × l_{toe} × t_{base} = **22.3** kN/m
Total shear for toe design	V_{toe} = V_{toe_bear} - $V_{toe\_wt\_base}$ = **123.6** kN/m

Calculate moment for toe design

Moment from bearing pressure	M_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} × (l_{toe} - x_{bar_f} + t_{wall} / 2) / 2 = **190.5** kNm/m
Moment from weight of base	$M_{toe\_wt\_base}$ = (γ_{f_d} × γ_{base} × t_{base} × (l_{toe} + t_{wall} / 2)^2 / 2) = **22.1** kNm/m
Total moment for toe design	M_{toe} = M_{toe_bear} - $M_{toe\_wt\_base}$ = **168.4** kNm/m



Check toe in bending

Width of toe	b = **1000** mm/m
Depth of reinforcement	d_{toe} = t_{base} – c_{toe} – (ϕ_{toe} / 2) = **412.0** mm
Constant	K_{toe} = M_{toe} / (b × d_{toe}^2 × f_{cu}) = **0.025**

Compression reinforcement is not required

Lever arm	z_{toe} = min(0.5 + √(0.25 - (min(K_{toe}, 0.225) / 0.9)),0.95) × d_{toe}
	z_{toe} = **391** mm
Area of tension reinforcement required	$A_{s\_toe\_des}$ = M_{toe} / (0.87 × f_y × z_{toe}) = **989** mm^2/m
Minimum area of tension reinforcement	$A_{s\_toe\_min}$ = k × b × t_{base} = **585** mm^2/m

Area of tension reinforcement required	$A_{s\_toe\_req}$ = Max($A_{s\_toe\_des}$, $A_{s\_toe\_min}$) = **989** mm²/m
Reinforcement provided	**16 mm dia.bars @ 200 mm centres**
Area of reinforcement provided	$A_{s\_toe\_prov}$ = **1005** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress	$v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.300** N/mm²
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress	v_{c_toe} = **0.462** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete	f_{cu} = **40** N/mm²
Characteristic strength of reinforcement	f_y = **500** N/mm²

Wall details

Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in stem	c_{stem} = **40** mm
Cover to reinforcement in wall	c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

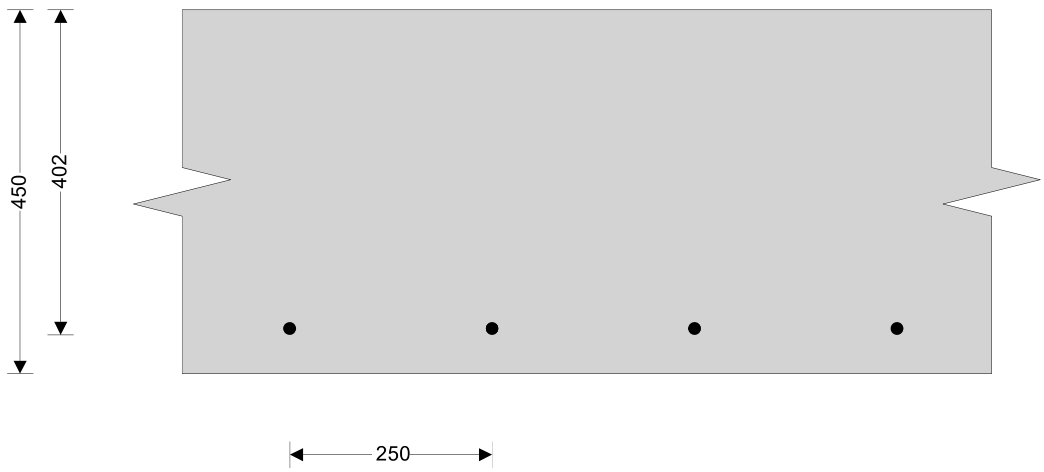
Surcharge	$F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **28.3** kN/m
Moist backfill above water table	$F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m
Moist backfill below water table	$F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m
Saturated backfill	$F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m
Water	$F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem	$V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **21.2** kN/m

Calculate moment for stem design

Surcharge	$M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **48.9** kNm/m
Moist backfill above water table	$M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m
Moist backfill below water table	$M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m
Saturated backfill	$M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m
Water	$M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m
Total moment for stem design	$M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **124.3** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **402.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.019**

Compression reinforcement is not required

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

z_{stem} = **382** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **748** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **585** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **748** mm²/m

Reinforcement provided — **16 mm dia.bars @ 250 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **804** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.053** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.432** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **310.2** N/mm²

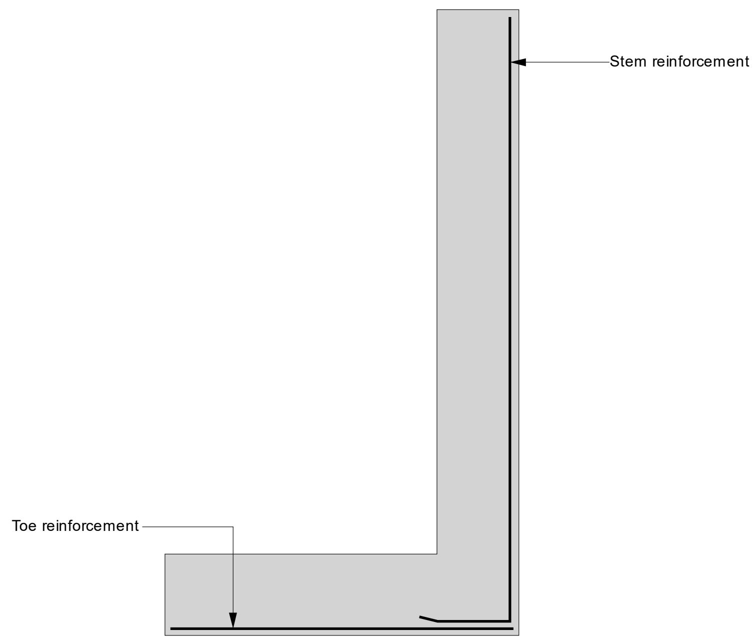
Modification factor — $factor_{tens} = \min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.38**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **9.68**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **7.46**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

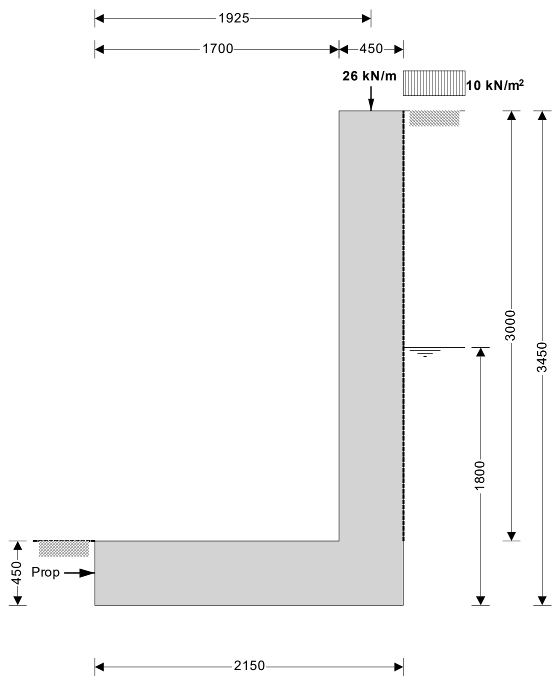


Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

Stem bars - 16 mm dia.@ 250 mm centres - (804 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **450** mm
Length of toe	l_{toe} = **1700** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **2150** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **1800** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **1350** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

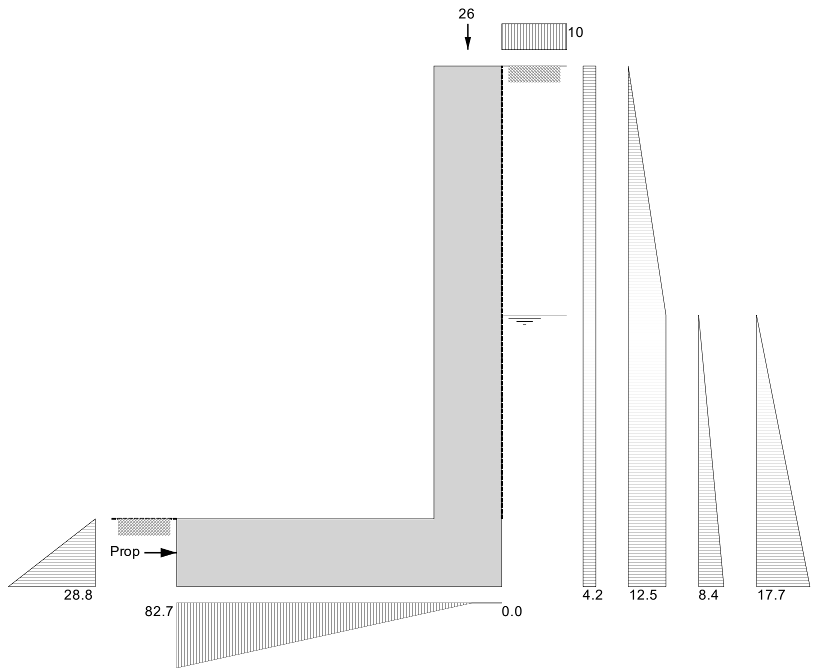
At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **10.0** kN/m^2
Applied vertical dead load on wall	W_{dead} = **21.4** kN/m
Applied vertical live load on wall	W_{live} = **4.5** kN/m
Position of applied vertical load on wall	l_{load} = **1925** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 10				Sheet no./rev. 3	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **31.9** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **22.8** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **26** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **80.7** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **14.5** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **10.3** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **22.4** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **7.6** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **15.9** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **70.7** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop} = **38.6** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **24.2** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **20.2** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **4.6** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **9.5** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **83.4** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **61.3** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2 =$ **24.5** kNm/m

Design vertical load — $M_v = W_v \times l_{load} =$ **50** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_v =$ **135.9** kNm/m

Check bearing pressure

Total moment for bearing — $M_{total} = M_{rest} - M_{ot} =$ **52.5** kNm/m

Total vertical reaction — $R = W_{total} =$ **80.7** kN/m

Distance to reaction — $x_{bar} = M_{total} / R =$ **650** mm

Eccentricity of reaction — $e = abs((l_{base} / 2) - x_{bar}) =$ **425** mm

Reaction acts outside middle third of base

Bearing pressure at toe — $p_{toe} = R / (1.5 \times x_{bar}) =$ **82.7** kN/m^2

Bearing pressure at heel — $p_{heel} = 0$ kN/m^2 = **0** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	γ_{f_d} = **1.4**
Live load factor	γ_{f_l} = **1.6**
Earth and water pressure factor	γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **44.6** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **32** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **37.3** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **113.8** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **32.6** kN/m
Moist backfill above water table	$F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **20.2** kN/m
Moist backfill below water table	$F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **44.2** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **15** kN/m
Water	$F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **22.2** kN/m
Total horizontal load	$F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **134.2** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m
Propping force	$F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop_f} = **89.3** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **56.2** kNm/m
Moist backfill above water table	$M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **47.6** kNm/m
Moist backfill below water table	$M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **39.7** kNm/m
Saturated backfill	$M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **9** kNm/m
Water	$M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.3** kNm/m
Total overturning moment	$M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **165.8** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **85.9** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **34.4** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **71.7** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **191.9** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **26.1** kNm/m
Total vertical reaction	$R_f = W_{total\_f}$ = **113.8** kN/m
Distance to reaction	$x_{bar\_f} = M_{total\_f} / R_f$ = **229** mm
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **846** mm

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **330.8** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction rate = p_{toe_f} / (3 × x_{bar_f}) = **480.80** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f}$ = max(p_{toe_f} - (rate × l_{toe}), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall} / 2)), 0 kN/m^2) = **0** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f}$ = max(p_{toe_f} - (rate × (l_{toe} + t_{wall})), 0 kN/m^2) = **0** kN/m^2

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in toe c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure V_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} / 2 = **113.8** kN/m

Shear from weight of base $V_{toe\_wt\_base}$ = γ_{f_d} × γ_{base} × l_{toe} × t_{base} = **25.3** kN/m

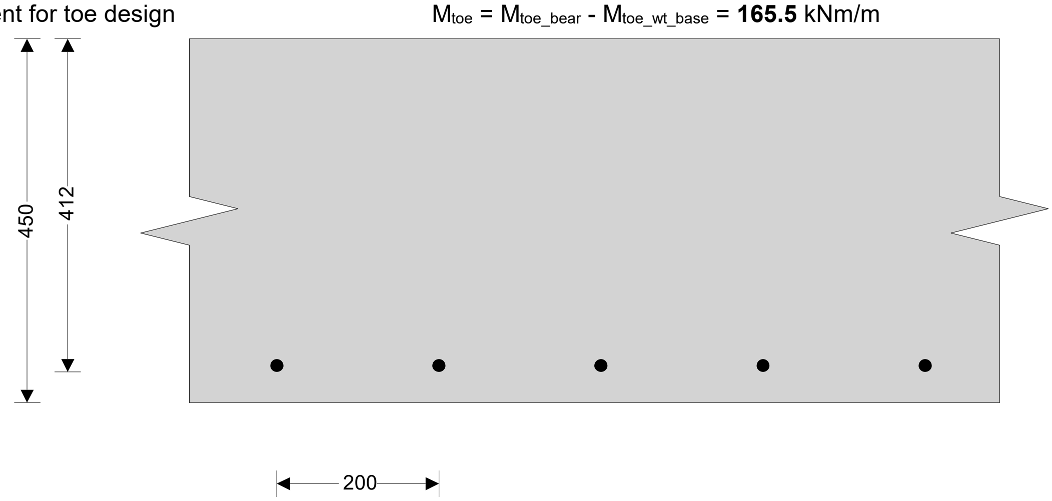
Total shear for toe design V_{toe} = V_{toe_bear} - $V_{toe\_wt\_base}$ = **88.6** kN/m

Calculate moment for toe design

Moment from bearing pressure M_{toe_bear} = 3 × p_{toe_f} × x_{bar_f} × (l_{toe} - x_{bar_f} + t_{wall} / 2) / 2 = **193** kNm/m

Moment from weight of base $M_{toe\_wt\_base}$ = (γ_{f_d} × γ_{base} × t_{base} × (l_{toe} + t_{wall} / 2)^2 / 2) = **27.5** kNm/m

Total moment for toe design M_{toe} = M_{toe_bear} - $M_{toe\_wt\_base}$ = **165.5** kNm/m



Check toe in bending

Width of toe b = **1000** mm/m

Depth of reinforcement d_{toe} = t_{base} – c_{toe} – (ϕ_{toe} / 2) = **412.0** mm

Constant K_{toe} = M_{toe} / (b × d_{toe}^2 × f_{cu}) = **0.024**

Compression reinforcement is not required

Lever arm z_{toe} = min(0.5 + √(0.25 - (min(K_{toe}, 0.225) / 0.9)),0.95) × d_{toe}

z_{toe} = **391** mm

Area of tension reinforcement required $A_{s\_toe\_des}$ = M_{toe} / (0.87 × f_y × z_{toe}) = **972** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min}$ = k × b × t_{base} = **585** mm^2/m

Area of tension reinforcement required	$A_{s\_toe\_req}$ = Max($A_{s\_toe\_des}$, $A_{s\_toe\_min}$) = **972** mm²/m
Reinforcement provided	**16 mm dia.bars @ 200 mm centres**
Area of reinforcement provided	$A_{s\_toe\_prov}$ = **1005** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress	$v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.215** N/mm²
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress	v_{c_toe} = **0.462** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete	f_{cu} = **40** N/mm²
Characteristic strength of reinforcement	f_y = **500** N/mm²

Wall details

Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in stem	c_{stem} = **40** mm
Cover to reinforcement in wall	c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

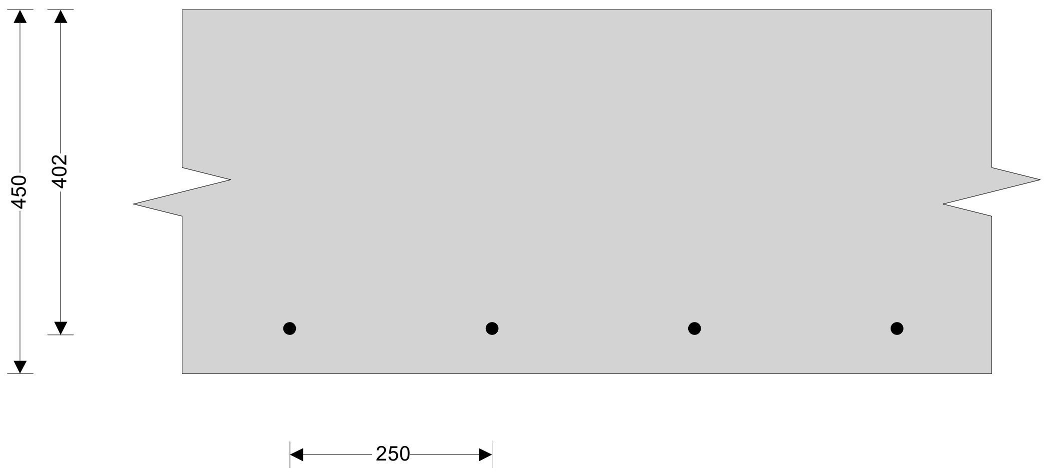
Surcharge	$F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **28.3** kN/m
Moist backfill above water table	$F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **20.2** kN/m
Moist backfill below water table	$F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.1** kN/m
Saturated backfill	$F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **8.4** kN/m
Water	$F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **12.5** kN/m

Calculate shear for stem design

Shear at base of stem	$V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **13.4** kN/m

Calculate moment for stem design

Surcharge	$M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **48.9** kNm/m
Moist backfill above water table	$M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **43** kNm/m
Moist backfill below water table	$M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **22.4** kNm/m
Saturated backfill	$M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **3.8** kNm/m
Water	$M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **5.6** kNm/m
Total moment for stem design	$M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **123.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **402.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.019**

Compression reinforcement is not required

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

z_{stem} = **382** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **744** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **585** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **744** mm²/m

Reinforcement provided — **16 mm dia.bars @ 250 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **804** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.033** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \mathrm{N/mm^2})}, 5) \times 1\ \mathrm{N/mm^2}$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.432** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **308.5** N/mm²

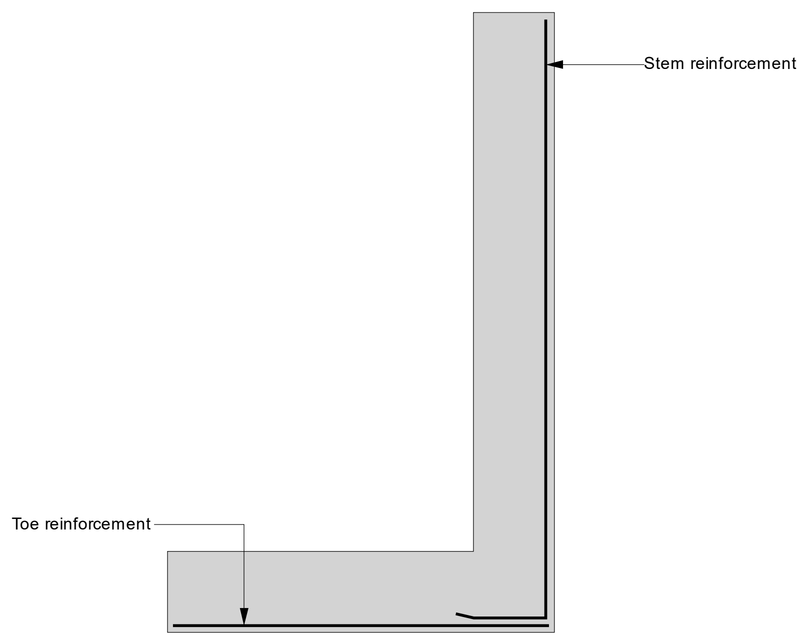
Modification factor — $factor_{tens} = \min(0.55 + (477\ \mathrm{N/mm^2} - f_s)/(120 \times (0.9\ \mathrm{N/mm^2} + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.39**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **9.75**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **7.46**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

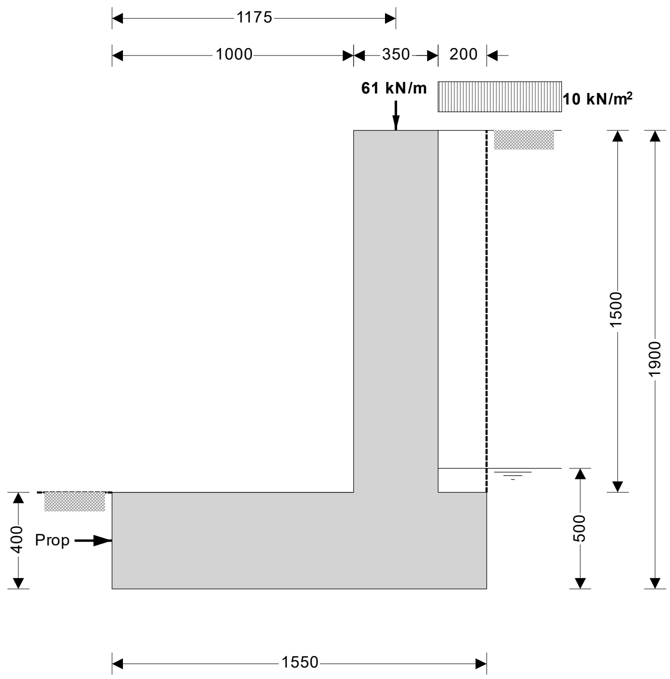


Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

Stem bars - 16 mm dia.@ 250 mm centres - (804 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **1500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **200** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1550** mm
Thickness of base	t_{base} = **400** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **400** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1900** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **500** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **100** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **1900** mm

Retained material details

Mobilisation factor M = **1.5**

Moist density of retained material γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **0.0** deg

Base material details

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio $r_a = \beta / \phi'$ = **0.00**

Wall friction ratio $r_b = \delta / \phi'$ = **0.00**

Active pressure coefficient for retained material K_a = **0.419**

Passive pressure coefficient for base material

Slope angle ratio r_a = 0 deg / ϕ'_b = **0.00**

Wall friction ratio $r_b = \delta_b / \phi'_b$ = **0.77**

Passive pressure coefficient for base material K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **49.6** kN/m

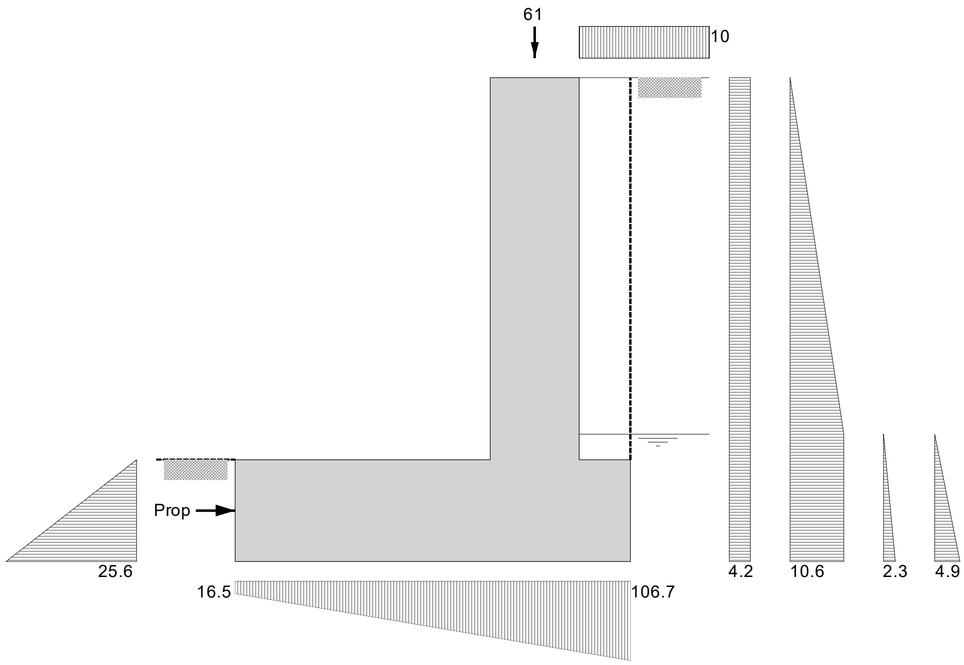
Applied vertical live load on wall W_{live} = **11.5** kN/m

Position of applied vertical load on wall l_{load} = **1175** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



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

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **12.4** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **14.6** kN/m
Surcharge	w_{sur} = Surcharge $\times\ l_{heel}$ = **2** kN/m
Moist backfill to top of wall	$w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **5** kN/m
Saturated backfill	$w_s = l_{heel} \times h_{sat} \times \gamma_s$ = **0.4** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **61.1** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + w_s + W_v$ = **95.5** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times$ Surcharge $\times\ h_{eff}$ = **8** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **5.3** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **0.6** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **1.2** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **22.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **5.1** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - w_{sur} - W_{live}) \times \tan(\delta_b), 0$ kN/m)
	F_{prop} = **0.0** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **7.6** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **7.2** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **1.3** kNm/m

Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 =$ **0.1** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 =$ **0.2** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water} =$ **16.3** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **14.6** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2 =$ **11.3** kNm/m
Surcharge	$M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2) =$ **2.9** kNm/m
Moist backfill	$M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3)) =$ **7.3** kNm/m
Saturated backfill	$M_{s\_r} = w_s \times (l_{base} - l_{heel} / 2) =$ **0.6** kNm/m
Design vertical load	$M_v = W_v \times l_{load} =$ **71.7** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{sur\_r} + M_{m\_r} + M_{s\_r} + M_v =$ **108.4** kNm/m

Check bearing pressure

Total moment for bearing	$M_{total} = M_{rest} - M_{ot} =$ **92.1** kNm/m
Total vertical reaction	$R = W_{total} =$ **95.5** kN/m
Distance to reaction	$x_{bar} = M_{total} / R =$ **964** mm
Eccentricity of reaction	$e = abs((l_{base} / 2) - x_{bar}) =$ **189** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) =$ **16.5** kN/m^2
Bearing pressure at heel	$p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) =$ **106.7** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **17.3** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **20.5** kN/m

Surcharge $w_{sur\_f} = \gamma_{f\_l} \times Surcharge \times l_{heel}$ = **3.2** kN/m

Moist backfill to top of wall $w_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **7.1** kN/m

Saturated backfill $w_{s\_f} = \gamma_{f\_d} \times l_{heel} \times h_{sat} \times \gamma_s$ = **0.6** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **87.8** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{m\_w\_f} + w_{s\_f} + W_{v\_f}$ = **136.4** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **17.9** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **14.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **10.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **1.2** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **1.7** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **45.8** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **7.2** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - w_{sur\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0\ kN/m)$

F_{prop_f} = **0.0** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **17** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **14.1** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **2.6** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.2** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **34.2** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **20.4** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **15.9** kNm/m

Surcharge $M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2)$ = **4.6** kNm/m

Moist backfill $M_{m\_r\_f} = (w_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + w_{m\_s\_f} \times (l_{base} - l_{heel} / 3))$ = **10.2** kNm/m

Saturated backfill $M_{s\_r\_f} = w_{s\_f} \times (l_{base} - l_{heel} / 2)$ = **0.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **103.1** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} + M_{s\_r\_f} + M_{v\_f}$ = **155.1** kNm/m

Factored bearing pressure

Total moment for bearing — $M_{total\_f} = M_{rest\_f} - M_{ot\_f} = \mathbf{120.9}$ kNm/m

Total vertical reaction — $R_f = W_{total\_f} = \mathbf{136.4}$ kN/m

Distance to reaction — $x_{bar\_f} = M_{total\_f} / R_f = \mathbf{886}$ mm

Eccentricity of reaction — $e_f = abs((l_{base} / 2) - x_{bar\_f}) = \mathbf{111}$ mm

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2) = \mathbf{50.2}$ kN/m^2

Bearing pressure at heel — $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = \mathbf{125.9}$ kN/m^2

Rate of change of base reaction — $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base} = \mathbf{-48.83}$ kN/m^2/m

Bearing pressure at stem / toe — $p_{stem\_toe\_f} = max(p_{heel\_f} + (rate \times (l_{heel} + t_{wall})), 0\ kN/m^2) = \mathbf{99}$ kN/m^2

Bearing pressure at mid stem — $p_{stem\_mid\_f} = max(p_{heel\_f} + (rate \times (l_{heel} + t_{wall} / 2)), 0\ kN/m^2) = \mathbf{107.6}$ kN/m^2

Bearing pressure at stem / heel — $p_{stem\_heel\_f} = max(p_{heel\_f} + (rate \times l_{heel}), 0\ kN/m^2) = \mathbf{116.1}$ kN/m^2

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

Material properties

Characteristic strength of concrete — $f_{cu} = \mathbf{40}$ N/mm^2

Characteristic strength of reinforcement — $f_y = \mathbf{500}$ N/mm^2

Base details

Minimum area of reinforcement — $k = \mathbf{0.13}$ %

Cover to reinforcement in toe — $c_{toe} = \mathbf{30}$ mm

Calculate shear for toe design

Shear from bearing pressure — $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{74.6}$ kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{13.2}$ kN/m

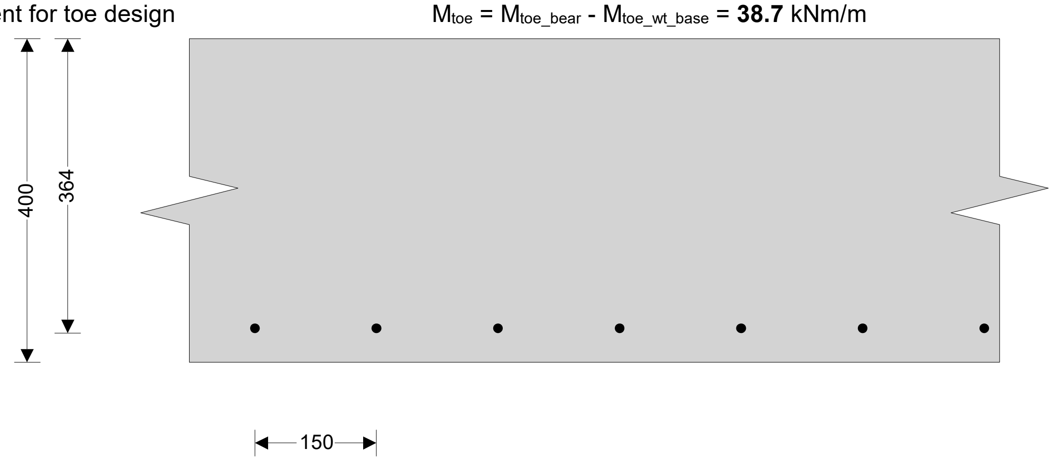
Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{61.4}$ kN/m

Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{47.8}$ kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{9.1}$ kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{38.7}$ kNm/m



Check toe in bending

Width of toe — $b = \mathbf{1000}$ mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{364.0}$ mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.007**

Compression reinforcement is not required

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

z_{toe} = **346** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **257** mm²/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base}$ = **520** mm²/m

Area of tension reinforcement required $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **520** mm²/m

Reinforcement provided **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov}$ = **754** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.169** N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.448** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall heel (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in heel c_{heel} = **30** mm

Calculate shear for heel design

Shear from bearing pressure $V_{heel\_bear} = (p_{heel\_f} + p_{stem\_heel\_f}) \times l_{heel} / 2$ = **24.2** kN/m

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base}$ = **2.6** kN/m

Shear from weight of moist backfill $V_{heel\_wt\_m} = w_{m\_w\_f}$ = **7.1** kN/m

Shear from weight of saturated backfill $V_{heel\_wt\_s} = w_{s\_f}$ = **0.6** kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f}$ = **3.2** kN/m

Total shear for heel design $V_{heel} = - V_{heel\_bear} + V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_wt\_s} + V_{heel\_sur}$ = **-10.7** kN/m

Calculate moment for heel design

Moment from bearing pressure $M_{heel\_bear} = (2 \times p_{heel\_f} + p_{stem\_mid\_f}) \times (l_{heel} + t_{wall} / 2)^2 / 6$ = **8.4** kNm/m

Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2)$ = **0.9** kNm/m

Moment from weight of moist backfill $M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2$ = **1.9** kNm/m

Moment from weight of saturated backfill $M_{heel\_wt\_s} = w_{s\_f} \times (l_{heel} + t_{wall}) / 2$ = **0.2** kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2$ = **0.9** kNm/m

Total moment for heel design $M_{heel} = - M_{heel\_bear} + M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_wt\_s} + M_{heel\_sur}$ = **-4.5** kNm/m

As the moment is negative the design of the retaining wall heel is beyond the scope of this calculation

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement — f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in stem — c_{stem} = **40** mm

Cover to reinforcement in wall — c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge — $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **14.2** kN/m

Moist backfill above water table — $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **14.6** kN/m

Moist backfill below water table — $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **2.1** kN/m

Saturated backfill — $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **0** kN/m

Water — $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **0.1** kN/m

Calculate shear for stem design

Shear at base of stem — $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f}$ = **30.9** kN/m

Calculate moment for stem design

Surcharge — $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **13.5** kNm/m

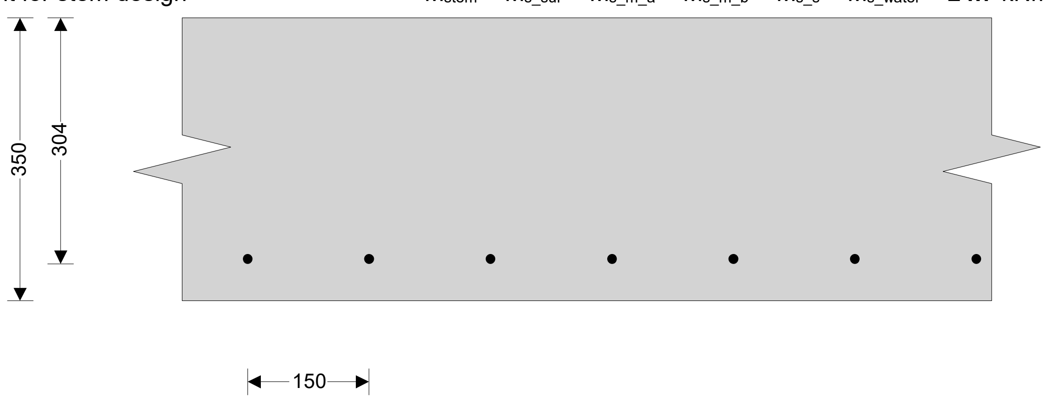
Moist backfill above water table — $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **11.2** kNm/m

Moist backfill below water table — $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **0.1** kNm/m

Saturated backfill — $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **0** kNm/m

Water — $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **0** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **24.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **304.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.007**

Compression reinforcement is not required

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

z_{stem} = **289** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **197** mm^2/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **455** mm^2/m

Area of tension reinforcement required $A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **455** mm^2/m

Reinforcement provided **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_stem\_prov}$ = **754** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.102** N/mm^2

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_stem} = **0.497** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas}$ = **7**

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **201.2** N/mm^2

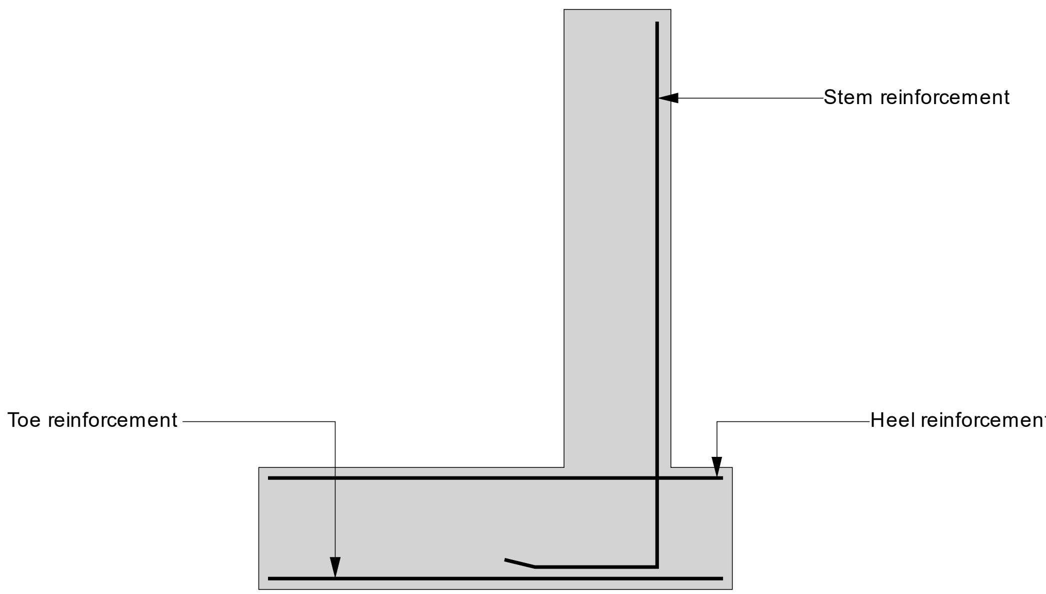
Modification factor $factor_{tens} = min(0.55 + (477 N/mm^2 - f_s)/(120 \times (0.9 N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **2.00**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **14.00**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **4.93**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

The design of the retaining wall heel is beyond the scope of this calculation!

Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

Architecture for London.	Project: 23 Dartmouth Park Hill	Job no.	
	Calcs for: Retaining wall Design	Start page no./Revision	
	Client	Calcs by: BS	Calcs date

* Wall 12

Load:-

	Dead	Live
- Masonry wall (h= 3.0m) (4.3)	12.9	—
- Ground floor (9.1/2)(1.0, 1.5)	4.55	6.83
- First floor (9.1/2) (1.0, 1.5)	4.55	6.83
- Second floor (9.1/2) (1.0, 1.5)	4.55	6.83
- Loft (9.1/2) (1.0, 1.5)	4.55	6.83
- Roof (9.1/2) (0.83, 0.75)	3.78	3.413
Total load	34.88	30.733

* Surcharge = 10kN/m²
* Water level = 1.0m (B.G.L) Assumed

* Wall 13

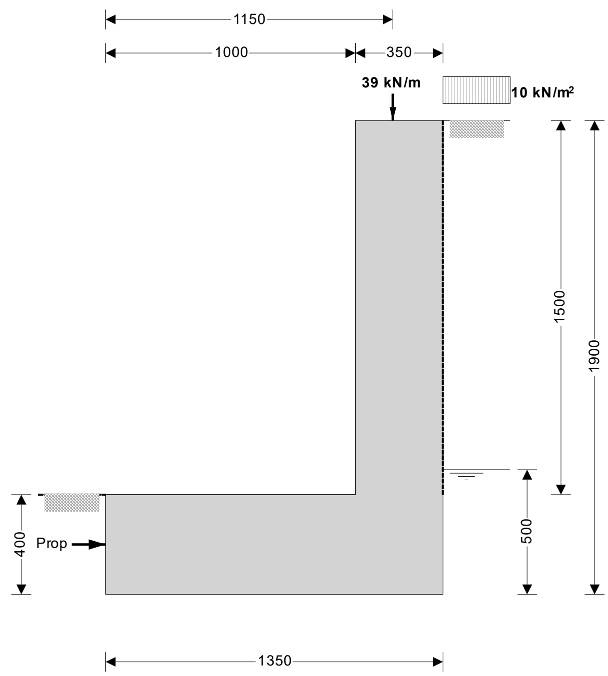
Load:-

	Dead	Live
- Masonry wall (h= 3.0m) (4.3)	12.9	—
- Ground floor (5.4/2) (1.0, 1.5)	2.7	4.0
- First floor (5.4/2) (1.0, 1.5)	2.7	4.0
- Second floor (5.4/2) (1.0, 1.5)	2.7	4.0
- Loft (5.4/2) (1.0, 1.5)	2.7	4.0
- Roof (5.4/2) (0.83, 0.75)	2.241	2.03
Total load	25.941	18.03

* Surcharge = 10kN/m²
* Water level = 1.0m (B.G.L) Assumed

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **1500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1350** mm
Thickness of base	t_{base} = **400** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **400** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1900** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **500** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **100** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **1900** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

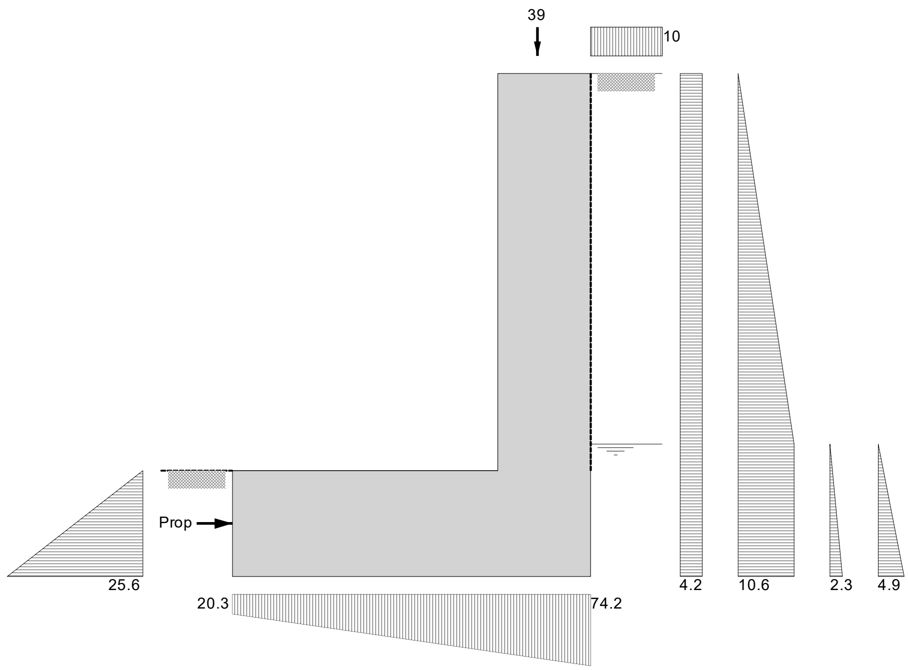
Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **10.0** kN/m^2
Applied vertical dead load on wall	W_{dead} = **34.9** kN/m
Applied vertical live load on wall	W_{live} = **3.7** kN/m
Position of applied vertical load on wall	l_{load} = **1150** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **12.4** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **12.7** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **38.6** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **63.7** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **8** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **5.3** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **0.6** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **1.2** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **22.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **5.1** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0\text{ kN/m})$
	F_{prop} = **0.0** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **7.6** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **7.2** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **1.3** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.1** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.2** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **16.3** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **14.6** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **8.6** kNm/m
Design vertical load	$M_v = W_v \times l_{load}$ = **44.4** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_v$ = **67.6** kNm/m

Check bearing pressure

Total moment for bearing	$M_{total} = M_{rest} - M_{ot}$ = **51.2** kNm/m
Total vertical reaction	$R = W_{total}$ = **63.7** kN/m
Distance to reaction	$x_{bar} = M_{total} / R$ = **803** mm
Eccentricity of reaction	$e = abs((l_{base} / 2) - x_{bar})$ = **128** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **20.3** kN/m^2
Bearing pressure at heel	$p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **74.2** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	γ_{f_d} = **1.4**
Live load factor	γ_{f_l} = **1.6**
Earth and water pressure factor	γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **17.3** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **17.8** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **54.8** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **90** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **17.9** kN/m
Moist backfill above water table	$F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **14.6** kN/m
Moist backfill below water table	$F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **10.4** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **1.2** kN/m
Water	$F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **1.7** kN/m
Total horizontal load	$F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **45.8** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **7.2** kN/m
Propping force	$F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop_f} = **10.3** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **17** kNm/m
Moist backfill above water table	$M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **14.1** kNm/m
Moist backfill below water table	$M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **2.6** kNm/m
Saturated backfill	$M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.2** kNm/m
Water	$M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.3** kNm/m
Total overturning moment	$M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **34.2** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **20.4** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **12** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **63** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **95.5** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **61.2** kNm/m
Total vertical reaction	$R_f = W_{total\_f}$ = **90.0** kN/m
Distance to reaction	$x_{bar\_f} = M_{total\_f} / R_f$ = **681** mm
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **6** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **65** kN/m^2

Bearing pressure at heel	$p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) =$ **68.3** kN/m^2
Rate of change of base reaction	rate $= (p_{toe\_f} - p_{heel\_f}) / l_{base} =$ **-2.42** kN/m^2/m
Bearing pressure at stem / toe	$p_{stem\_toe\_f} = \max(p_{heel\_f} + (\text{rate} \times (l_{heel} + t_{wall})), 0\ \text{kN/m}^2) =$ **67.4** kN/m^2
Bearing pressure at mid stem	$p_{stem\_mid\_f} = \max(p_{heel\_f} + (\text{rate} \times (l_{heel} + t_{wall} / 2)), 0\ \text{kN/m}^2) =$ **67.9** kN/m^2
Bearing pressure at stem / heel	$p_{stem\_heel\_f} = \max(p_{heel\_f} + (\text{rate} \times l_{heel}), 0\ \text{kN/m}^2) =$ **68.3** kN/m^2

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

Material properties

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

Base details

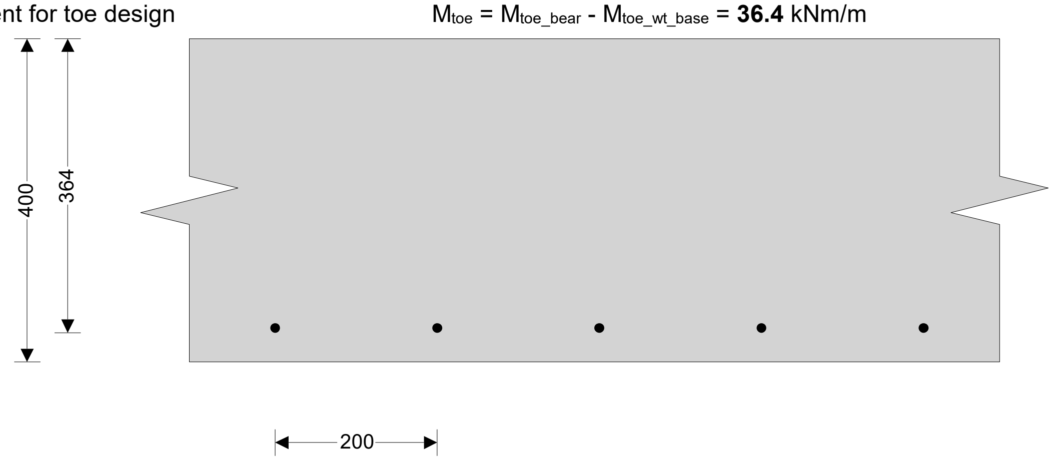
Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in toe	$c_{toe} =$ **30** mm

Calculate shear for toe design

Shear from bearing pressure	$V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **66.2** kN/m
Shear from weight of base	$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **13.2** kN/m
Total shear for toe design	$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **53** kN/m

Calculate moment for toe design

Moment from bearing pressure	$M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **45.5** kNm/m
Moment from weight of base	$M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **9.1** kNm/m
Total moment for toe design	$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **36.4** kNm/m



Check toe in bending

Width of toe	b = **1000** mm/m
Depth of reinforcement	$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **364.0** mm
Constant	$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.007**
	Compression reinforcement is not required
Lever arm	$z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
	$z_{toe} =$ **346** mm
Area of tension reinforcement required	$A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **242** mm^2/m
Minimum area of tension reinforcement	$A_{s\_toe\_min} = k \times b \times t_{base} =$ **520** mm^2/m
Area of tension reinforcement required	$A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **520** mm^2/m

Reinforcement provided **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov}$ = **565** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.146** N/mm^2

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.407** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **40** mm

Cover to reinforcement in wall c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **14.2** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **14.6** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **2.1** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **0** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **0.1** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **20.6** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **13.5** kNm/m

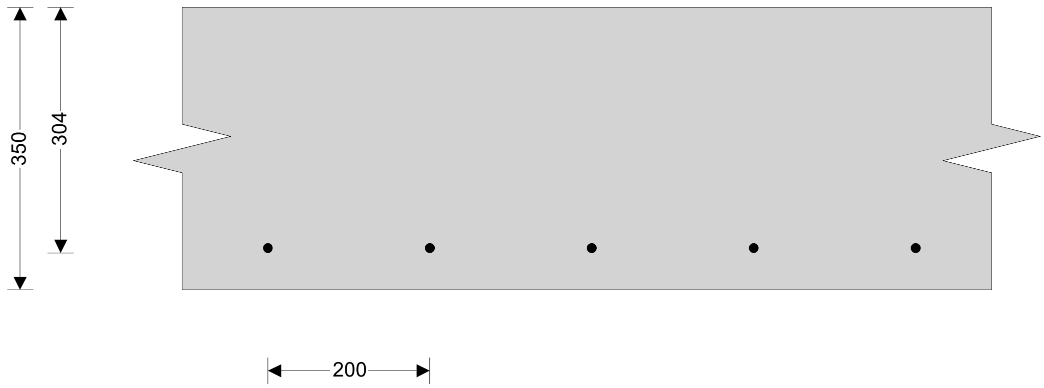
Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **11.2** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **0.1** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **0** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **0** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **24.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **304.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.007**

Compression reinforcement is not required

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

z_{stem} = **289** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **197** mm^2/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **455** mm^2/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **455** mm^2/m

Reinforcement provided — **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **565** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.068** N/mm^2

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.452** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **268.2** N/mm^2

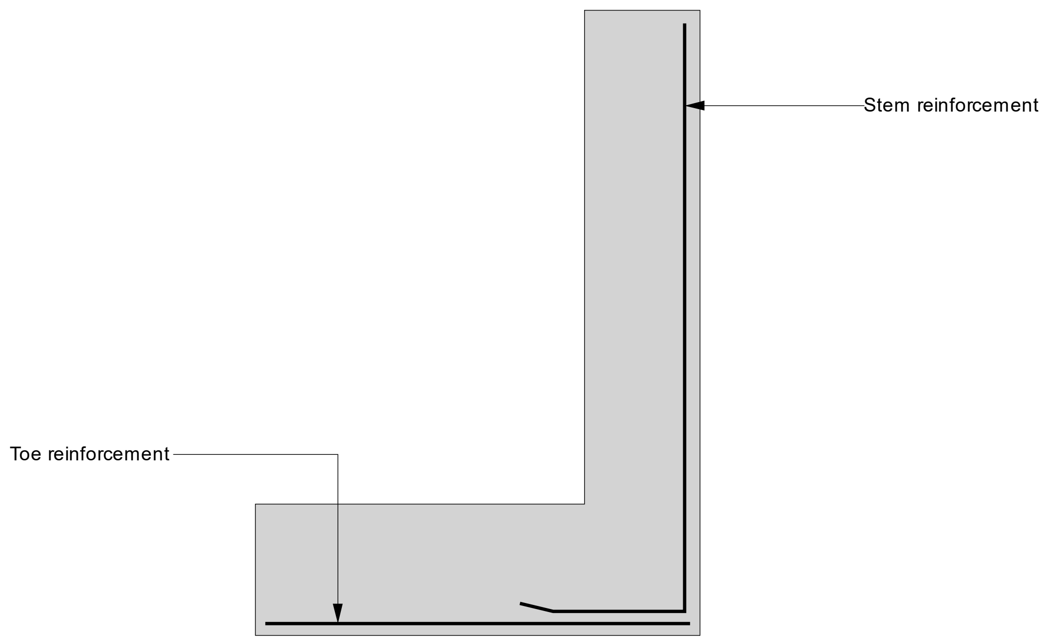
Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **2.00**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **14.00**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **4.93**

PASS - Span to depth ratio is acceptable

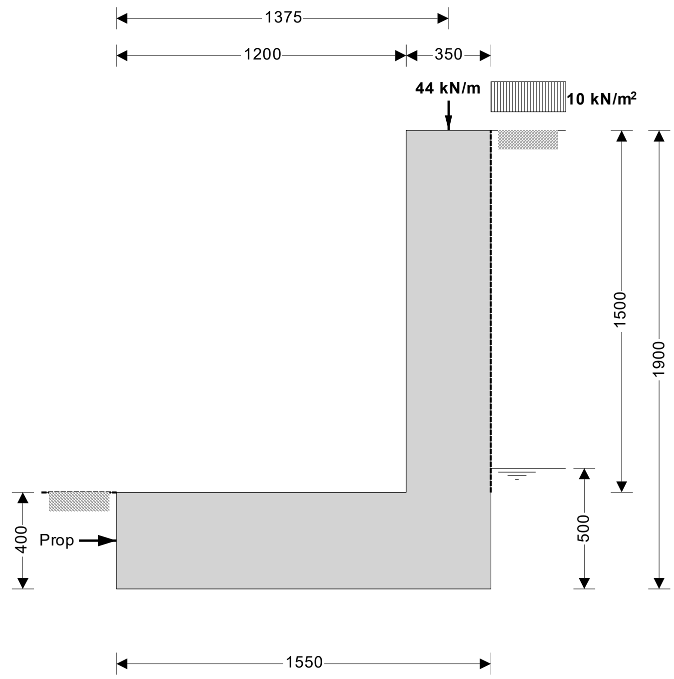
Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)
Stem bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **1500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1200** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1550** mm
Thickness of base	t_{base} = **400** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **400** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1900** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **500** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **100** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **1900** mm

Retained material details

Mobilisation factor M = **1.5**

Moist density of retained material γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **0.0** deg

Base material details

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio $r_a = \beta / \phi'$ = **0.00**

Wall friction ratio $r_b = \delta / \phi'$ = **0.00**

Active pressure coefficient for retained material K_a = **0.419**

Passive pressure coefficient for base material

Slope angle ratio r_a = 0 deg / ϕ'_b = **0.00**

Wall friction ratio $r_b = \delta_b / \phi'_b$ = **0.77**

Passive pressure coefficient for base material K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **25.9** kN/m

Applied vertical live load on wall W_{live} = **18.0** kN/m

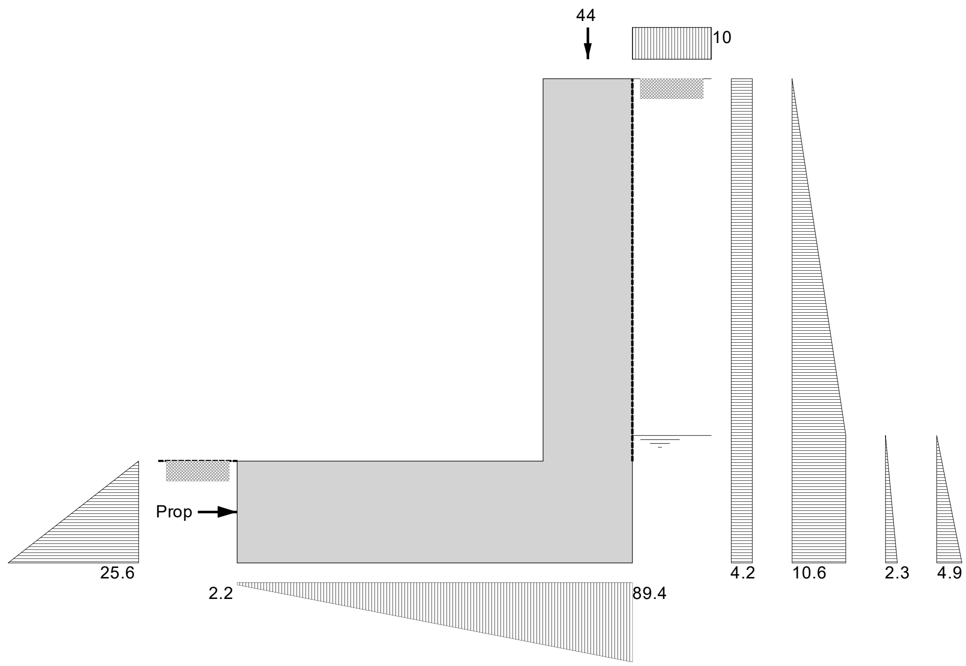
Position of applied vertical load on wall l_{load} = **1375** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 13				Sheet no./rev. 3	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **12.4** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **14.6** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **44** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **71** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **8** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **5.3** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **0.6** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **1.2** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **22.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **5.1** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0\ \text{kN/m})$

F_{prop} = **0.0** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **7.6** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **7.2** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **1.3** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.1** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.2** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **16.3** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **17** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2 =$ **11.3** kNm/m

Design vertical load $M_v = W_v \times l_{load} =$ **60.5** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_v =$ **88.8** kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot} =$ **72.5** kNm/m

Total vertical reaction $R = W_{total} =$ **71.0** kN/m

Distance to reaction $x_{bar} = M_{total} / R =$ **1021** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) =$ **246** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) =$ **2.2** kN/m^2

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) =$ **89.4** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

Architecture for London.	Project 23 Dartmouth Park Hill			Job Ref. 19047	
	Section Wall 13			Sheet no./rev. 5	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **17.3** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **20.5** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **65.2** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **103** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **17.9** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **14.6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **10.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **1.2** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **1.7** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **45.8** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **7.2** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **13.7** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **17** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **14.1** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **2.6** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.2** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **0.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **34.2** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **23.9** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **15.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **89.6** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **129.3** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **95.1** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **103.0** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **924** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **149** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **28.2** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = \mathbf{104.7}$ kN/m^2

Rate of change of base reaction rate $= (p_{toe\_f} - p_{heel\_f}) / l_{base} = \mathbf{-49.30}$ kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{heel\_f} + (rate \times (l_{heel} + t_{wall})), 0$ kN/m$^2) = \mathbf{87.4}$ kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{heel\_f} + (rate \times (l_{heel} + t_{wall} / 2)), 0$ kN/m$^2) = \mathbf{96}$ kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{heel\_f} + (rate \times l_{heel}), 0$ kN/m$^2) = \mathbf{104.7}$ kN/m^2

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

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}$ N/mm^2

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm^2

Base details

Minimum area of reinforcement $k = \mathbf{0.13}$ %

Cover to reinforcement in toe $c_{toe} = \mathbf{30}$ mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{69.4}$ kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{15.9}$ kN/m

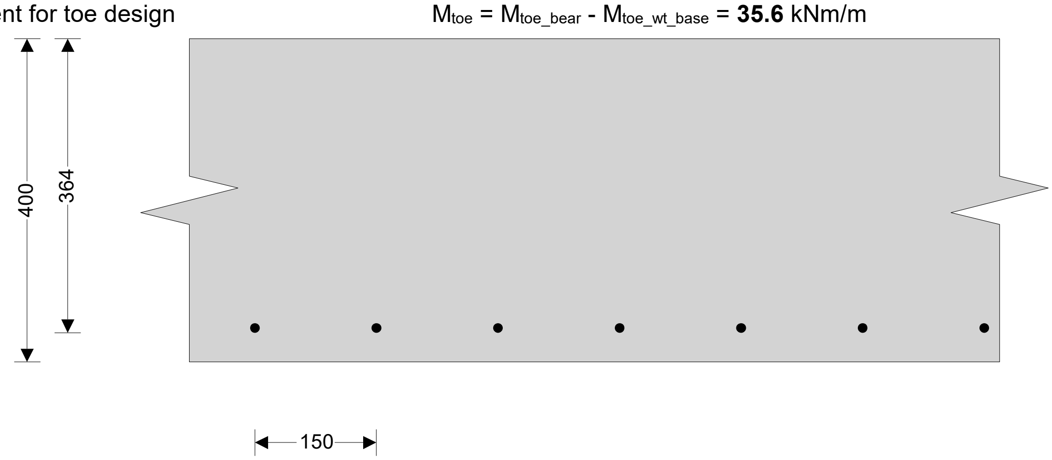
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{53.5}$ kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{48.1}$ kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{12.5}$ kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{35.6}$ kNm/m



Check toe in bending

Width of toe $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{364.0}$ mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.007}$

Compression reinforcement is not required

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

$z_{toe} = \mathbf{346}$ mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{236}$ mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{520}$ mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{520}$ mm^2/m

Reinforcement provided — **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided — $A_{s\_toe\_prov}$ = **754** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.147** N/mm^2

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_toe} = **0.448** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement — f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in stem — c_{stem} = **40** mm

Cover to reinforcement in wall — c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge — $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **14.2** kN/m

Moist backfill above water table — $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **14.6** kN/m

Moist backfill below water table — $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **2.1** kN/m

Saturated backfill — $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **0** kN/m

Water — $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **0.1** kN/m

Calculate shear for stem design

Shear at base of stem — $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **17.3** kN/m

Calculate moment for stem design

Surcharge — $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **13.5** kNm/m

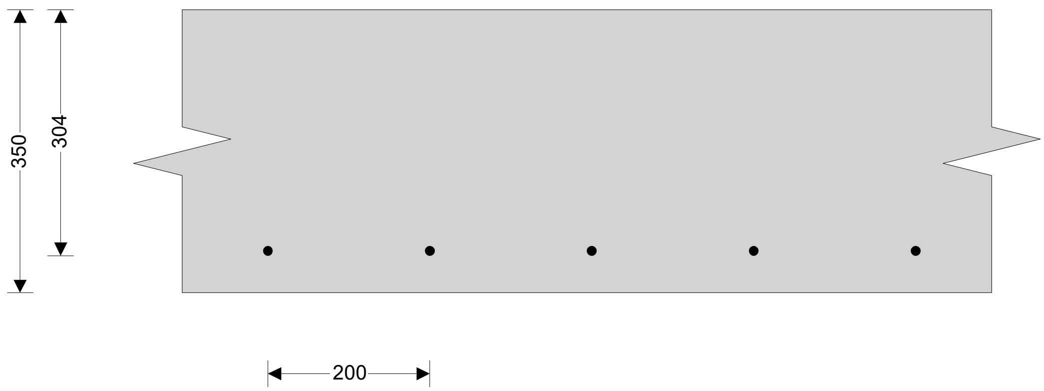
Moist backfill above water table — $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **11.2** kNm/m

Moist backfill below water table — $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **0.1** kNm/m

Saturated backfill — $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **0** kNm/m

Water — $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **0** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **24.7** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **304.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.007**

Compression reinforcement is not required

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

z_{stem} = **289** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **197** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **455** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \max(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **455** mm²/m

Reinforcement provided — **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **565** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.057** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.452** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **268.2** N/mm²

Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **2.00**

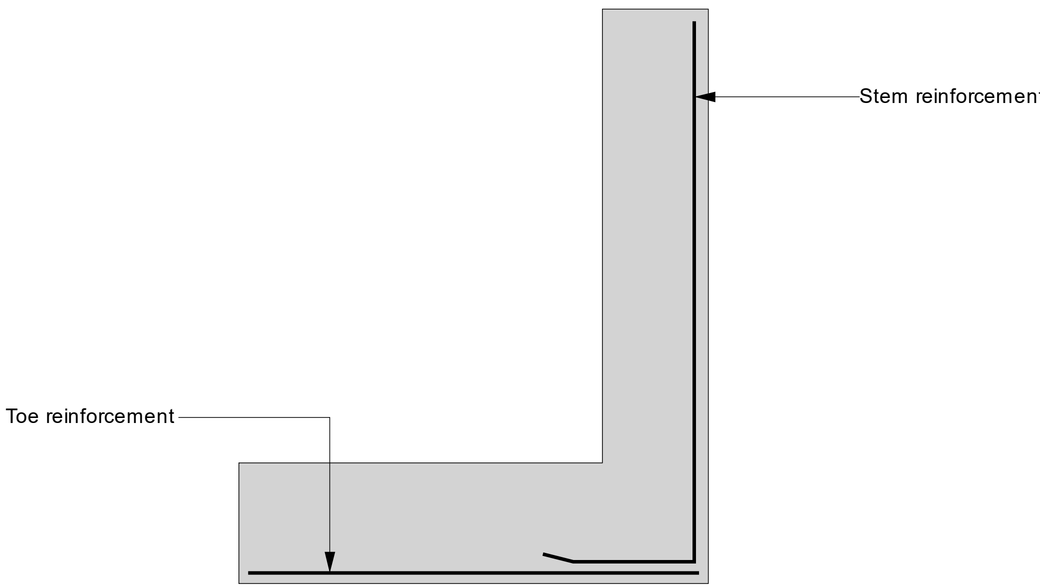
Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **14.00**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **4.93**

PASS - Span to depth ratio is acceptable

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 13				Sheet no./rev. 9	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)

Architecture for London.	Project: 23 Dartmouth Park Hill	Job no.
	Calcs for: Retaining wall Design	Start page no./Revision
	Client	Calcs by: BS / Calcs date

* Wall 14

Load:-	Dead	Live
- Beam & Block (7.1/2) (5.85, 1.5)	20.77	5.33
- Rear wall (h=9.5m) (4.3)	40.85	–
- First Floor (4.4/2) (1.0, 1.5)	2.2	3.3
- Ground Floor (4.4/2) (1.0, 1.5)	2.2	3.3
- Second Floor (4.4/2) (1.0, 1.5)	2.2	3.3
- Loft (4.4/2) (1.0, 1.5)	2.2	3.3
- Pitched Roof $\alpha = 30°$ (5.3/2) (0.83, 0.75)	2.2	2.0
Total	72.62	20.53

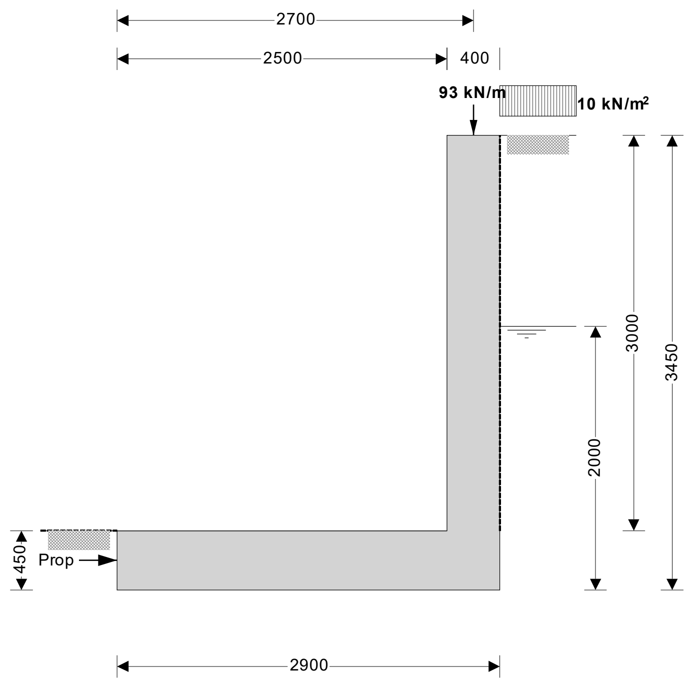
* Surcharge = 10 kN/m²

* Water level = 1.0m (B.G.L) Assumed

Architecture for London.	Project 23 Dartmouth Park Hill				Job Ref. 19047	
	Section Wall 14				Sheet no./rev. 1	
	Calc. by BS	Date 23/01/2020	Chk'd by	Date	App'd by	Date

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **400** mm
Length of toe	l_{toe} = **2500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **2900** mm
Thickness of base	t_{base} = **450** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **2450** mm
Thickness of downstand	t_{ds} = **450** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3450** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **1550** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3450** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **24.2** deg
Angle of wall friction	δ = **0.0** deg

Base material details

Moist density	γ_{mb} = **18.0** kN/m^3
Design shear strength	ϕ'_b = **24.2** deg
Design base friction	δ_b = **18.6** deg
Allowable bearing pressure	$P_{bearing}$ = **110** kN/m^2

Based on Kerisel & Absi - 'Active and passive earth pressure tables'

Active pressure coefficient for retained material

Slope angle ratio	$r_a = \beta / \phi'$ = **0.00**
Wall friction ratio	$r_b = \delta / \phi'$ = **0.00**
Active pressure coefficient for retained material	K_a = **0.419**

Passive pressure coefficient for base material

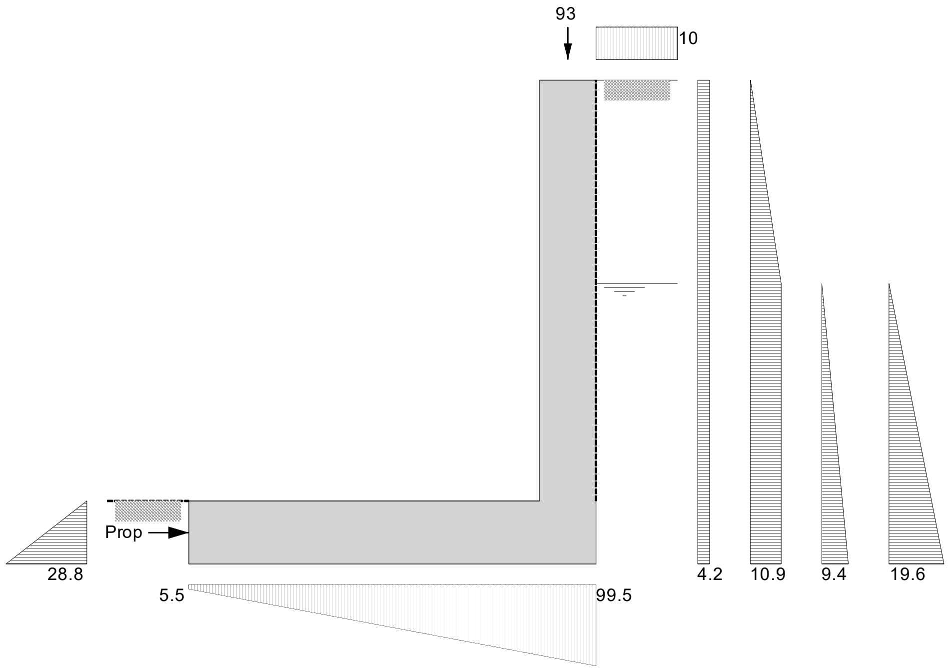
Slope angle ratio	r_a = 0 deg / ϕ'_b = **0.00**
Wall friction ratio	$r_b = \delta_b / \phi'_b$ = **0.77**
Passive pressure coefficient for base material	K_p = **3.754**

At-rest pressure

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

Loading details

Surcharge load on plan	Surcharge = **10.0** kN/m^2
Applied vertical dead load on wall	W_{dead} = **72.6** kN/m
Applied vertical live load on wall	W_{live} = **20.5** kN/m
Position of applied vertical load on wall	l_{load} = **2700** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm



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

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.3** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **30.8** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **93.2** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **152.3** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **14.5** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.9** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **21.9** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.4** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **73.3** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.5** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop} = **22.5** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **19.7** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **21.9** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **6.3** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **85.9** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \mathbf{76.5}$ kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2 = \mathbf{44.7}$ kNm/m

Design vertical load $M_v = W_v \times l_{load} = \mathbf{251.5}$ kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_v = \mathbf{372.6}$ kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot} = \mathbf{286.7}$ kNm/m

Total vertical reaction $R = W_{total} = \mathbf{152.3}$ kN/m

Distance to reaction $x_{bar} = M_{total} / R = \mathbf{1883}$ mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) = \mathbf{433}$ mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = \mathbf{5.5}$ kN/m^2

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = \mathbf{99.5}$ kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	γ_{f_d} = **1.4**
Live load factor	γ_{f_l} = **1.6**
Earth and water pressure factor	γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **39.6** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **43.1** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **134.5** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **217.3** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **32.6** kN/m
Moist backfill above water table	$F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **15.6** kN/m
Moist backfill below water table	$F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **43.1** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.5** kN/m
Water	$F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m
Total horizontal load	$F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **137.3** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **9.1** kN/m
Propping force	$F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0\ kN/m)$
	F_{prop_f} = **66.1** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **56.2** kNm/m
Moist backfill above water table	$M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **38.8** kNm/m
Moist backfill below water table	$M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **43.1** kNm/m
Saturated backfill	$M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **12.3** kNm/m
Water	$M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m
Total overturning moment	$M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **168.8** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **107** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **62.5** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **363.2** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **532.8** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **364** kNm/m
Total vertical reaction	$R_f = W_{total\_f}$ = **217.3** kN/m
Distance to reaction	$x_{bar\_f} = M_{total\_f} / R_f$ = **1675** mm
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **225** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **40** kN/m^2

Bearing pressure at heel	$p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **109.8** kN/m^2
Rate of change of base reaction	rate = $(p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **-24.08** kN/m^2/m
Bearing pressure at stem / toe	$p_{stem\_toe\_f} = \max(p_{heel\_f} + (rate \times (l_{heel} + t_{wall})), 0\ kN/m^2)$ = **100.2** kN/m^2
Bearing pressure at mid stem	$p_{stem\_mid\_f} = \max(p_{heel\_f} + (rate \times (l_{heel} + t_{wall} / 2)), 0\ kN/m^2)$ = **105** kN/m^2
Bearing pressure at stem / heel	$p_{stem\_heel\_f} = \max(p_{heel\_f} + (rate \times l_{heel}), 0\ kN/m^2)$ = **109.8** kN/m^2

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

Material properties

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

Base details

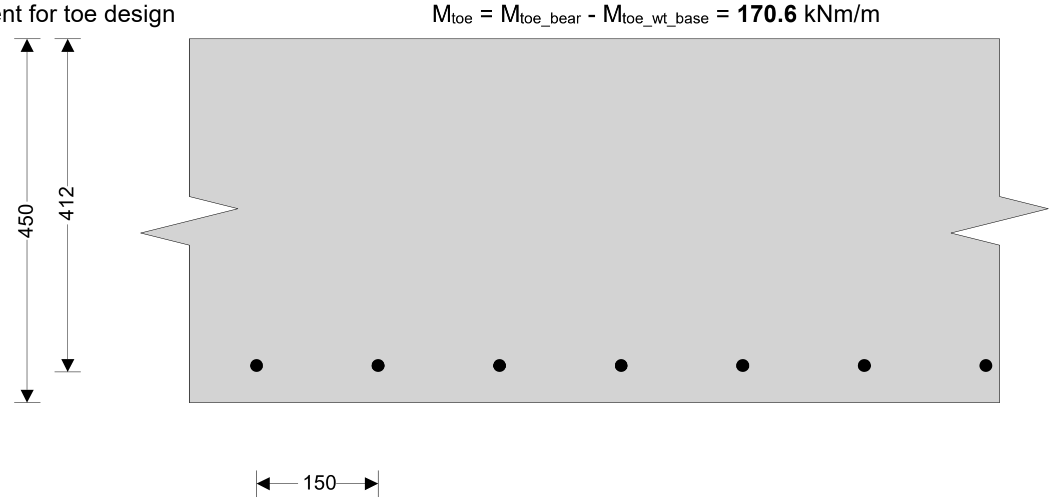
Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in toe	c_{toe} = **30** mm

Calculate shear for toe design

Shear from bearing pressure	$V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2$ = **175.3** kN/m
Shear from weight of base	$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **37.2** kN/m
Total shear for toe design	$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base}$ = **138.1** kN/m

Calculate moment for toe design

Moment from bearing pressure	$M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6$ = **224.8** kNm/m
Moment from weight of base	$M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **54.2** kNm/m
Total moment for toe design	$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base}$ = **170.6** kNm/m



Check toe in bending

Width of toe	b = **1000** mm/m
Depth of reinforcement	$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **412.0** mm
Constant	$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.025**
	Compression reinforcement is not required
Lever arm	$z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
	z_{toe} = **391** mm
Area of tension reinforcement required	$A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **1002** mm^2/m
Minimum area of tension reinforcement	$A_{s\_toe\_min} = k \times b \times t_{base}$ = **585** mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = Max(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **1002** mm²/m

Reinforcement provided **16 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov}$ = **1340** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.335** N/mm²

Allowable shear stress $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5) \times 1 N/mm^2$ = **5.000** N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.508** N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **40** mm

Cover to reinforcement in wall c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **28.3** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **15.6** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **33.4** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **11.1** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **16.5** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **38.8** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **48.9** kNm/m

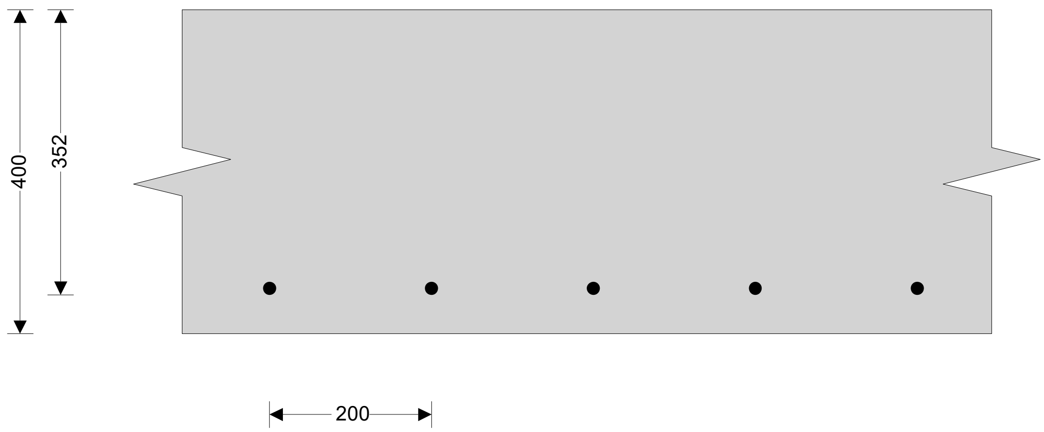
Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **35.3** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **25.9** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **5.7** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **8.5** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **124.3** kNm/m



Check wall stem in bending

Width of wall stem — b = **1000** mm/m

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **352.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.025**

Compression reinforcement is not required

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

z_{stem} = **334** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **855** mm^2/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **520** mm^2/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **855** mm^2/m

Reinforcement provided — **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **1005** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.110** N/mm^2

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — v_{c_stem} = **0.503** N/mm^2

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **7**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **283.4** N/mm^2

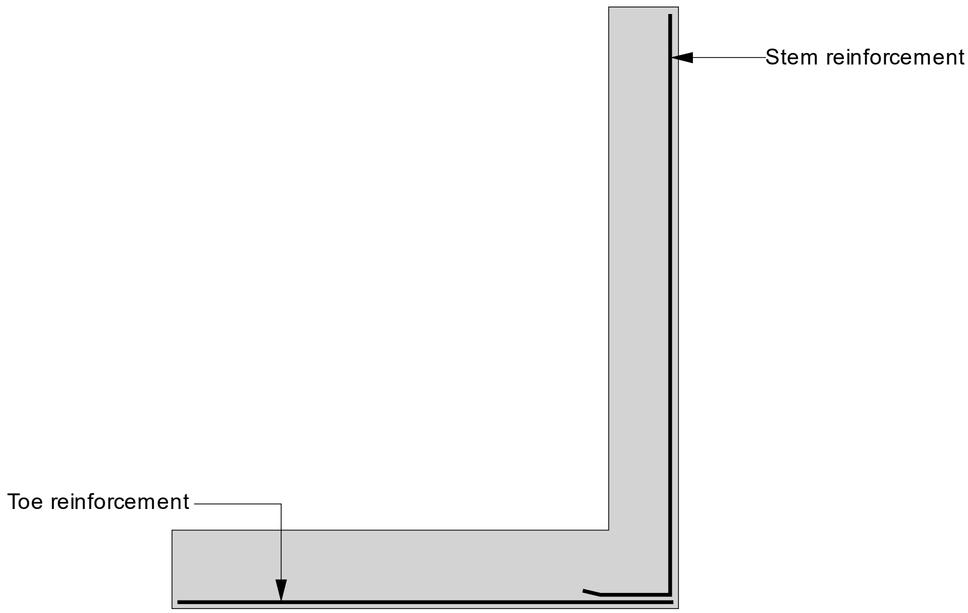
Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.40**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **9.78**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **8.52**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 150 mm centres - (1340 mm^2/m)
Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

Architecture for London.	Project: 23 Dartmouth Park Hill	Job no. 19047
	Calcs for: Slab Design	Start page no./Revision
	Client	Calcs by: BS / Calcs date

* Slab Design

- Hydrostatic Pressure :-

• $P = \rho \times g \times h \Rightarrow 1000 \times 9.81\ kN/m^3 \times (2.8m - 1.0m)$

$\Rightarrow 17.658\ kN/m^2$

- Over burden pressure :-

$\gamma_{clay} = 19\ kN/m^3$ $\gamma h = 19 \times 2.8m$

$= 53.2\ kN/m^2$

- Heave :-

$\Rightarrow$ hydrostatic pressure + (Over burden pressure − hydrostatic pressure) x (½)

$= 17.66 + [(53.2 - 17.66) \times ½]$

$\Rightarrow 35.43\ kN/m^2$

- Slab self weight :

$\Rightarrow$ 250mm thick (Assumed)

$\Rightarrow 0.25 \times 25\ kN/m^3 = 6.25\ kN/m^2$

- Overall lift $\Rightarrow 35.43 - 6.25 = 29.18\ kN/m^2$
- Ultimate heave $\Rightarrow 1.6 \times 29.18 = 46.69\ kN/m^2$

- Design Moment $= \frac{wL^2}{12} = \frac{46.69 \times (6.0^2)}{12} = 140.1\ kN/m$

$\Rightarrow$ Adopt 300mm thick slab H16 Bars @ 125mm Centres Top + Bottom In Both Direction

ELEMENT DESIGN to BS 8110:2005

SOLID SLABS

Originated from RCC11.xls v4.0 © 2006 - 2010 TCC

mpa The Concrete Centre

INPUT Location Dartmouth Park Hill

Design moment, M	140.1	kNm/m	fcu	40	N/mm²	γc =	1.50
ßb	1.00		fy	500	N/mm²	γs =	1.15
span	6000	mm	steel class	A			
Height, h	300	mm	Section location	CONTINUOUS SPAN			
Bar Ø	16	mm	Compression steel	NOMINAL			
cover	50	mm to these bars		*(deflection control only)*			

ONE or TWO WAY SLAB

OUTPUT Dartmouth Park Hill Compression steel = NOMINAL 0.13%

d = 300 - 50 - 16/2 = 242.0 mm

(3.4.4.4) K' = 0.156 > K = 0.060 ok

(3.4.4.4) z = 242.0 [0.5 + (0.25 - 0.060 /0.893)]^½ = 224.7 < 0.95d = 229.9 mm

(3.4.4.1) As = 140.10E6 /500 /224.5 x 1.15 = 1435 > min As = 390 mm²/m

PROVIDE H16 @ 125 = 1608 mm²/m *As increased by 0.2% for deflection*

(Eqn 8) fs = 2/3 x 500 x 1435 /1608 /1.00 = 297.4 N/mm²

(Eqn 7) Tens mod factor = 0.55 + (477 - 297.4) /120 /(0.9 + 2.392) = 1.005

(Equation 9) Comp mod factor = 1 + 0.130/(3 + 0.130) = 1.042

(3.4.6.3) Permissible L/d = 26.0 x 1.005 x 1.042 = 27.205

Actual L/d = 6000 /242.0 = 24.793 ok

Architecture for London.	Project: 23 Dartmouth Park Hill	Job no.: 19047
	Calcs for: Thickening Design	Start page no./Revision:
	Client:	Calcs by: BS — Calcs date:

* check thickening

– Wall load:-

	Dead	Live
• Cavity wall (h=6.0m) (3.14)	18.84	–
• Beam + Block floor (4.7/2) (5.85, 1.5)	13.75	3.53
• Flat Roof (5.1/2) (0.68, 0.75)	1.734	1.913
Total UDL	34.324	5.443

– Total load = 39.77 kN/m / 110 kN/m

= 0.4m ⇒ 600mm wide x 700mm Deep