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Project at:
4 Foundry Mill Mount
Seacroft
Leeds, LS14 6TL

Client: **AHR Building Consultancy Ltd**

Title: **Boundary Retaining Wall Design**

Structural Calculations
for Building Regulations
and Construction Purposes

Project No : 2021/231
Date : 13th September 2021

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CALCULATION SHEET

Project Number	**2021/231**
Sheet Number	**01**
Date	**OCT. 2021**

Project: 4 Foundry Mill Mount, Seacroft, Leeds	**Prepared by** CD
Sub Section	**Introduction & Loadings**

Introduction

The proposed works comprises the demolition of part of the existing mass masonry boundary wall (approx.. 20m linear meters) at the above site location following rotational failure of the existing wall. A new retaining wall is to be constructed in its place to ensure its future serviceability.

SGM Structural Design have been commissioned to only design the new boundary retaining wall. The retaining wall supports the existing earth that bounds the domestic garden areas of the neighbouring communal flats.

Structural calculations to be read in conjunction with drawings by the Project Architect and copied to the Builder, Client and Principal Designer (see below).

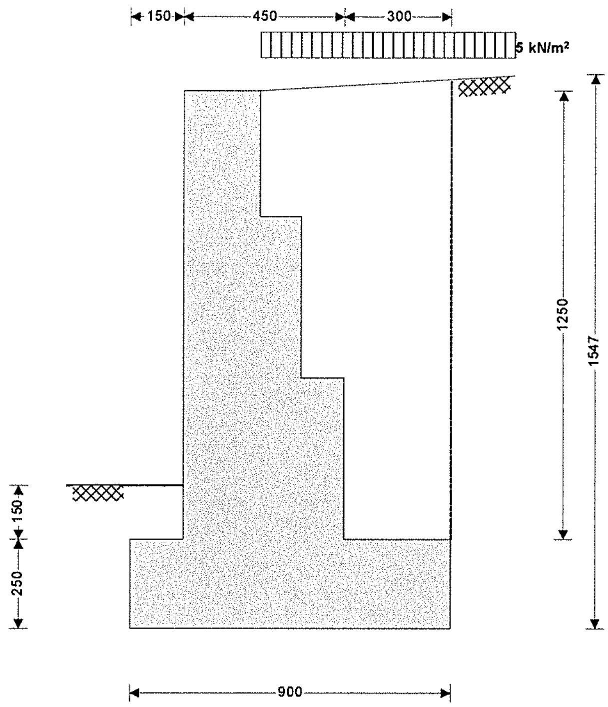
General Notes

1. All temporary works design & details are to be provided and/or commissioned by the general contractor. Contractor must ensure full adequate support of the existing excavated earth during works.

2. Calculations / Drawings must be forwarded to the 'Principal Designer' as referred to in CDM Regulations 2015. The role of 'Principal Designer' is outside the scope of the Engineers brief.

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Unpropped cantilever with stepped rear face**
Number of steps	**3**
Height of retaining wall stem	h_{stem} = **1250** mm
Length of toe	l_{toe} = **150** mm
Length of heel	l_{heel} = **300** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{s1}$ = **900** mm
Thickness of base	t_{base} = **250** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **350** mm
Thickness of downstand	t_{ds} = **250** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1500** mm
Depth of cover in front of wall	d_{cover} = **150** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **0** mm
Density of wall construction	γ_{wall} = **16.0** kN/m^3
Density of base construction	γ_{base} = **24.0** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **5.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + (l_{heel} + t_{s1} - t_{s3}) \times \tan(\beta)$ = **1547** 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' = **30.0** 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 = **30.0** deg

Design base friction δ_b = **20.0** deg

Allowable bearing pressure $P_{bearing}$ = **75** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.352}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{6.105}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.500**

Loading details

Surcharge load on plan Surcharge = **5.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **0.0** kN/m

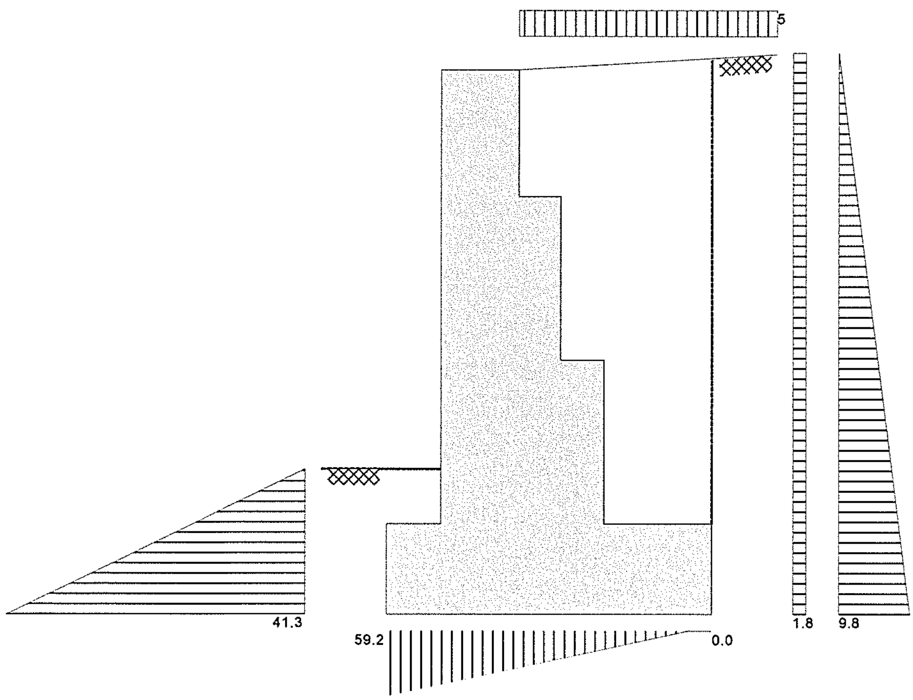
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **0** 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 step no. 3 — $w_{step3} = h_{s3} \times t_{s3} \times \gamma_{wall}$ = **1.2** kN/m

Wall step no. 2 — $w_{step2} = h_{s2} \times t_{s2} \times \gamma_{wall}$ = **2.4** kN/m

Wall step no. 1 — $w_{step1} = h_{s1} \times t_{s1} \times \gamma_{wall}$ = **3.2** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **5.4** kN/m

Surcharge — $w_{sur} = Surcharge \times [l_{heel} + (t_{s1} - t_{s3})]$ = **2.7** kN/m

Moist backfill above top of wall — $w_{m\_s} = 0.5 \times (l_{heel} + t_{s1} - t_{s3})^2 \times \tan(\beta) \times \gamma_m$ = **0.2** kN/m

Moist backfill to step no. 3 — $w_{m\_w3} = (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} \times \gamma_m$ = **3.4** kN/m

Moist backfill to step no. 2 — $w_{m\_w2} = (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} \times \gamma_m$ = **3.4** kN/m

Moist backfill to step no. 1 — $w_{m\_w1} = (l_{heel} + t_{s1} - t_{s1}) \times h_{s1} \times \gamma_m$ = **2.4** kN/m

Soil in front of wall — $w_p = l_{toe} \times d_{cover} \times \gamma_m$ = **0.4** kN/m

Total vertical load — $W_{total} = w_{step3} + w_{step2} + w_{step1} + w_{base} + w_{sur} + w_{m\_s} + w_{m\_w3} + w_{m\_w2} + w_{m\_w1} + w_p$ = **24.7** kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times Surcharge \times h_{eff}$ = **2.7** kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.6** kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a}$ = **10.3** kN/m

Calculate stability against sliding

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **8.3** kN/m

Resistance to sliding — $F_{res} = F_p + (W_{total} - w_{sur} - w_p) \times \tan(\delta_b)$ = **16.1** kN/m

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **2.1** kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **3.9** kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a}$ = **6** kNm/m

Restoring moments

Wall step no. 3 — $M_{step3} = w_{step3} \times (l_{toe} + t_{s3} / 2)$ = **0.3** kNm/m

Wall step no. 2 — $M_{step2} = w_{step2} \times (l_{toe} + t_{s2} / 2)$ = **0.7** kNm/m

Wall step no. 1 — $M_{step1} = w_{step1} \times (l_{toe} + t_{s1} / 2)$ = **1.2** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2$ = **2.4** kNm/m

Moist backfill above top of wall — $M_{m\_s} = w_{m\_s} \times (l_{base} - (l_{heel} + t_{s1} - t_{s3}) / 3)$ = **0.2** kNm/m

Moist backfill to step no. 3 — $M_{m\_w3} = w_{m\_w3} \times (l_{base} - (l_{heel} + t_{s1} - t_{s3}) / 2)$ = **2.1** kNm/m

Moist backfill to step no. 2 — $M_{m\_w2} = w_{m\_w2} \times (l_{base} - (l_{heel} + t_{s1} - t_{s2}) / 2)$ = **2.3** kNm/m

Moist backfill to step no. 1 — $M_{m\_w1} = w_{m\_w1} \times (l_{base} - (l_{heel} + t_{s1} - t_{s1}) / 2)$ = **1.8** kNm/m

Total restoring moment — $M_{rest} = M_{step3} + M_{step2} + M_{step1} + M_{base} + M_{m\_s} + M_{m\_w3} + M_{m\_w2} + M_{m\_w1}$ = **11.2** kNm/m

Check stability against overturning

Total overturning moment — M_{ot} = **6.0** kNm/m

Total restoring moment — M_{rest} = **11.2** kNm/m

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge — $M_{sur\_r} = w_{sur} \times (l_{base} - (l_{heel} + t_{s1} - t_{s3}) / 2)$ = **1.7** kNm/m

Soil in front of wall — $M_{p\_r} = w_p \times l_{toe} / 2$ = **0** kNm/m

Total moment for bearing — $M_{total} = M_{rest} - M_{ot} + M_{sur\_r} + M_{p\_r}$ = **6.9** kNm/m

Total vertical reaction $R = W_{total} =$ **24.7** kN/m

Distance to reaction $x_{bar} = M_{total} / R =$ **278** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar}) =$ **172** mm

Reaction acts outside middle third of base

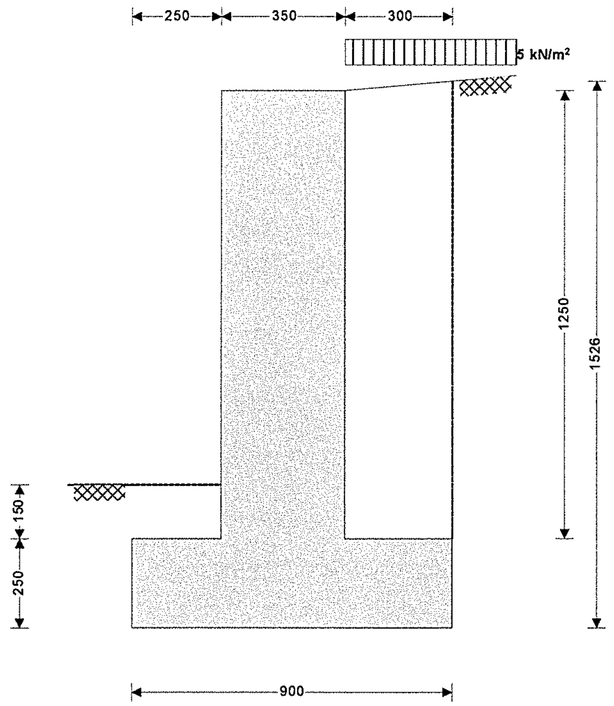
Bearing pressure at toe $p_{toe} = R / (1.5 \times x_{bar}) =$ **59.2** kN/m^2

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 ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Unpropped cantilever**
Height of retaining wall stem	h_{stem} = **1250** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **250** mm
Length of heel	l_{heel} = **300** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **900** mm
Thickness of base	t_{base} = **250** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **350** mm
Thickness of downstand	t_{ds} = **250** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1500** mm
Depth of cover in front of wall	d_{cover} = **150** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **0** mm
Density of wall construction	γ_{wall} = **20.0** kN/m^3
Density of base construction	γ_{base} = **24.0** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **5.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **1526** 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' = **30.0** 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 = **30.0** deg

Design base friction δ_b = **20.0** deg

Allowable bearing pressure $P_{bearing}$ = **75** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.352}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{6.105}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.500**

Loading details

Surcharge load on plan Surcharge = **5.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **0.0** kN/m

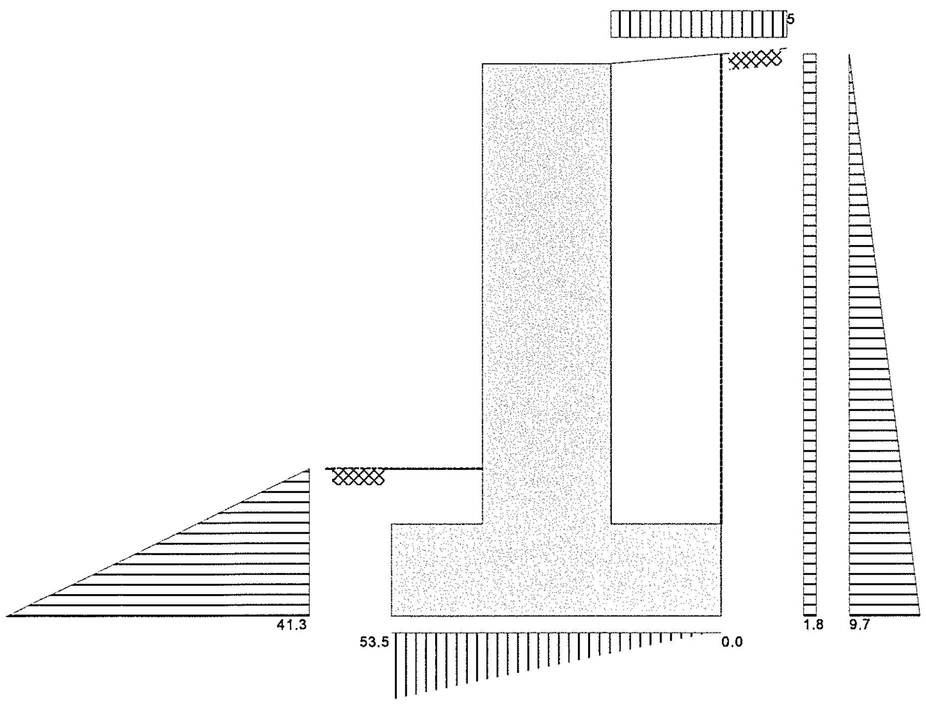
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **0** 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 $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **8.8** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **5.4** kN/m

Surcharge $w_{sur} = Surcharge \times l_{heel}$ = **1.5** kN/m

Moist backfill to top of wall $w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **6.8** kN/m

Moist backfill above top of wall $w_{m\_s} = 0.5 \times l_{heel}^2 \times \tan(\beta) \times \gamma_m$ = **0.1** kN/m

Soil in front of wall $w_p = l_{toe} \times d_{cover} \times \gamma_{mb}$ = **0.7** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + w_{m\_s} + w_p$ = **23.1** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times Surcharge \times h_{eff}$ = **2.7** 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

Total horizontal load $F_{total} = F_{sur} + F_{m\_a}$ = **10.1** kN/m

Calculate stability against sliding

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **8.3** kN/m

Resistance to sliding $F_{res} = F_p + (W_{total} - w_{sur} - w_p) \times \tan(\delta_b)$ = **15.9** kN/m

PASS - Resistance force is greater than sliding force

Overturning moments

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

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **3.7** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a}$ = **5.8** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **3.7** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **2.4** kNm/m

Moist backfill $M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3))$ = **5.1** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{m\_r}$ = **11.3** kNm/m

Check stability against overturning

Total overturning moment M_{ot} = **5.8** kNm/m

Total restoring moment M_{rest} = **11.3** kNm/m

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge $M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **1.1** kNm/m

Soil in front of wall $M_{p\_r} = w_p \times l_{toe} / 2$ = **0.1** kNm/m

Total moment for bearing $M_{total} = M_{rest} - M_{ot} + M_{sur\_r} + M_{p\_r}$ = **6.7** kNm/m

Total vertical reaction $R = W_{total}$ = **23.1** kN/m

Distance to reaction $x_{bar} = M_{total} / R$ = **289** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar})$ = **161** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe} = R / (1.5 \times x_{bar})$ = **53.5** 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **12.3** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **7.6** kN/m

Surcharge $w_{sur\_f} = \gamma_{f\_l} \times \text{Surcharge} \times l_{heel}$ = **2.4** kN/m

Moist backfill to top of wall $w_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **9.5** kN/m

Moist backfill above top of wall $w_{m\_s\_f} = \gamma_{f\_d} \times 0.5 \times l_{heel}^2 \times \tan(\beta) \times \gamma_m$ = **0.1** kN/m

Soil in front of wall $w_{p\_f} = \gamma_{f\_d} \times l_{toe} \times d_{cover} \times \gamma_{mb}$ = **0.9** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{m\_w\_f} + w_{m\_s\_f} + w_{p\_f}$ = **32.7** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **6.1** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **14.7** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f}$ = **20.8** kN/m

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **11.6** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **4.7** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **7.5** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f}$ = **12.1** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **5.2** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **3.4** kNm/m

Surcharge $M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2)$ = **1.8** kNm/m

Moist backfill $M_{m\_r\_f} = (w_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + w_{m\_s\_f} \times (l_{base} - l_{heel} / 3))$ = **7.2** kNm/m

Soil in front of wall $M_{p\_r\_f} = w_{p\_f} \times l_{toe} / 2$ = **0.1** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} + M_{p\_r\_f}$ = **17.7** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **5.6** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **32.7** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **170** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **280** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **128.1** kN/m^2

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

Rate of change of base reaction $\text{rate} = p_{toe\_f} / (3 \times x_{bar\_f})$ = **250.70** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0\ \text{kN/m}^2)$ = **65.4** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0\ \text{kN/m}^2)$ = **21.5** kN/m^2

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

SGM Structural Design Ltd Springfield Lodge 4 Thornhill Road, Edgerton, Huddersfield, HD3 3AU	Project 4 FOUNDRY MILL MOUNT, SEACROFT, LEEDS				Job no. 2021/231	
	Calcs for BOUNDARY RETAINING WALL - OPTION 2				Start page no./Revision 10	
	Calcs by CD	Calcs date OCT. 2021	Checked by	Checked date	Approved by	Approved date

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

Material properties

Characteristic strength of concrete — f_{cu} = **30** 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} = **50** mm

Calculate shear for toe design

Shear from bearing pressure — $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2$ = **24.2** kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **2.1** kN/m

Shear from weight of soil — $V_{toe\_wt\_soil} = w_{p\_f} - (\gamma_{f\_d} \times \gamma_m \times l_{toe} \times d_{exc})$ = **0.9** kN/m

Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} - V_{toe\_wt\_soil}$ = **21.1** kN/m

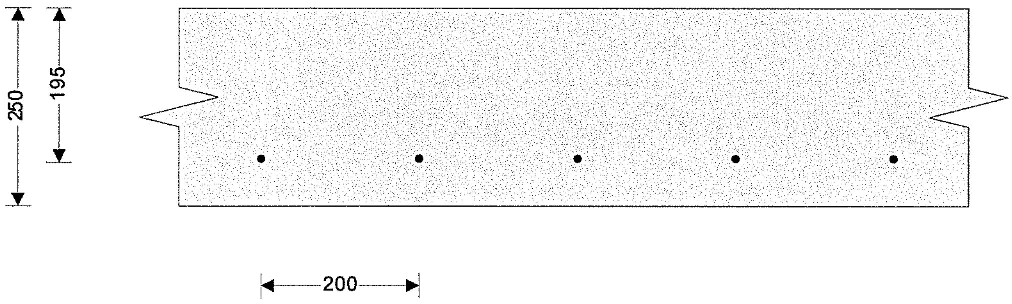
Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6$ = **8.4** kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **0.8** kNm/m

Moment from weight of soil — $M_{toe\_wt\_soil} = (w_{p\_f} - (\gamma_{f\_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall}) / 2$ = **0.3** kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} - M_{toe\_wt\_soil}$ = **7.3** kNm/m



Check toe in bending

Width of toe — b = **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **195.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.006**

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} = **185** mm

Area of tension reinforcement required — $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **91** mm^2/m

Minimum area of tension reinforcement — $A_{s\_toe\_min} = k \times b \times t_{base}$ = **325** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **325** mm^2/m

Reinforcement provided — **A393 mesh**

Area of reinforcement provided — $A_{s\_toe\_prov}$ = **393** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.108** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \mathrm{N/mm^2})}, 5) \times 1\ \mathrm{N/mm^2}$ = **4.382** 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} = **0.471** N/mm^2

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

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

Material properties

Characteristic strength of concrete f_{cu} = **30** 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 heel c_{heel} = **50** mm

Calculate shear for heel design

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base}$ = **2.5** kN/m

Shear from weight of moist backfill $V_{heel\_wt\_m} = w_{m\_w\_f} + w_{m\_s\_f}$ = **9.5** kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f}$ = **2.4** kN/m

Total shear for heel design $V_{heel} = V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_sur}$ = **14.5** kN/m

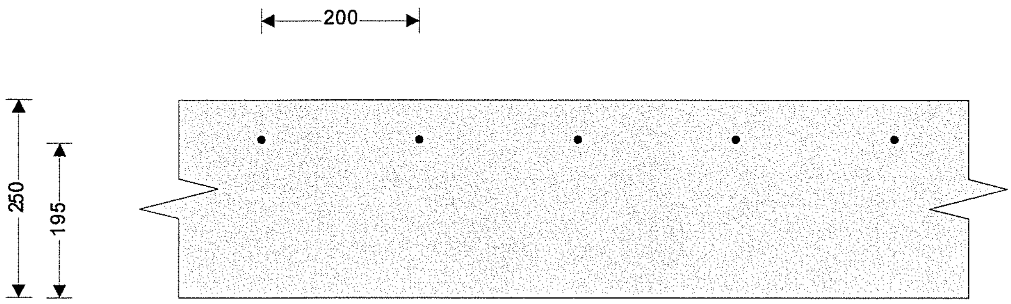
Calculate moment for heel design

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 $M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2 + w_{m\_s\_f} \times (2 \times l_{heel} / 3 + t_{wall} / 2)$ = **3.1** kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2$ = **0.8** kNm/m

Total moment for heel design $M_{heel} = M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_sur}$ = **4.8** kNm/m



Check heel in bending

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

Depth of reinforcement $d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2)$ = **195.0** mm

Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu})$ = **0.004**

Compression reinforcement is not required

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

z_{heel} = **185** mm

Area of tension reinforcement required $A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel})$ = **60** mm^2/m

Minimum area of tension reinforcement $A_{s\_heel\_min} = k \times b \times t_{base}$ = **325** mm^2/m

Area of tension reinforcement required $A_{s\_heel\_req} = \mathrm{Max}(A_{s\_heel\_des}, A_{s\_heel\_min})$ = **325** mm^2/m

Reinforcement provided **A393 mesh**

Area of reinforcement provided $A_{s\_heel\_prov}$ = **393** mm^2/m

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel})$ = **0.074** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **4.382** N/mm^2

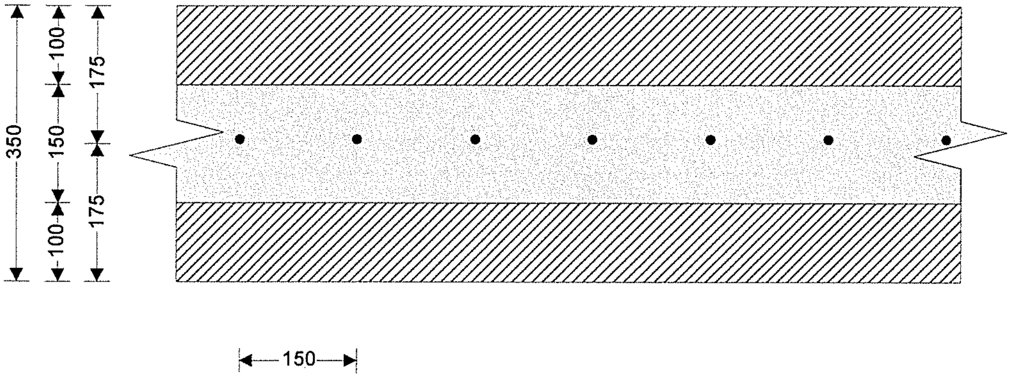
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_heel} = **0.471** N/mm^2

v_{heel} < v_{c_heel} - No shear reinforcement required

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



Wall details

Thickness of outer leaf of wall t_{outer} = **100** mm

Thickness of inner leaf of wall t_{inner} = **100** mm

Thickness of reinforced cavity $t_{cavity} = t_{wall} - t_{outer} - t_{inner}$ = **150** mm

Depth of stem reinforcement d_{stem} = **175** mm

Masonry details

Masonry type **Aggregate concrete blocks no voids**

Compressive strength of units p_{unit} = **10.0** N/mm^2

Mortar designation **(ii)**

Category of manufactoring control of units **Normal**

Partial safety factor for material strength γ_{mm} = **2.3**

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units b_{unit} = **100.0** mm

Height of masonry units h_{unit} = **215.0** mm

Ratio of height to least horizontal dimension ratio = h_{unit} / b_{unit} = **2.2**

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength f_k = **8.1** N/mm^2

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **5.1** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **10.3** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f}$ = **15.4** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **3.8** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **5.6** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a}$ = **9.5** kNm/m

Check maximum design moment for wall stem

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

Maximum design moment $M_{d\_stem} = 0.4 \times f_k \times b \times d_{stem}^2 / \gamma_{mm}$ = **43.4** kNm/m

PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor $Q = M_{stem} / d_{stem}^2$ = **0.309** N/mm²

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

Lever arm factor c = **0.954**

Lever arm $z_{stem} = \min(0.95, c) \times d_{stem}$ = **166.3** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} \times \gamma_{ms} / (f_y \times z_{stem})$ = **131** 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 $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **455** mm²/m

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

Area of reinforcement provided $A_{s\_stem\_prov} = \pi \times \phi_{stem}^2 / (4 \times s_{stem})$ = **754** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.088** N/mm²

Basic characteristic shear strength of masonry $f_{vbas} = \min[0.35 + (17.5 \times A_{s\_stem\_prov} / (b \times d_{stem})), 0.7] \times 1$ N/mm²

f_{vbas} = **0.425** N/mm²

Shear span $a = M_{stem} / V_{stem}$ = **616.7** mm

Characteristic shear strength of masonry $f_v = \mathrm{Min}(f_{vbas} \times \max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75\ \text{N/mm}^2)$

f_v = **0.689** N/mm²

Allowable shear stress $v_{adm} = f_v / \gamma_{mv}$ = **0.344** N/mm²

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio $ratio_{max}$ = **18.00**

Actual span/effective depth ratio $ratio_{act} = (h_{stem} + d_{stem} / 2) / d_{stem}$ = **7.64**

PASS - Span to depth ratio is acceptable

Axial load check

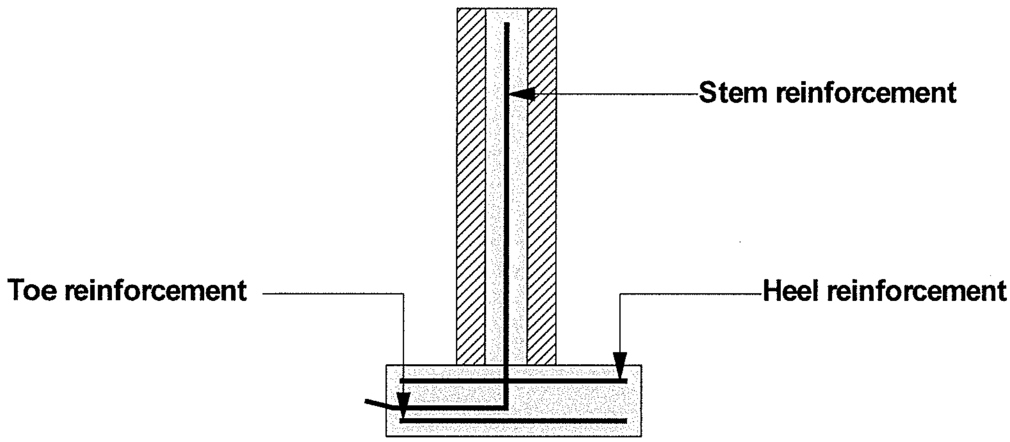
Factored axial load on wall $N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f\_d}) + (W_{live} \times \gamma_{f\_l})$ = **12.3** kN/m

Limiting axial load $N_{limit} = 0.1 \times f_k \times t_{wall}$ = **285.0** kN/m

Applied axial load may be ignored - calculations valid

SGM Structural Design Ltd Springfield Lodge 4 Thornhill Road, Edgerton, Huddersfield, HD3 3AU	Project 4 FOUNDRY MILL MOUNT, SEACROFT, LEEDS				Job no. 2021/231	
	Calcs for BOUNDARY RETAINING WALL - OPTION 2				Start page no./Revision 14	
	Calcs by CD	Calcs date OCT. 2021	Checked by	Checked date	Approved by	Approved date

Indicative retaining wall reinforcement diagram



Toe mesh - A393 - (393 mm^2/m)
Heel mesh - A393 - (393 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)