

**STRUCTURAL CALCULATIONS FOR BUILDING REGULATIONS
AND CONSTRUCTION PURPOSES**

SGM STRUCTURAL DESIGN

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Project No: 2025 / 202
Project: 29 Cliff Road
Holmfirth
HD9 1UY
Title: Proposed Gym / Store
Date: 19 September 2025
Client: Kit Gardner

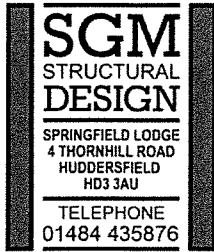
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CALCULATION SHEET

Project Number 2025/202
 Sheet Number 01
 Date 19/09/2025

Project: 29 Cliff Road, Holmfirth, HD9 1UY	Prepared by KB
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Sub Section Introduction & Loadings

Introduction

The proposed development comprises a construction of a new Gym/Store building with a parking space on top.

SGM Structural Design have been commissioned to only design structural members and a retaining wall to allow for the proposed new structure.

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

Loadings

Plan Load in
kN/m²

<u>Floor</u>	<u>Dead</u>		
		Beam & Block floor with screed and plaster under.	4.80
	<u>Imposed</u>	Parking loading to BS6399-1:1996	2.50
<u>Walls</u>	<u>Dead</u>	Stone Outer Leaf 100mm thick	2.20
		Inner block and plaster 100mm thick	1.85

General Notes

1. It remains the responsibility of the Local Authority Building Control Officer to inspect and approve the excavated formation and assess the adequacy of the ground to sustain applied pressure. If any doubt exists regarding the adequacy of the ground to sustain the loads then the Engineer must be informed to carry out an inspection. Where any new construction increases loading on existing footings it is recommended that trial holes be excavated and an inspection be made by Building Control.
2. Masonry design is outside the scope of the Engineers brief. Install movement joints as required by Architect.
3. Any temporary propping of existing structure required prior to installation of new support elements remains the responsibility of the General Builder. If the builder is in any doubt regarding the form of temporary propping or applied loads the Engineer must be informed prior to removal of load-bearing elements.
4. 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. As you may or may not be aware CDM Regulations have changed in 2015. As a 'Designer', it is our legal requirement to draw your attention to your duties as a 'client' (if you have employed more than one contractor). Please review important information regarding your duties on www.hse.gov.uk/construction/cdm/2015/domestic-clients.htm.

CALCULATION SHEET

Project number 2025/202

Sheet number 02

Date 17/09/2025

Project 29 CLIFF ROAD

Prepared by

KB

Sub section WIND POST DESIGN (GYM / STORE)

Checked by

WIND POST DESIGN

$$H = 2.8 \text{ m}$$

LOADINGS:

$$- 152 \text{ UC R. (TOP)} = 36.0 \text{ kN (ULT)}$$

$$- 152 \text{ UC R. (BOTTOM)} = [(13.0 + 2.4) \times 1.4^{(y_e)} + 5.3 \times 1.6^{(y_e)}] \times 0.8 =$$
$$= 24.0 \text{ kN (ULT)}$$

$$- \text{WIND LOAD; CHAR} = 0.85 \times 2.4 = 2.0 \text{ kN/m}$$

$$\text{ULT} = 2.0 \times 1.4^{(y_e)} = 2.8 \text{ kN/m}$$

$$\text{APPL. B.M. DUE TO ECCENTRICITY, } x_x = (36.0 - 24.0) \times 0.15 = 1.8 \text{ kNm}$$

$$\text{APPL. B.M. DUE TO WIND LOAD} = \frac{2.8 \times 2.8^2}{8} = 2.7 \text{ kNm}$$

TRY 100 x 100 x 6.3 SHS

$$M_c = 22.1 \text{ kNm} \quad \left. \vphantom{M_c} \right\} > \text{APPL.} \Rightarrow \text{OK}$$

$$P_c = 500.2 \text{ kN} \quad \left. \vphantom{P_c} \right\} > \text{APPL.} \Rightarrow \text{OK}$$

COMBINED CHECK:

$$\frac{1.8}{22.1} + \frac{2.7}{22.1} + \frac{36.0 + 24.0}{500.2} = 0.3 < 1.0 \Rightarrow \text{OK}$$

$$\text{APPL. } \delta = \frac{5 \times 2.0 \times 2.8 \times 2800^3}{384 \times 205 \times 336 \times 10^4} = 2.3 \text{ mm} < \frac{\text{SPAN}}{300} = 9.3 \text{ mm} \Rightarrow \text{OK}$$

PROVIDE 100 x 100 x 6.3 SHSWIND POST

Project 29 CLIFF ROAD	Prepared by KB
Sub section LINTEL BEAMS DESIGN (GYM/STORE)	Checked by

BEAM AND PLATE DESIGN

SPAN = 2.4m

LOADINGS	kN/m ²	LOAD WITH	CHAR	
<u>INNER LEAF</u>				
BEAM AND BLOCK, \mathcal{D}_L	4.8	2.1	10.1	} $\Sigma \mathcal{D}_L = 13.0 \text{ kN/m}$
↓	2.5	2.1	5.3	
WALL, \mathcal{D}_L	2.4	1.1	2.6	
S.W., \mathcal{D}_L			0.3	
<u>OUTER LEAF</u>				
WALL, \mathcal{D}_L	2.2	1.1	<u>2.4</u>	
			kN/m	

* REFER TO THE FOLLOWING ANALYSIS →

TRY 152 x 152 x 23 UC ; APPL. B.M. = 21.6 kNm

$L_e = (1.4 \times 2.4) + (2 \times 0.15) = 3.7 \text{ m} \Rightarrow M_b = 34.1 \text{ kNm} > \text{APPL. B.M.} = \text{OK}$

APPL. $\delta = 3.5 \text{ mm} < \frac{\text{SPAN}}{360} = 6.7 \text{ mm} = \text{OK}$

APPL. TWIST = $0.3^\circ = \text{OK}$

PROVIDE 152 x 152 x 23 UC

C/W 10mm THICK LOWER

PLATE



Project 29 CLIFF ROAD				Job no. 2025/202	
Calcs for BEAM AND PLATE (GYM/STORE)				Start page no./Revision 0 4	
Calcs by KB	Calcs date 17/09/2025	Checked by	Checked date	Approved by	Approved date

Analysis for simple beam with torsion to BS 5950 & SCI-P-057

TEDDS calculation version 1.0.02

Span length & partial factors for loading

Span (mm)	Factors for moments & forces			Factors for deflection		
	γ_{fd}	γ_{fi}	γ_{fw}	γ_{dd}	γ_{di}	γ_{dw}
2400	1.40	1.60	0.00	1.00	1.00	1.00

Load descriptions

Loads are applied normal to the major principal axis (x-axis) of the member.

Ref.	Category	Description
1	"Dead"	"IN, DL"
2	"Imposed"	"IN, IL"
3	"Dead"	"OUT, DL"

Loading data

Ref. #	Category	Type	Load kN/m	Position mm	Load kN/m	Position mm	Eccentricity mm
1	"Dead"	UDL	13.0	0	-	2400	-20
2	"Imposed"	UDL	5.3	0	-	2400	-20
3	"Dead"	UDL	2.4	0	-	2400	185

Analysis results - entire span

R_a kN (fac)	R_b kN (fac)	F_{vy} kN (fac)	M_x kNm (fac)	Sense	T_q kNm (fac)	Deflection: $\delta E I_x$	
						kNm ³	Direction
36.0	36.0	36.0	21.6	"Sagging"	0.21	8.94	"Down"

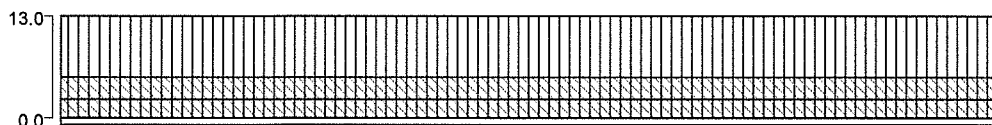
Unfactored support reactions

Support A; Dead load; -18.5 kN; Live load; -6.4 kN; Wind load; 0.0 kN;
 Support B; Dead load; -18.5 kN; Live load; -6.4 kN; Wind load; 0.0 kN;

LTB segment results

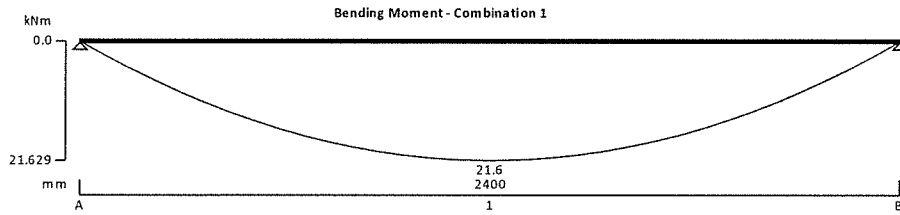
Seg.	x_s mm	x_e mm	L_{LT} mm	M_{LT} kNm (fac)	M_{MLT2} kNm (fac)	M_{MLT3} kNm (fac)	M_{MLT4} kNm (fac)
1	0	2400	2400	21.6	16.2	21.6	16.2

Beam Loads





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KB	17/09/2025						



Member design checks for simple beam with torsion to BS 5950 & SCI-P-057

Tedds calculation version 1.0.05

Summary

Span & restraint	L = 2400 mm	Torsion fixed & warping free each end.
Design load effects	F _{vy} = 36.0 kN; M _x = 21.6 kNm T _q = 0.21 kNm; torsion from uniformly distributed loads.	
Material	Grade = "S275"	p _y = 275 N/mm ²
Section	"UC 152x152x23"	"Semi-Compact"

Check;	Load;	Capacity;	Notes;	Result;
Deflection;	δ _{y_max} = 3.5 mm;	δ _{lim} = 6.7 mm;	Span / 360 or 6.7 mm;	Pass
Twist angle	φ _{sls} = 0.30 deg	φ _{lim} = 1.00 deg	T _{qu} = 0.19 kNm	Pass
Shear;	F _{vy} = 36.0 kN;	P _{vy} = 145.8 kN;	Low shear;	Pass;
Moment;	M _x = 21.6 kNm;	M _{cx} = 45.1 kNm;	Low shear;	Pass
LTB;	M _{LT} = 21.6 kNm;	M _b / m _{LT} = 35.5 kNm;	L _{E_LT} = 3.7 m; m _{LT} = 0.93;	Pass;
Overall buckling	Index; i _b = 0.673	Limit = 1.0	σ _{byt} = 2 N/mm ² σ _w = 11 N/mm ²	Pass
Local capacity	σ _{bx} + σ _{byt} + σ _w = 145 N/mm ²	p _y = 275 N/mm ²	σ _{bx} = 132 N/mm ² σ _{byt} = 2 N/mm ² σ _w = 11 N/mm ²	Pass
Combined shear stresses	τ _w = 50 N/mm ² τ _f = 22 N/mm ²	p _v = 165 N/mm ²	Web governs	Pass



End slips and T Blocks

L x W x H mm (Nominal)	Inner skin mm	Unit weight kg	Pack quantity	Pack weight kg	Crushing strength N/mm ²
375 x 90 x 40 End Slip	100	2.84	200	570	10.0
375 x 140 x 40 End Slip	140	4.20	200	840	10.0
530 x 100 x 140 T-Block	100	16.00	40	640	7.3
280 x 100 x 140 T-Block	100	8.60	40	640	7.3

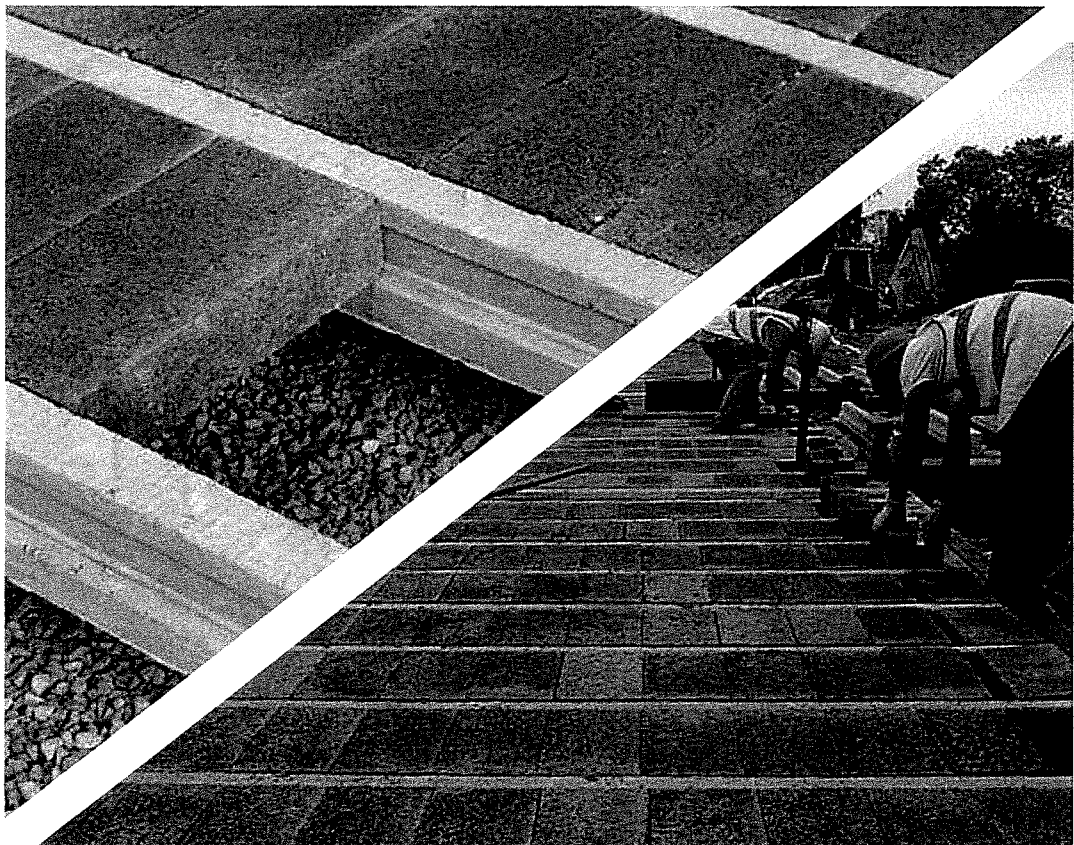
Garage floors

Beam Section (mm)	Centres (mm)	Maximum Clear Span (m)
105 x 150	510	2.77
	510/285	3.00
	285	3.30
125 x 150	530	3.64
	530/305	3.95
	305	4.36
165 x 150	570	4.36
	570/345	4.78
	345	5.26
125 x 225	530	5.68
	530/305	6.33
	305	7.19

Superimposed load: 2.5 kN/m²

75mm structural topping (minimum grade C30) with minimum A98 mesh 1.88 kN/m² has been included.

1970 kg/m³ dense blocks (440x215x100) included.



CALCULATION SHEET

Project number 2025/202

Sheet number 07

Date 19/09/2025

Project 29 CLIFF ROAD	Prepared by KB
Sub section RETAINING WALL DESIGN (GYM STORE)	Checked by

RETAINING WALL DESIGN

LEVEL DIFFERENCE ; APPROX. 2.5m

SURCHARGE LOADING = 10 kN/m^2

GYM LOADINGS	kN/m^2	LOAD WITH	CHAR
<u>INNER LEAF</u>			
BEAM AND BLOCK, D_L	4.8	2.1	10.1
$1/2$	2.5	2.1	5.3
WALL, D_L	1.85	2.7	5.0
<u>OUTER LEAF</u>			
WALL, D_L	1.85	2.7	<u>5.0</u>
			$\Sigma D_L = 20.1 \text{ kN/m}$
			$\Sigma 1/2 = 5.3 \text{ kN/m}$

* REFER TO THE FOLLOWING ANALYSIS →

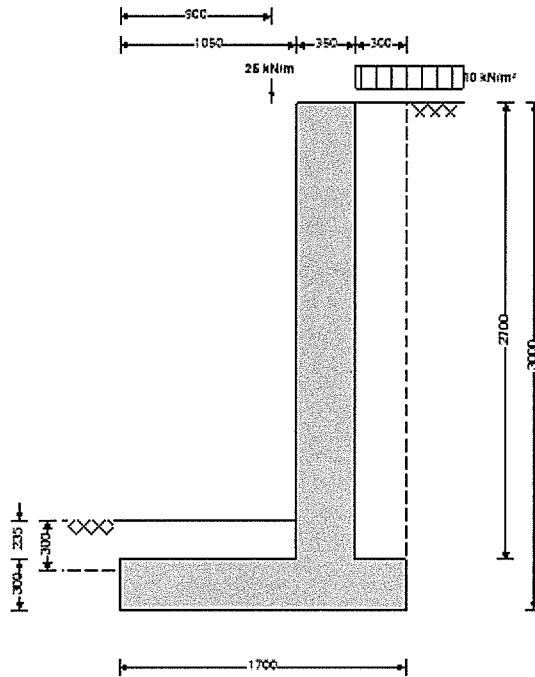


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Calcs for		RETAINING WALL - GYM		Start page no./Revision		8	
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KB	22/09/2025						

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

- Retaining wall type
- Height of retaining wall stem
- Thickness of wall stem
- Length of toe
- Length of heel
- Overall length of base
- Thickness of base
- Depth of downstand
- Position of downstand
- Thickness of downstand
- Height of retaining wall
- Depth of cover in front of wall
- Depth of unplanned excavation
- Height of ground water behind wall
- Height of saturated fill above base
- Density of wall construction
- Density of base construction
- Angle of rear face of wall
- Angle of soil surface behind wall
- Effective height at virtual back of wall

Unpropped cantilever

- $h_{stem} = 2700$ mm
- $t_{wall} = 350$ mm
- $l_{toe} = 1050$ mm
- $l_{heel} = 300$ mm
- $l_{base} = l_{toe} + l_{heel} + t_{wall} = 1700$ mm
- $t_{base} = 300$ mm
- $d_{ds} = 0$ mm
- $l_{ds} = 1200$ mm
- $t_{ds} = 300$ mm
- $h_{wall} = h_{stem} + t_{base} + d_{ds} = 3000$ mm
- $d_{cover} = 235$ mm
- $d_{exc} = 300$ mm
- $h_{water} = 0$ mm
- $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 0$ mm
- $\gamma_{wall} = 23.6$ kN/m³
- $\gamma_{base} = 23.6$ kN/m³
- $\alpha = 90.0$ deg
- $\beta = 0.0$ deg
- $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 3000$ mm

Retained material details

- Mobilisation factor $M = 1.5$
- Moist density of retained material $\gamma_m = 18.0$ kN/m³



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Calcs for RETAINING WALL - GYM			Start page no./Revision 10		
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Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 22.3 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 12 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} \times l_{heel} = 3 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 14.6 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 4.4 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 25.4 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{sur} + W_{m_w} + W_p + W_v = 81.8 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 10 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = 27 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 37 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 2.9 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p - W_{live}) \times \tan(\delta_b) = 28.0 \text{ kN/m}$

FAIL - Sliding force is greater than resisting force

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 15 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 27 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} = 42 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 27.3 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 10.2 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 22.6 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 18.1 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m_r} + M_{dead} = 78.2 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 42.0 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 78.2 \text{ kNm/m}$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 4.7 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p \times l_{toe} / 2 = 2.3 \text{ kNm/m}$
Design vertical live load	$M_{live} = W_{live} \times l_{load} = 4.8 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} + M_{live} = 48 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 81.8 \text{ kN/m}$
Distance to reaction	$X_{bar} = M_{total} / R = 587 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - X_{bar}) = 263 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 92.7 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 3.4 \text{ kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure



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KB	22/09/2025						

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor $\gamma_{f,d} = 1.4$
 Live load factor $\gamma_{f,l} = 1.6$
 Earth and water pressure factor $\gamma_{f,e} = 1.4$

Factored vertical forces on wall

Wall stem $W_{wall,f} = \gamma_{f,d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 31.2 \text{ kN/m}$
 Wall base $W_{base,f} = \gamma_{f,d} \times l_{base} \times t_{base} \times \gamma_{base} = 16.9 \text{ kN/m}$
 Surcharge $W_{sur,f} = \gamma_{f,l} \times \text{Surcharge} \times l_{heel} = 4.8 \text{ kN/m}$
 Moist backfill to top of wall $W_{m,w,f} = \gamma_{f,d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 20.4 \text{ kN/m}$
 Soil in front of wall $W_{p,f} = \gamma_{f,d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 6.2 \text{ kN/m}$
 Applied vertical load $W_{v,f} = \gamma_{f,d} \times W_{dead} + \gamma_{f,l} \times W_{live} = 36.6 \text{ kN/m}$
 Total vertical load $W_{total,f} = W_{wall,f} + W_{base,f} + W_{sur,f} + W_{m,w,f} + W_{p,f} + W_{v,f} = 116.1 \text{ kN/m}$

Factored horizontal at-rest forces on wall

Surcharge $F_{sur,f} = \gamma_{f,l} \times K_0 \times \text{Surcharge} \times h_{eff} = 24 \text{ kN/m}$
 Moist backfill above water table $F_{m,a,f} = \gamma_{f,e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 56.7 \text{ kN/m}$
 Total horizontal load $F_{total,f} = F_{sur,f} + F_{m,a,f} = 80.7 \text{ kN/m}$
 Passive resistance of soil in front of wall $F_{p,f} = \gamma_{f,e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 4 \text{ kN/m}$

Factored overturning moments

Surcharge $M_{sur,f} = F_{sur,f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 36 \text{ kNm/m}$
 Moist backfill above water table $M_{m,a,f} = F_{m,a,f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 56.7 \text{ kNm/m}$
 Total overturning moment $M_{ot,f} = M_{sur,f} + M_{m,a,f} = 92.7 \text{ kNm/m}$

Restoring moments

Wall stem $M_{wall,f} = W_{wall,f} \times (l_{toe} + t_{wall} / 2) = 38.2 \text{ kNm/m}$
 Wall base $M_{base,f} = W_{base,f} \times l_{base} / 2 = 14.3 \text{ kNm/m}$
 Surcharge $M_{sur_r,f} = W_{sur,f} \times (l_{base} - l_{heel} / 2) = 7.4 \text{ kNm/m}$
 Moist backfill $M_{m_r,f} = (W_{m,w,f} \times (l_{base} - l_{heel} / 2) + W_{m_s,f} \times (l_{base} - l_{heel} / 3)) = 31.6 \text{ kNm/m}$
 Soil in front of wall $M_{p_r,f} = W_{p,f} \times l_{toe} / 2 = 3.3 \text{ kNm/m}$
 Design vertical load $M_{v,f} = W_{v,f} \times l_{load} = 33 \text{ kNm/m}$
 Total restoring moment $M_{rest,f} = M_{wall,f} + M_{base,f} + M_{sur_r,f} + M_{m_r,f} + M_{p_r,f} + M_{v,f} = 127.9 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing $M_{total,f} = M_{rest,f} - M_{ot,f} = 35.2 \text{ kNm/m}$
 Total vertical reaction $R_f = W_{total,f} = 116.1 \text{ kN/m}$
 Distance to reaction $X_{bar,f} = M_{total,f} / R_f = 303 \text{ mm}$
 Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - X_{bar,f}) = 547 \text{ mm}$

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe,f} = R_f / (1.5 \times X_{bar,f}) = 255.6 \text{ kN/m}^2$
 Bearing pressure at heel $p_{heel,f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
 Rate of change of base reaction $rate = p_{toe,f} / (3 \times X_{bar,f}) = 281.29 \text{ kN/m}^2/\text{m}$
 Bearing pressure at stem / toe $p_{stem_toe,f} = \text{max}(p_{toe,f} - (rate \times l_{toe}), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$
 Bearing pressure at mid stem $p_{stem_mid,f} = \text{max}(p_{toe,f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$
 Bearing pressure at stem / heel $p_{stem_heel,f} = \text{max}(p_{toe,f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$



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

Material properties

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

Base details

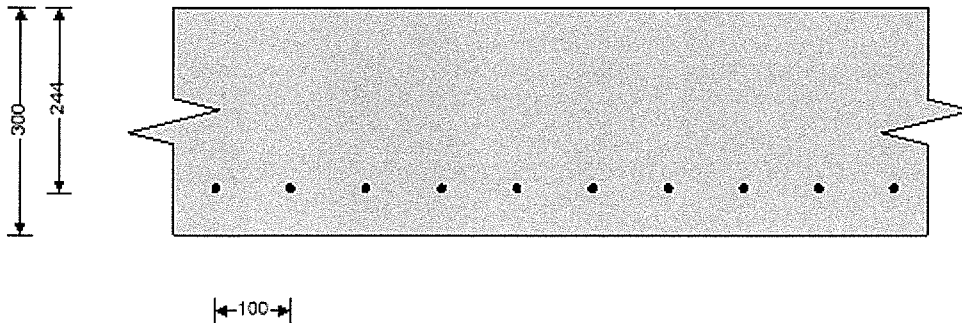
Minimum area of reinforcement $k = 0.13 \%$
 Cover to reinforcement in toe $c_{toe} = 50 \text{ mm}$

Calculate shear for toe design

Shear from bearing pressure $V_{toe_bear} = 3 \times p_{toe_f} \times X_{bar_f} / 2 = 116.1 \text{ kN/m}$
 Shear from weight of base $V_{toe_wt_base} = \gamma_{f,d} \times \gamma_{base} \times l_{toe} \times t_{base} = 10.4 \text{ kN/m}$
 Total shear for toe design $V_{toe} = V_{toe_bear} - V_{toe_wt_base} = 105.7 \text{ kN/m}$

Calculate moment for toe design

Moment from bearing pressure $M_{toe_bear} = 3 \times p_{toe_f} \times X_{bar_f} \times (l_{toe} - X_{bar_f} + t_{wall} / 2) / 2 = 107.1 \text{ kNm/m}$
 Moment from weight of base $M_{toe_wt_base} = (\gamma_{f,d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2) / 2 = 7.4 \text{ kNm/m}$
 Total moment for toe design $M_{toe} = M_{toe_bear} - M_{toe_wt_base} = 99.6 \text{ kNm/m}$



Check toe in bending

Width of toe $b = 1000 \text{ mm/m}$
 Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 244.0 \text{ mm}$
 Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.042$

Compression reinforcement is not required

Lever arm $Z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
 $Z_{toe} = 232 \text{ mm}$

Area of tension reinforcement required $A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times Z_{toe}) = 988 \text{ mm}^2/\text{m}$
 Minimum area of tension reinforcement $A_{s_toe_min} = k \times b \times t_{base} = 390 \text{ mm}^2/\text{m}$
 Area of tension reinforcement required $A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = 988 \text{ mm}^2/\text{m}$
 Reinforcement provided **B1131 mesh**
 Area of reinforcement provided $A_{s_toe_prov} = 1131 \text{ mm}^2/\text{m}$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = 0.433 \text{ N/mm}^2$
 Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 5.000 \text{ N/mm}^2$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $V_{c_toe} = 0.647 \text{ N/mm}^2$

$V_{toe} < V_{c_toe}$ - No shear reinforcement required



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

Material properties

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

Characteristic strength of reinforcement $f_y = 500 \text{ N/mm}^2$

Base details

Minimum area of reinforcement $k = 0.13 \%$

Cover to reinforcement in heel $C_{heel} = 50 \text{ mm}$

Calculate shear for heel design

Shear from weight of base $V_{heel_wt_base} = \gamma_{f,d} \times \gamma_{base} \times l_{heel} \times t_{base} = 3 \text{ kN/m}$

Shear from weight of moist backfill $V_{heel_wt_m} = W_{m_w_f} = 20.4 \text{ kN/m}$

Shear from surcharge $V_{heel_sur} = W_{sur_f} = 4.8 \text{ kN/m}$

Total shear for heel design $V_{heel} = V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 28.2 \text{ kN/m}$

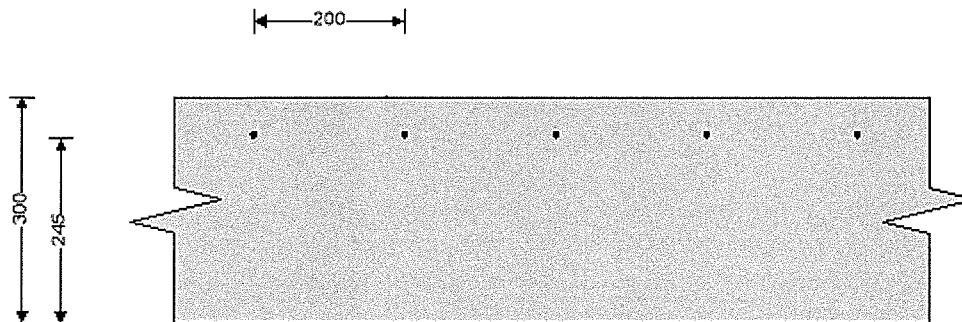
Calculate moment for heel design

Moment from weight of base $M_{heel_wt_base} = (\gamma_{f,d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 1.1 \text{ kNm/m}$

Moment from weight of moist backfill $M_{heel_wt_m} = W_{m_w_f} \times (l_{heel} + t_{wall}) / 2 = 6.6 \text{ kNm/m}$

Moment from surcharge $M_{heel_sur} = W_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 1.6 \text{ kNm/m}$

Total moment for heel design $M_{heel} = M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 9.3 \text{ kNm/m}$



Check heel in bending

Width of heel $b = 1000 \text{ mm/m}$

Depth of reinforcement $d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 245.0 \text{ mm}$

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

Compression reinforcement is not required

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

$Z_{heel} = 233 \text{ mm}$

Area of tension reinforcement required $A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = 92 \text{ mm}^2/\text{m}$

Minimum area of tension reinforcement $A_{s_heel_min} = k \times b \times t_{base} = 390 \text{ mm}^2/\text{m}$

Area of tension reinforcement required $A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = 390 \text{ mm}^2/\text{m}$

Reinforcement provided **A393 mesh**

Area of reinforcement provided $A_{s_heel_prov} = 393 \text{ mm}^2/\text{m}$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel}) = 0.115 \text{ N/mm}^2$

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

PASS - Design shear stress is less than maximum shear stress

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From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = 0.454 \text{ N/mm}^2$$

$V_{heel} < V_{c_heel}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

$$f_{cu} = 40 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

Wall details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in stem

$$c_{stem} = 50 \text{ mm}$$

Cover to reinforcement in wall

$$c_{wall} = 50 \text{ mm}$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 21.6 \text{ kN/m}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{f_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 45.9 \text{ kN/m}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = 67.5 \text{ kN/m}$$

Calculate moment for stem design

Surcharge

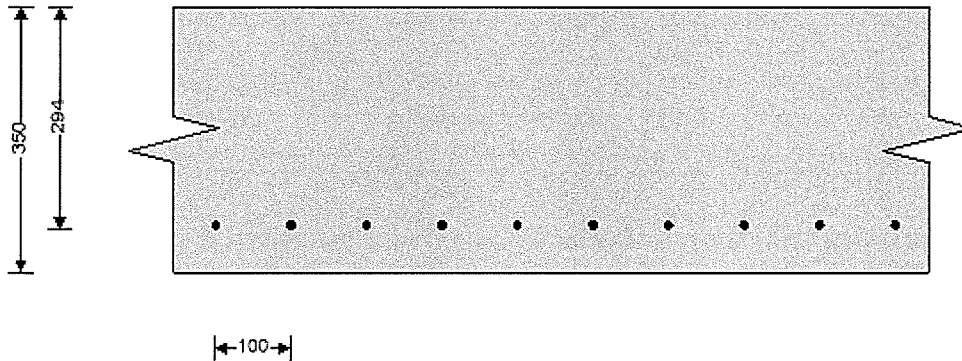
$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = 32.4 \text{ kNm/m}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 48.2 \text{ kNm/m}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = 80.6 \text{ kNm/m}$$



Check wall stem in bending

Width of wall stem

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = 294.0 \text{ mm}$$

Constant

$$K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = 0.023$$

Compression reinforcement is not required

Lever arm

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

$$Z_{stem} = 279 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{stem} / (0.87 \times f_y \times Z_{stem}) = 664 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{wall} = 455 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = 664 \text{ mm}^2/\text{m}$$

Reinforcement provided

B1131 mesh

Area of reinforcement provided

$$A_{s_stem_prov} = 1131 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate



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Check shear resistance at wall stem

Design shear stress

$$v_{stem} = V_{stem} / (b \times d_{stem}) = 0.230 \text{ N/mm}^2$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_stem} = 0.581 \text{ N/mm}^2$$

$v_{stem} < v_{c_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio

$$ratio_{bas} = 7$$

Design service stress

$$f_s = 2 \times f_y \times A_{s_stem_req} / (3 \times A_{s_stem_prov}) = 195.6 \text{ N/mm}^2$$

Modification factor

$$factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + (M_{stem} / (b \times d_{stem}^2)))), 2) = 1.83$$

Maximum span/effective depth ratio

$$ratio_{max} = ratio_{bas} \times factor_{tens} = 12.81$$

Actual span/effective depth ratio

$$ratio_{act} = h_{stem} / d_{stem} = 9.18$$

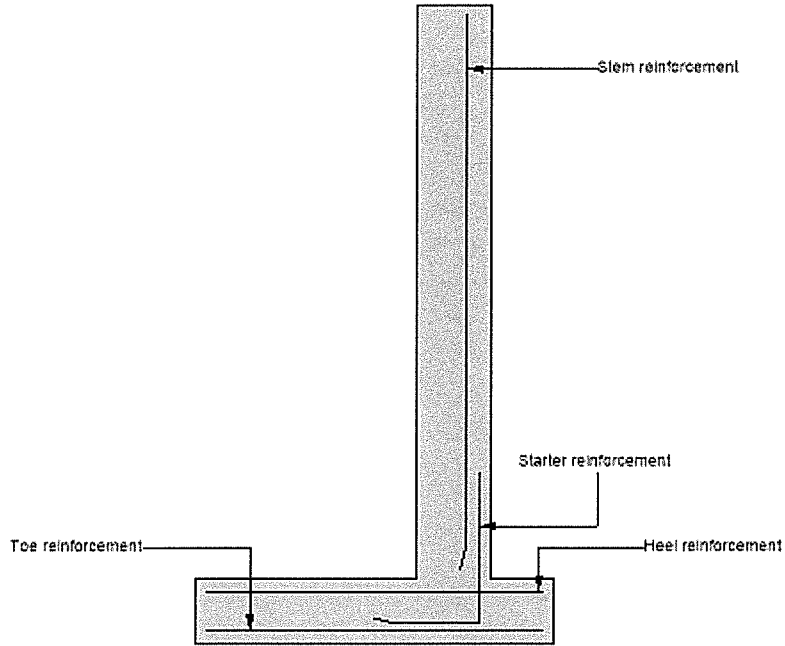
PASS - Span to depth ratio is acceptable



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Indicative retaining wall reinforcement diagram



Toe mesh - B1131 - (1131 mm²/m)

Heel mesh - A393 - (393 mm²/m)

Stem mesh - B1131 - (1131 mm²/m)