

Calculations for the Design of Standard 1500mm high 'L' Wall Units
with Standard Design Parameters

Note that the L wall units must form part of an overall retaining structure designed by a competent engineer, which includes a base slab of at least 200mm thickness to ensure sufficient anchorage for the dowel bars fixing the L unit base. This slab when considered together with the L wall units must be sufficient to resist the sliding and overturning on the whole retaining structure resulting from its function. This is likely to result in the need for a slab to extend significantly beyond either the toe or the heel (or both) of the L unit and have sufficient bending reinforcement in the top or bottom (or both) as dictated by the design and the site circumstances.

Contract Name: Standard Product Design

Contract Number: -

Client: -

Reference: -

In accordance with: BS EN 1992-1:2004
BS EN 1997-1:2004

Assumed parameters: Maximum soil/backfill density: 18.0 kN/m³
Minimum angle of internal friction: 32.5°
Maximum angle of slope: 30.0°
Maximum live load surcharge: 10.0 kN/m²

Design cases considered: Buried foot (toe in), zero slope + maximum surcharge
Exposed foot (toe out), zero slope + maximum surcharge
Buried foot (toe in), maximum slope + zero surcharge
Exposed foot (toe out), maximum slope + zero surcharge

Calculation By: S.J.H 06-Jan-17

Checked By: C.B. 09-Jan-17

C.M. Baker.

Rev	Description	By	Date

**1500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

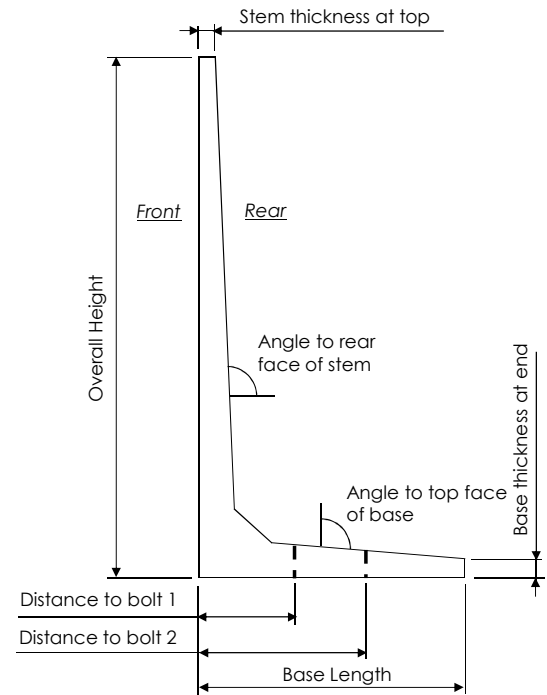
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1.0 Retaining Wall Design

Overall height (h)	1500 mm
Base length (L _{base})	750 mm
Stem thickness at top (t _{stem_top})	110 mm
Base thickness at end (t _{base_min})	110 mm
Unit width (w _u)	1000 mm
Distance to bolt 1 (from face)	375 mm
Distance to bolt 2 (from face)	N/A
Number of bolts / row (No.)	2 No.
Angle to rear face of stem (a1)	90.9°
Angle to top face of base (a2)	92.2°
Concrete Density (γ _c)	25.0 kN/m³
Average stem thickness (t _{stem})	121 mm
Average base thickness (t _{base})	124 mm
Stem height (h _{stem})	1376 mm
Toe length (L _{toe})	629 mm

Cover block (c)	45 mm
Cover deviation (ΔC _{dev})	5 mm

Height of retained soil (h _{ret})	1500 mm
Moist density (γ _{mr})	18.0 kN/m³
Char' eff' shear angle (φ' _{r,k})	32.5°
Char' wall friction angle (δ _{r,k})	21.7°
Angle of soil surface (β)	30.0°
Variable surcharge (Surcharge _G)	10.0 kN/m²



Depth to action of shear / moment (z)	500 mm
Additional shear force acting at z (V _z)	0.0 kN
Additional concentrated moment acting at z (M _z)	0.0 kNm

The following design is carried out in accordance with BS EN 1992-1:2004 & BS EN 1997-1:2004 at the ultimate limit state. Global Design (2.0) done on a per metre run basis and then pro-rated to the unit width, where not equal to a metre, in Design Values (2.6).

Partial Factors on Actions	Equilibrium (Table A.1)	Comb' 1 (Table A.3)	Comb' 2 (Table A.3)
Permanent unfavourable action (γ _G)	1.10	1.35	1.00
Permanent favourable action (γ _{Gf})	0.90	1.00	1.00
Variable unfavourable action (γ _Q)	1.50	1.50	1.30
Variable favourable action (γ _{Qf})	0.00	0.00	0.00
V _z partial factor (γ _{Vz})	1.50	1.50	1.30
M _z partial factor (γ _{Mz})	1.50	1.50	1.30

Partial Factors for Soil Parameters	Equilibrium (Table A.NA.2)	Comb' 1 (Table A.4)	Comb' 2 (Table A.4)
Angle of shearing resistance (γ _φ)	1.10	1.00	1.25
Effective cohesion (γ _c)	1.10	1.00	1.25
Weight density (γ _y)	1.00	1.00	1.00

Retained Soil Properties based on Coulomb	Equilibrium	Combination 1	Combination 2
Design eff' shear resistance angle (φ' _{r,d});	30.0°	32.5°	27.0°
Design wall friction angle (δ _{r,d});	19.9°	21.7°	17.7°
Level backfill active pressure coefficient (k _a);	0.304	0.276	0.341
Sloped backfill active pressure coefficient (k _a);	0.817	0.537	0.851

Soil Heights & Areas		Equilibrium		Combination 1		Combination 2	
		Rear (h _{eff1})	Front (h _{eff2})	Rear (h _{eff1})	Front (h _{eff2})	Rear (h _{eff1})	Front (h _{eff2})
Effective height of sloped soil (h _{eff})		1863 mm	1500 mm	1863 mm	1500 mm	1821 mm	1500 mm
Dimension properties (see diagram over page)	Property A	2.24254m	1.299m	2.125m	1.204m	2.396m	1.422m
	Property B	1.29473m	0.750m	1.227m	0.695m	1.383m	0.821m
	Property C	1.29473m	0.750m	1.354m	0.767m	1.221m	0.725m
	Property D	0.00000m	0.000m	-0.107m	-0.061m	0.144m	0.086m
	Property E	0.00000m	0.000m	-0.195m	-0.111m	0.236m	0.140m
	Property F	0.00000m	0.000m	-0.068m	-0.039m	0.074m	0.044m
Area of Soil (A)		0.000 m²	0.000 m²	-0.142 m²	-0.045 m²	0.183 m²	0.064 m²

**1500mm Standard L-Wall
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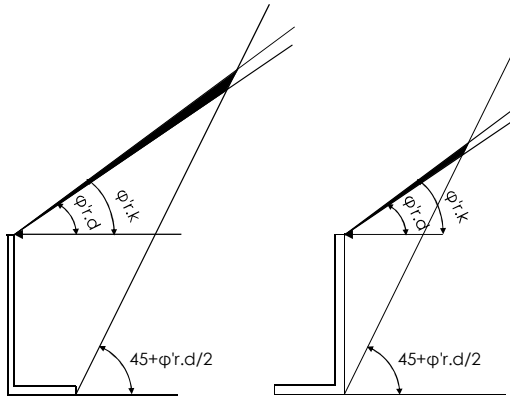
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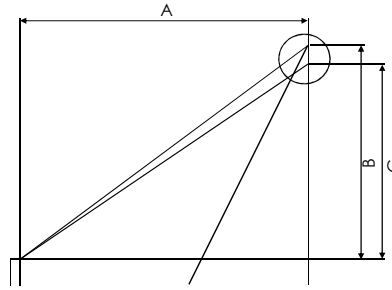
Additional Line Load

Method given in Reynolds (Table 21) to allow for the effect of the additional slope beyond the theoretical angle of repose

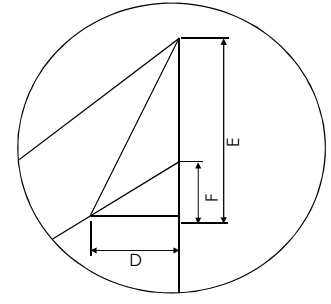


Sketch 1: Line load to rear of retaining wall

Sketch 2: Line load to front of retaining wall



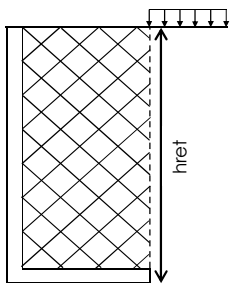
Primary Critical Dimensions



Secondary Critical Dimensions

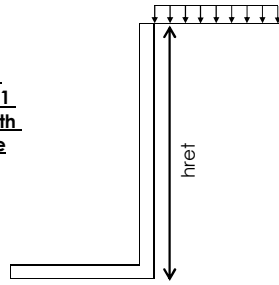
2.0 Retaining Wall Global Design

The global design determines a maximum overturning and sliding force on the retaining wall for each of the three combinations (EQU, Comb'1, Comb'2) in the two loading conditions (presented below) applied to the front and the back of the wall. All designs are done on a per/metre run basis.

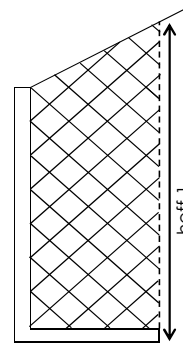


Backfill to rear of wall (A)

**Loading
condition 1
Level fill with
surcharge**

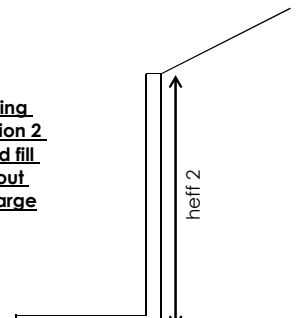


Backfill to front of wall (B)



Backfill to rear of wall (C)

**Loading
condition 2
Sloped fill
without
surcharge**



Backfill to front of wall (D)

2.1 Global Forces at EQU

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (A)

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret};$$

$$0.304 \cdot 0.935 \cdot 1.5 \cdot 10 \cdot 1.5 =$$

$$6.4 \text{ kN}$$

Lever Arm

Moment

$$0.750 \text{ m}$$

$$4.8 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2;$$

$$1.1 \cdot 0.304 \cdot 0.935 \cdot 18 \cdot 1.5^2 / 2 =$$

$$6.3 \text{ kN}$$

$$0.500 \text{ m}$$

$$3.2 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz}$$

$$0 \cdot 1.5 =$$

$$0.0 \text{ kN}$$

$$1.000 \text{ m}$$

$$0.0 \text{ kNm}$$

Horizontal Force (H):

$$12.7 \text{ kN}$$

$$M_H;$$

$$8.0 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$$

$$0.9 \cdot 1.376 \cdot 0.121 \cdot 25 =$$

$$3.7 \text{ kN}$$

$$0.061 \text{ m}$$

$$0.2 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$$

$$0.9 \cdot 0.75 \cdot 0.124 \cdot 25 =$$

$$2.1 \text{ kN}$$

$$0.375 \text{ m}$$

$$0.8 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot (h_{ret} \cdot t_{base}) \cdot L_{toe} \cdot \gamma_{mr};$$

$$0.9 \cdot 1.376 \cdot 0.629 \cdot 18 =$$

$$14.0 \text{ kN}$$

$$0.436 \text{ m}$$

$$6.1 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2;$$

$$0.9 \cdot 0.304 \cdot 0.34 \cdot 18 \cdot 1.5^2 / 2 =$$

$$1.9 \text{ kN}$$

$$0.750 \text{ m}$$

$$1.4 \text{ kNm}$$

Vertical Force (V):

$$21.7 \text{ kN}$$

$$M_V;$$

$$8.5 \text{ kNm}$$

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Loading condition 1 -Backfill to front of wall with level fill and surcharge (B)

Lever Arm Moment

Surcharge Load;

$$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ref}; \quad 0.304 \cdot 0.94 \cdot 1.5 \cdot 10 \cdot 1.5 = \quad 6.4 \text{ kN} \quad 0.750 \text{ m} \quad 4.8 \text{ kNm}$$

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 1.1 \cdot 0.304 \cdot 0.94 \cdot 18 \cdot 1.5^2/2 = \quad 6.4 \text{ kN} \quad 0.500 \text{ m} \quad 3.2 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 12.8 \text{ kN} \quad M_H; \quad 8.0 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 1.376 \cdot 0.121 \cdot 25 = \quad 3.7 \text{ kN} \quad 0.690 \text{ m} \quad 2.6 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 0.75 \cdot 0.124 \cdot 25 = \quad 2.1 \text{ kN} \quad 0.375 \text{ m} \quad 0.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 0.9 \cdot 0.304 \cdot 0.34 \cdot 18 \cdot 1.5^2/2 = \quad 1.9 \text{ kN} \quad 0.750 \text{ m} \quad 1.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 7.7 \text{ kN} \quad M_V; \quad 4.8 \text{ kNm}$$

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (C)

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d} \cdot (90-\alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 1.1 \cdot 0.817 \cdot 0.935 \cdot 18 \cdot 1.863^2/2 = \quad 26.2 \text{ kN} \quad 0.621 \text{ m} \quad 16.3 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\varphi'_{r,d}) \cdot \cos(\varphi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = \quad 0.0 \text{ kN} \quad 1.500 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 26.2 \text{ kN} \quad M_H; \quad 16.3 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 1.376 \cdot 0.121 \cdot 25 = \quad 3.7 \text{ kN} \quad 0.061 \text{ m} \quad 0.2 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 0.75 \cdot 0.124 \cdot 25 = \quad 2.1 \text{ kN} \quad 0.375 \text{ m} \quad 0.8 \text{ kNm}$$

Retained Soil;

$$F_{ret}=\gamma_{Gf} \cdot ((h_{ret} \cdot t_{base}) + (L_{toe} \cdot \tan(\beta)/2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 0.9 \cdot (1.376 + (0.629 \cdot 0.577/2)) \cdot 0.629 \cdot 18 = \quad 15.9 \text{ kN} \quad 0.436 \text{ m} \quad 6.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 0.9 \cdot 0.817 \cdot 0.34 \cdot 18 \cdot 1.863^2/2 = \quad 7.8 \text{ kN} \quad 0.750 \text{ m} \quad 5.9 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 29.5 \text{ kN} \quad M_V; \quad 13.8 \text{ kNm}$$

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (D)

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 1.1 \cdot 0.817 \cdot 0.94 \cdot 18 \cdot 1.5^2/2 = \quad 17.1 \text{ kN} \quad 0.500 \text{ m} \quad 8.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\varphi'_{r,d}) \cdot \cos(\varphi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = \quad 0.0 \text{ kN} \quad 1.500 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 17.1 \text{ kN} \quad M_H; \quad 8.6 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 1.376 \cdot 0.121 \cdot 25 = \quad 3.7 \text{ kN} \quad 0.690 \text{ m} \quad 2.6 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 0.75 \cdot 0.124 \cdot 25 = \quad 2.1 \text{ kN} \quad 0.375 \text{ m} \quad 0.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 0.9 \cdot 0.817 \cdot 0.34 \cdot 18 \cdot 1.5^2/2 = \quad 5.1 \text{ kN} \quad 0.750 \text{ m} \quad 3.8 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 10.9 \text{ kN} \quad M_V; \quad 7.2 \text{ kNm}$$

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2.2 Global Forces at Combination 1

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (A)

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.276 \cdot 0.923 \cdot 1.5 \cdot 10 \cdot 1.5 = 5.7 \text{ kN} \quad 0.750 \text{ m} \quad 4.3 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.276 \cdot 0.923 \cdot 18 \cdot 1.5^2 / 2 = 7.0 \text{ kN} \quad 0.500 \text{ m} \quad 3.5 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 12.7 \text{ kN} \quad M_H: \quad 7.8 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.061 \text{ m} \quad 0.3 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot (h_{ret} \cdot t_{base}) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot 1.376 \cdot 0.629 \cdot 18 = 15.6 \text{ kN} \quad 0.436 \text{ m} \quad 6.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.276 \cdot 0.37 \cdot 18 \cdot 1.5^2 / 2 = 2.1 \text{ kN} \quad 0.750 \text{ m} \quad 1.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 24.1 \text{ kN} \quad M_V: \quad 9.5 \text{ kNm}$$

Loading condition 1 -Backfill to front of wall with level fill and surcharge (B)

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.276 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 1.5 = 5.8 \text{ kN} \quad 0.750 \text{ m} \quad 4.3 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.276 \cdot 0.929 \cdot 18 \cdot 1.5^2 / 2 = 7.0 \text{ kN} \quad 0.500 \text{ m} \quad 3.5 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 12.8 \text{ kN} \quad M_H: \quad 7.8 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.690 \text{ m} \quad 2.9 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.276 \cdot 0.37 \cdot 18 \cdot 1.5^2 / 2 = 2.1 \text{ kN} \quad 0.750 \text{ m} \quad 1.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 8.6 \text{ kN} \quad M_V: \quad 5.3 \text{ kNm}$$

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (C)

Lever Arm Moment

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1.35 \cdot 0.537 \cdot 0.923 \cdot 18 \cdot 1.863^2 / 2 = 20.9 \text{ kN} \quad 0.621 \text{ m} \quad 13.0 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.142 = -1.6 \text{ kN} \quad 1.500 \text{ m} \quad -2.3 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 19.3 \text{ kN} \quad M_H: \quad 10.6 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.061 \text{ m} \quad 0.3 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot ((h_{ret} \cdot t_{base}) + (L_{toe} \cdot \tan(\beta) / 2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot (1.376 + (0.629 \cdot 0.577 / 2)) \cdot 0.629 \cdot 18 = 17.6 \text{ kN} \quad 0.436 \text{ m} \quad 7.7 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1 \cdot 0.537 \cdot 0.37 \cdot 18 \cdot 1.863^2 / 2 = 6.2 \text{ kN} \quad 0.750 \text{ m} \quad 4.7 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 30.3 \text{ kN} \quad M_V: \quad 13.5 \text{ kNm}$$

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Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (D)

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = Y_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot Y_{mr} \cdot h_{\text{eff}2}^2 / 2; \quad 1.35 \cdot 0.537 \cdot 0.929 \cdot 18 \cdot 1.5^2 / 2 = 13.6 \text{ kN} \quad 0.500 \text{ m} \quad 6.8 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = Y_G \cdot Y_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.142 = -0.5 \text{ kN} \quad 1.500 \text{ m} \quad -0.7 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot Y_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 13.1 \text{ kN} \quad M_{Ht}; \quad 6.1 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = Y_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot Y_{\text{stem}}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.690 \text{ m} \quad 2.9 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = Y_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot Y_{\text{base}}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{\text{eff}2}^2 / 2; \quad 1 \cdot 0.537 \cdot 0.37 \cdot 18 \cdot 1.5^2 / 2 = 4.0 \text{ kN} \quad 0.750 \text{ m} \quad 3.0 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 10.5 \text{ kN} \quad M_{Vt}; \quad 6.8 \text{ kNm}$$

2.3 Global Forces at Combination 2

Loading condition 1 - Backfill to rear of wall with level fill and surcharge (A)

Lever Arm Moment

Surcharge Load;

$$F_{\text{sur,h}} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot Y_Q \cdot \text{Surcharge}_Q \cdot h_{\text{ret}}; \quad 0.341 \cdot 0.948 \cdot 1.3 \cdot 10 \cdot 1.5 = 6.3 \text{ kN} \quad 0.750 \text{ m} \quad 4.7 \text{ kNm}$$

Active Pressure;

$$F_{\text{ret,h}} = Y_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot Y_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.341 \cdot 0.948 \cdot 18 \cdot 1.5^2 / 2 = 6.5 \text{ kN} \quad 0.500 \text{ m} \quad 3.3 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot Y_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 12.9 \text{ kN} \quad M_{Ht}; \quad 8.0 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = Y_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot Y_{\text{stem}}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.061 \text{ m} \quad 0.3 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = Y_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot Y_{\text{base}}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = Y_{Gf} \cdot (h_{\text{ret}} - t_{\text{base}}) \cdot L_{\text{toe}} \cdot Y_{mr}; \quad 1 \cdot 1.376 \cdot 0.629 \cdot 18 = 15.6 \text{ kN} \quad 0.436 \text{ m} \quad 6.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.341 \cdot 0.303 \cdot 18 \cdot 1.5^2 / 2 = 2.1 \text{ kN} \quad 0.750 \text{ m} \quad 1.6 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 24.2 \text{ kN} \quad M_{Vt}; \quad 9.5 \text{ kNm}$$

Loading condition 1 - Backfill to front of wall with level fill and surcharge (B)

Lever Arm Moment

Surcharge Load;

$$F_{\text{sur,h}} = K_a \cdot \cos(\delta_{r,d}) \cdot Y_Q \cdot \text{Surcharge}_Q \cdot h_{\text{ret}}; \quad 0.341 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 1.5 = 6.3 \text{ kN} \quad 0.750 \text{ m} \quad 4.8 \text{ kNm}$$

Active Pressure;

$$F_{\text{ret,h}} = Y_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot Y_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.341 \cdot 0.953 \cdot 18 \cdot 1.5^2 / 2 = 6.6 \text{ kN} \quad 0.500 \text{ m} \quad 3.3 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot Y_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 12.9 \text{ kN} \quad M_{Ht}; \quad 8.0 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = Y_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot Y_{\text{stem}}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.690 \text{ m} \quad 2.9 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = Y_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot Y_{\text{base}}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.341 \cdot 0.303 \cdot 18 \cdot 1.5^2 / 2 = 2.1 \text{ kN} \quad 0.750 \text{ m} \quad 1.6 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 8.6 \text{ kN} \quad M_{Vt}; \quad 5.3 \text{ kNm}$$

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Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (C)

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.851 \cdot 0.948 \cdot 18 \cdot 1.821^2 / 2 = 24.1 \text{ kN} \quad 0.607 \text{ m} \quad 14.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.183 = 1.3 \text{ kN} \quad 1.500 \text{ m} \quad 2.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 25.4 \text{ kN} \quad M_H: \quad 16.6 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.061 \text{ m} \quad 0.3 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = \gamma_{Gf} \cdot ((h_{\text{ret}} - t_{\text{base}}) + (L_{\text{toe}} \cdot \tan(\beta) / 2)) \cdot L_{\text{toe}} \cdot \gamma_{mr}; \quad 1 \cdot (1.376 + (0.629 \cdot 0.577 / 2)) \cdot 0.629 \cdot 18 = 17.6 \text{ kN} \quad 0.436 \text{ m} \quad 7.7 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.851 \cdot 0.303 \cdot 18 \cdot 1.821^2 / 2 = 7.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.8 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 31.8 \text{ kN} \quad M_V: \quad 14.6 \text{ kNm}$$

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (D)

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.851 \cdot 0.953 \cdot 18 \cdot 1.5^2 / 2 = 16.4 \text{ kN} \quad 0.500 \text{ m} \quad 8.2 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.064 = 0.5 \text{ kN} \quad 1.500 \text{ m} \quad 0.7 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 16.9 \text{ kN} \quad M_H: \quad 8.9 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 1.376 \cdot 0.121 \cdot 25 = 4.2 \text{ kN} \quad 0.690 \text{ m} \quad 2.9 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 0.75 \cdot 0.124 \cdot 25 = 2.3 \text{ kN} \quad 0.375 \text{ m} \quad 0.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.851 \cdot 0.303 \cdot 18 \cdot 1.5^2 / 2 = 5.2 \text{ kN} \quad 0.750 \text{ m} \quad 3.9 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 11.7 \text{ kN} \quad M_V: \quad 7.7 \text{ kNm}$$

2.4 Summary of forces and moments on wall

Equilibrium	H	M _H	V	M _V
A: LC1 - Backfill to rear:	12.7 kN	8.0 kNm	21.7 kN	8.5 kNm
B: LC1 - Backfill to front:	12.8 kN	8.0 kNm	7.7 kN	4.8 kNm
C: LC2 - Backfill to rear:	26.2 kN	16.3 kNm	29.5 kN	13.8 kN
D: LC2 - Backfill to front:	17.1 kN	8.6 kNm	10.9 kN	7.2 kN
Combination 1	H	M _H	V	M _V
A: LC1 - Backfill to rear:	12.7 kN	7.8 kNm	24.1 kN	9.5 kNm
B: LC1 - Backfill to front:	12.8 kN	7.8 kNm	8.6 kN	5.3 kNm
C: LC2 - Backfill to rear:	19.3 kN	10.6 kNm	30.3 kN	13.5 kN
D: LC2 - Backfill to front:	13.1 kN	6.1 kNm	10.5 kN	6.8 kN
Combination 2	H	M _H	V	M _V
A: LC1 - Backfill to rear:	12.9 kN	8.0 kNm	24.2 kN	9.5 kNm
B: LC1 - Backfill to front:	12.9 kN	8.0 kNm	8.6 kN	5.3 kNm
C: LC2 - Backfill to rear:	25.4 kN	16.6 kNm	31.8 kN	14.6 kN
D: LC2 - Backfill to front:	16.9 kN	8.9 kNm	11.7 kN	7.7 kN

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2.5 Resultant actions

Sliding force

Assuming the characteristic base friction (μ) is equal to the vertical force multiplied by **0.4**

		<u>Equilibrium</u>	<u>Combination 1</u>	<u>Combination 2</u>
V• μ -H	LC1 - Backfill to rear:	4.0 kN 0.68 ULS Ratio	3.0 kN 0.76 ULS Ratio	3.2 kN 0.75 ULS Ratio
	LC1 - Backfill to front:	9.7 kN 0.24 ULS Ratio	9.4 kN 0.27 ULS Ratio	9.5 kN 0.27 ULS Ratio
	LC2 - Backfill to rear:	14.4 kN 0.45 ULS Ratio	7.2 kN 0.63 ULS Ratio	12.7 kN 0.50 ULS Ratio
	LC2 - Backfill to front:	12.8 kN 0.25 ULS Ratio	8.9 kN 0.32 ULS Ratio	12.2 kN 0.28 ULS Ratio

Resultant moment

*Positive values indicate a stabilising moment and negative values indicate a destabilising moment

		<u>Equilibrium</u>	<u>Combination 1</u>	<u>Combination 2</u>
M_V - M_H	LC1 - Backfill to rear:	0.6 kNm 1.07 ULS Ratio	1.7 kNm 1.22 ULS Ratio	1.5 kNm 1.19 ULS Ratio
	LC1 - Backfill to front:	-3.2 kNm 0.60 ULS Ratio	-2.5 kNm 0.68 ULS Ratio	-2.7 kNm 0.66 ULS Ratio
	LC2 - Backfill to rear:	-2.5 kNm 0.85 ULS Ratio	2.8 kNm 1.26 ULS Ratio	-2.0 kNm 0.88 ULS Ratio
	LC2 - Backfill to front:	-1.4 kNm 0.84 ULS Ratio	0.7 kNm 1.11 ULS Ratio	-1.2 kNm 0.86 ULS Ratio

2.6 Design Values

The stability of the structure is defined by the EQU load combination and therefore the stability of the foundation design should be based upon the following maximum values which relate to this specific load combination. These values are pro-rated to take account of the width of the retaining wall. The loading condition will determine the direction of the sliding force and whether the moments are clockwise or anti-clockwise.

Resultant sliding force; 14.4 kN/m - Loading condition 2 (Backfill to the rear)
Vertical load; 29.5 kN/m - Loading condition 2 (Backfill to the rear)
Resultant destabilising moment; 3.2 kNm/m - Loading condition 1 (Backfill to the front)

The structural design of the retaining wall is based upon the following maximum pro-rated values from Combinations 1 & 2.

Resultant sliding force; 12.7 kN/m - Combination 2 with loading condition 2 (Backfill to the rear)
Resultant anti-clockwise destabilising moment; 2.0 kNm/m - Combination 2 with loading condition 2 (Backfill to the rear)
Resultant clockwise destabilising moment; 2.7 kNm/m - Combination 2 with loading condition 1 (Backfill to the front)

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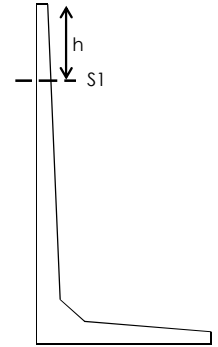
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3.1 Analysis Height 1

Analysis height 1 (S1) 500 mm
Soil depth at S1 500 mm



Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.401m	0.474m
Property B	0.232m	0.274m
Property C	0.256m	0.242m
Property D	-0.020m	0.029m
Property E	-0.037m	0.047m
Property F	-0.013m	0.015m
Area of Soil (A)	-0.005 m ²	0.007 m ²

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 1) (A)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.923 \cdot 1.5 \cdot 10 \cdot 0.5 =$	1.9 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.276 \cdot 0.923 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.7 kN	$M_H:$ 0.6 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 1) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.5 =$	1.9 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.276 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.7 kN	$M_H:$ 0.6 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 1) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.923 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	1.5 kN	$M_H:$ 0.2 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 1) (D)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	1.5 kN	$M_H:$ 0.2 kNm

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 2) (A)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.948 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.341 \cdot 0.948 \cdot 18 \cdot 0.5^2 / 2 =$	0.7 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.8 kN	$M_H:$ 0.6 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 2) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.341 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	0.7 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.8 kN	$M_H:$ 0.6 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 2) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.948 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	1.9 kN	$M_H:$ 0.3 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 2) (D)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	1.9 kN	$M_H:$ 0.3 kNm

**1500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

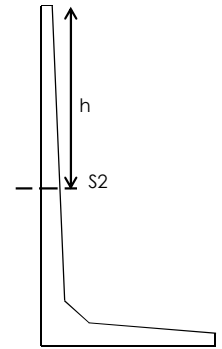
CHK: C.B.

SHEET: 10 of 20

3.2 Analysis Height 2

Analysis height 2 (S2) 1030 mm
Soil depth at S2 1030 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.827m	0.977m
Property B	0.477m	0.564m
Property C	0.527m	0.498m
Property D	-0.042m	0.059m
Property E	-0.076m	0.096m
Property F	-0.027m	0.030m
Area of Soil (A)	-0.021 m ²	0.030 m ²



Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 1) (A)

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.923 \cdot 1.5 \cdot 10 \cdot 1.03=$	3.9 kN	0.515 m	2.0 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.276 \cdot 0.923 \cdot 18 \cdot 1.03^2/2=$	3.3 kN	0.343 m	1.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			7.2 kN	$M_H:$	3.2 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 1) (B)

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 1.03=$	4.0 kN	0.515 m	2.0 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.276 \cdot 0.929 \cdot 18 \cdot 1.03^2/2=$	3.3 kN	0.343 m	1.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			7.3 kN	$M_H:$	3.2 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 1) (C)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.923 \cdot 18 \cdot 1.03^2 / 2 =$	6.4kN	0.343 m	2.2 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.021 =$	-0.2kN	1.030 m	-0.2 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			6.2 kN	$M_H:$	2.0 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 1) (D)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.929 \cdot 18 \cdot 1.03^2 / 2 =$	6.4kN	0.343 m	2.2 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.021 =$	-0.2kN	1.030 m	-0.2 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			6.2 kN	$M_H:$	2.0 kNm

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 2) (A)

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.948 \cdot 1.3 \cdot 10 \cdot 1.03=$	4.3 kN	0.515 m	2.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.341 \cdot 0.948 \cdot 18 \cdot 1.03^2/2=$	3.1 kN	0.343 m	1.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			7.4 kN	$M_H:$	3.3 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 2) (B)

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 1.03=$	4.4 kN	0.515 m	2.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.341 \cdot 0.953 \cdot 18 \cdot 1.03^2/2=$	3.1 kN	0.343 m	1.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			7.5 kN	$M_H:$	3.3 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 2) (C)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.948 \cdot 18 \cdot 1.03^2 / 2 =$	7.7kN	0.343 m	2.6 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.03 =$	0.2kN	1.030 m	0.2 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			7.9 kN	$M_H:$	2.9 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 2) (D)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.953 \cdot 18 \cdot 1.03^2 / 2 =$	7.7kN	0.343 m	2.7 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.03 =$	0.2kN	1.030 m	0.2 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.530 m	0.0 kNm
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			8.0 kN	$M_H:$	2.9 kNm

**1500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

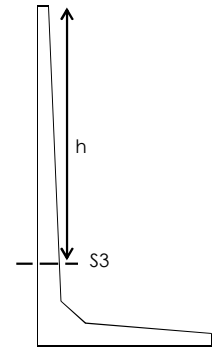
CHK: C.B.

SHEET: 11 of 20

3.3 Analysis Height 3

Analysis height 3 (S3) 1270 mm
Soil depth at S3 1270 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	1.020m	1.204m
Property B	0.589m	0.695m
Property C	0.650m	0.614m
Property D	-0.051m	0.073m
Property E	-0.094m	0.119m
Property F	-0.033m	0.037m
Area of Soil (A)	-0.033 m ²	0.046 m ²



Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 1) (A)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.923 \cdot 1.5 \cdot 10 \cdot 1.27 =$	4.9 kN	0.635 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.276 \cdot 0.923 \cdot 18 \cdot 1.27^2 / 2 =$	5.0 kN	0.423 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		9.8 kN	$M_H:$	5.2 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 1) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 1.27 =$	4.9 kN	0.635 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.276 \cdot 0.929 \cdot 18 \cdot 1.27^2 / 2 =$	5.0 kN	0.423 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		9.9 kN	$M_H:$	5.2 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 1) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.923 \cdot 18 \cdot 1.27^2 / 2 =$	9.7kN	0.423 m
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.033 =$	-0.4kN	1.270 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		9.4 kN	$M_H:$	3.7 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 1) (D)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.929 \cdot 18 \cdot 1.27^2 / 2 =$	9.8kN	0.423 m
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.033 =$	-0.4kN	1.270 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		9.4 kN	$M_H:$	3.7 kNm

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 2) (A)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.948 \cdot 1.3 \cdot 10 \cdot 1.27 =$	5.3 kN	0.635 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.341 \cdot 0.948 \cdot 18 \cdot 1.27^2 / 2 =$	4.7 kN	0.423 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		10.0 kN	$M_H:$	5.4 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 2) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 1.27 =$	5.4 kN	0.635 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.341 \cdot 0.953 \cdot 18 \cdot 1.27^2 / 2 =$	4.7 kN	0.423 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		10.1 kN	$M_H:$	5.4 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 2) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.948 \cdot 18 \cdot 1.27^2 / 2 =$	11.7kN	0.423 m
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.046 =$	0.3kN	1.270 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		12.0 kN	$M_H:$	5.4 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 2) (D)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.953 \cdot 18 \cdot 1.27^2 / 2 =$	11.8kN	0.423 m
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.046 =$	0.3kN	1.270 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.770 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		12.1 kN	$M_H:$	5.4 kNm

**1500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

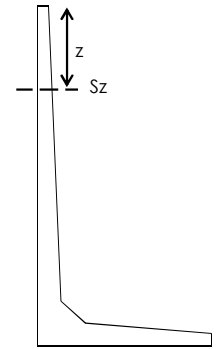
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CHK: C.B.

SHEET: 12 of 20

3.3 Analysis Height Z

Height - Variable z (Sz) 500 mm
Soil depth at Sz 500 mm



Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.401m	0.474m
Property B	0.232m	0.274m
Property C	0.256m	0.242m
Property D	-0.020m	0.029m
Property E	-0.037m	0.047m
Property F	-0.013m	0.015m
Area of Soil (A)	-0.005 m ²	0.007 m ²

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 1) (A)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.923 \cdot 1.5 \cdot 10 \cdot 0.5 =$	1.9 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.276 \cdot 0.923 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.7 kN	$M_H:$	0.6 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 1) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.276 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.5 =$	1.9 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.276 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.7 kN	$M_H:$	0.6 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 1) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.923 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.5 kN	$M_H:$	0.2 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 1) (D)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.537 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.5 kN	$M_H:$	0.2 kNm

Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 2) (A)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.948 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.341 \cdot 0.948 \cdot 18 \cdot 0.5^2 / 2 =$	0.7 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.8 kN	$M_H:$	0.6 kNm

Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 2) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.341 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.341 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	0.7 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.8 kN	$M_H:$	0.6 kNm

Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 2) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.948 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.9 kN	$M_H:$	0.3 kNm

Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 2) (D)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.851 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.9 kN	$M_H:$	0.3 kNm

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3.4 Summary of forces and moments on wall

These values are pro-rated to take account of the width of the retaining wall.

Combination 1	Analysis 1 @ 500		Analysis 2 @ 1030		Analysis 3 @ 1270		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Rear level fill & surcharge (A)	2.7 kN	0.6 kNm	7.2 kN	3.2 kNm	9.8 kN	5.2 kNm	2.7 kN	0.6 kNm
Front level fill & surcharge (B)	2.7 kN	0.6 kNm	7.3 kN	3.2 kNm	9.9 kN	5.2 kNm	2.7 kN	0.6 kNm
Rear sloped fill without surcharge (C)	1.5 kN	0.2 kNm	6.2 kN	2.0 kNm	9.4 kN	3.7 kNm	1.5 kN	0.2 kNm
Front sloped fill without surcharge (D)	1.5 kN	0.2 kNm	6.2 kN	2.0 kNm	9.4 kN	3.7 kNm	1.5 kN	0.2 kNm
Combination 2	H	M _H	H	M _H	H	M _H	H	M _H
Rear level fill & surcharge (A)	2.8 kN	0.6 kNm	7.4 kN	3.3 kNm	10.0 kN	5.4 kNm	2.8 kN	0.6 kNm
Front level fill & surcharge (B)	2.8 kN	0.6 kNm	7.5 kN	3.3 kNm	10.1 kN	5.4 kNm	2.8 kN	0.6 kNm
Rear sloped fill without surcharge (C)	1.9 kN	0.3 kNm	7.9 kN	2.9 kNm	12.0 kN	5.4 kNm	1.9 kN	0.3 kNm
Front sloped fill without surcharge (D)	1.9 kN	0.3 kNm	8.0 kN	2.9 kNm	12.1 kN	5.4 kNm	1.9 kN	0.3 kNm
Back face is in tension values	Analysis 1 @ 500		Analysis 2 @ 1030		Analysis 3 @ 1270		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	2.8 kN	0.3 kNm	7.9 kN	2.9 kNm	12.0 kN	5.4 kNm	1.9 kN	0.3 kNm
Front face is in tension values	Analysis 1 @ 500		Analysis 2 @ 1030		Analysis 3 @ 1270		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	2.8 kN	0.6 kNm	8.0 kN	3.3 kNm	12.1 kN	5.4 kNm	2.8 kN	0.6 kNm

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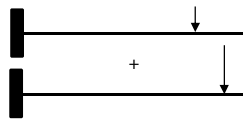
4.0 Wall Base Design

Analysis of the wall base is carried out at the following lengths (measured from the stem face of the wall):

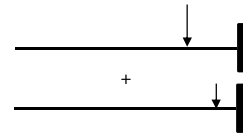
Analysis length 1 (B1)	230 mm
Analysis length 2 (B2)	460 mm
Analysis length 3 (B3)	705 mm

The number of rows of bolts will determine how the forces are distributed in the base.
This design is done on the basis of an anchor system using: **1 rows of bolts**

Since the overturning forces must be balanced by the force in the anchors there can be no rotation at the pivot point. Therefore the base can be modelled as having a fixed support at the pivot point as shown below.



Anti-Clockwise rotation (two Anchor system)



Clockwise rotation (two Anchor system)

Forces in single row anchor system

$$M = FS_1 \cdot lb_1$$

Forces in two row anchor system

$$M = FS_1 \cdot lb_1 + FS_2 \cdot lb_2 \quad (1)$$

$$FS_1 / lb_1 = FS_2 / lb_2 \quad (2)$$

$$FS_1 = lb_1 \cdot FS_2 / lb_2 \quad \text{Rearrange (2)}$$

$$M = (lb_1^2) \cdot FS_2 / lb_2 + FS_2 \cdot lb_2 \quad \text{Substituting into (1)}$$

$$FS_2 = M / [(lb_1^2) / lb_2 + lb_2] \quad \text{Factorise \& rearrange}$$

4.1 Anchored Anticlockwise Rotation

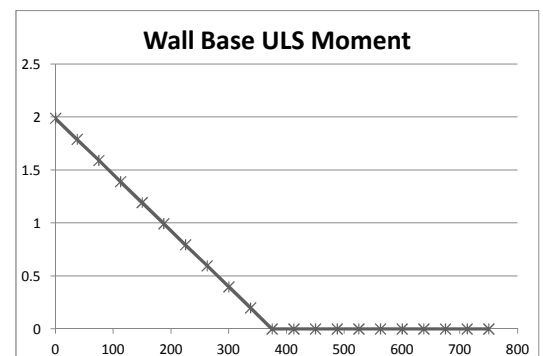
Maximum overturning moment	2.0 kNm
Lever arm to closest anchor (lb1)	375 mm
Lever arm to furthest anchor (lb2)	N/A

From the above equations:

$$\text{Tension force in closest anchors (FS1)} = 5.3 \text{ kN}$$

$$\text{Tension force in furthest anchors (FS2)} = 0.0 \text{ kN}$$

X:	230mm	460mm	705mm
Tension Moment Top face:	0.8 kNm	0.0 kNm	0.0 kNm
Shear:	5.3 kN	0.0 kN	0.0 kN



4.2 Anchored Clockwise Rotation

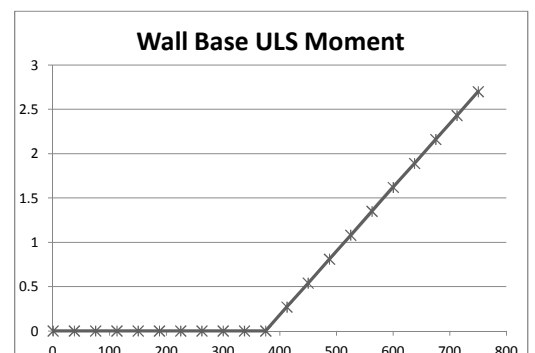
Maximum overturning moment	2.7 kNm
Lever arm to closest anchor (lb1)	375 mm
Lever arm to furthest anchor (lb2)	N/A

From the above equations:

$$\text{Tension force in closest anchors (FS1)} = 7.2 \text{ kN}$$

$$\text{Tension force in furthest anchors (FS2)} = 0.0 \text{ kN}$$

X:	230mm	460mm	705mm
Tension Moment Top face:	0.0 kNm	0.6 kNm	2.4 kNm
Shear:	0.0 kN	7.2 kN	7.2 kN



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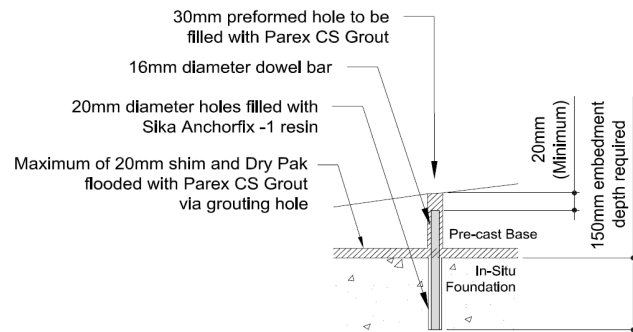
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5.0 Anchor Design

The anchor design, shown right, is considered for the effects of tension and shear. The dowel connections in the first row (closest to the face) and the second row are checked independently at ultimate limit state.

Char' ultimate tensile strength of dowel (f_{uk});	550 N/mm²
Dowel bar diameter(ϕ)	16 mm
Height of Shims	20 mm
Standard Embedment Length	150 mm
First Row: Dowel Bar Length (D_L)	250 mm
First Row: Effective Depth In Precast (h_{eff1});	80 mm
First Row: Effective Depth In Foundation (h_{eff2});	150 mm
Second Row: Dowel Bar Length (D_L)	N/A
Second Row: Effective Depth In Precast (h_{eff1});	N/A
Second Row: Effective Depth In Foundation (h_{eff2});	N/A



Determination of the bond resistance of grout

Conbextra GP grout has been tested in tension by the manufacturer in accordance with EN1504 Part 6 - Anchoring of reinforcing steel bar yielding the following results:

	Deformation 75kN	Maximum Load ($N_{u,m}$)
Dry test	0.49 mm	92.8 kN
Wet Test	0.44 mm	106.3 kN

Contact area of 16mm diameter test bar with 150mm embedment is equal to: 7540mm²

From the results of the tension tests in dry conditions the average bond resistance is calculated according to the following equation.

Average bond resistance;
 $f_{bm} = N_{u,m} / A;$ $92.8 / 7540 = 12.3 \text{ N/mm}^2$

5.1 Anchorage in Precast

5.1.1 Resistance to Tension Loads

The resistance to tension loads in the pre-cast base shall be defined by the point of steel failure and the initial basic resistance of the anchor to pull-out. The design assumes that concrete cone failure and splitting failure cannot occur in the base due to the reinforcement cage used. The resistance to tension loads in the foundation is based on test data.

Maximum Tensile Load per Anchor (N);	<u>First Row</u>	<u>Second Row</u>
$N = \text{Max}\{\text{Clockwise Force, Anticlockwise Force}\} / \text{No.}$	$\text{Max}\{5.3, 0\} / 2 = 3.6 \text{ kN}$	N/A

5.1.1.1 Steel Failure

Area of steel;	
$A_s = \pi \cdot \phi^2 / 4;$	$\pi \cdot 16^2 / 4 = 201 \text{ mm}^2$
Characteristic resistance of an anchor in the case of steel failure;	
$N_{Rk,s} = A_s \cdot f_{uk};$	$201 \cdot 550 / 1000 = 110.6 \text{ kN}$
Design resistance of an anchor in the case of steel failure;	
$N_{Rd,s} = N_{Rk,s} / \gamma_{Ms};$	$110.6 / 1.15 = 96.1 \text{ kN}$

Ratio between design action and design resistance	<u>First Row</u>	<u>Second Row</u>
$\beta_N = N / N_{Rd,s}$	$3.6 / 96.1 = 0.04$	N/A

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5.1.1.2 Pull-Out Failure to Pre-Cast Base

Characteristic resistance to pull-out;

$$N_{Rk,p} = \pi \cdot \phi \cdot H_{eff} \cdot f_{dm}$$

First Row
 $\pi \cdot 16 \cdot 80 \cdot 12.3 = 49.5 \text{ kN}$

Second Row
N/A

Design tension capacity of anchorage;

$$N_{Rd,p} = N_{Rk,p} / \gamma_{grout}$$

49.5/3 = 16.5 kN

N/A

Ratio between design action and design resistance

$$\beta_N = N / N_{Rd,s}$$

3.6/16.5 = 0.22

N/A

5.1.2 Resistance to Shear Loads

The resistance to shear loads is defined by the point of steel failure. The design assumes that the shear load acts at the failure surface and therefore there is no lever arm and that concrete pry out failure or edge failure cannot occur in the pre-cast base due to the reinforcement cage used.

Maximum shearing force per anchor;

$$V = \text{Max Shear Force} / \text{No. Dowels}$$

12.7/(2 \cdot 1) = 6.4 kN

5.1.2.1 Steel Failure, Shear Load without Lever Arm

Area of steel;

$$A_s = \pi \cdot \phi^2 / 4$$

$\pi \cdot 16^2 / 4 = 201 \text{ mm}^2$

Characteristic resistance of an anchor in the case of steel failure;

$$V_{Rk,s} = 0.5 \cdot A_s \cdot f_{yk}$$

0.5 \cdot 201 \cdot 550 / 1000 = 55.3 kN

Design resistance of an anchor in the case of steel failure;

$$V_{Rd,s} = V_{Rk,s} / \gamma_{Ms}$$

55.3 / 1.15 = 48.1 kN

Ratio between design action and design resistance

$$\beta_V = V / V_{Rd,s}$$

First Row

6.4/48.1 = 0.13

Second Row

N/A

5.1.3 Resistance to combined tension and shear loads

$$(N_{ED} / N_{RD,Dowel})^{1.5} + (V_{ED} / V_{Rd,dowel})^{1.5} < 1.0;$$

First Row

0.06

Second Row

$$(N_{ED} / N_{RD})^{1.5} + (V_{ED} / V_{Rd})^{1.5} < 1.0;$$

0.15

N/A

$$(N_{ED} / N_{RD}) + (V_{ED} / V_{Rd}) < 1.2;$$

0.35

N/A

5.1 Anchorage in Foundation

From Sika Technical information - Characteristic resistance to pull-out of deformed bar;

$$N_{Rk,p} = 30 \text{ kN}$$

30.0 kN

Design tension capacity of anchorage;

$$N_{Rd,p} = N_{Rk,p} / \gamma_{resin}$$

30/3 = 10.0 kN

Ratio between design action and design resistance

$$\beta_N = N / N_{Rd,s}$$

First Row

3.6/10 = 0.36

Second Row

N/A

Anchorage provided is adequate

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6.0 Reinforcement Design

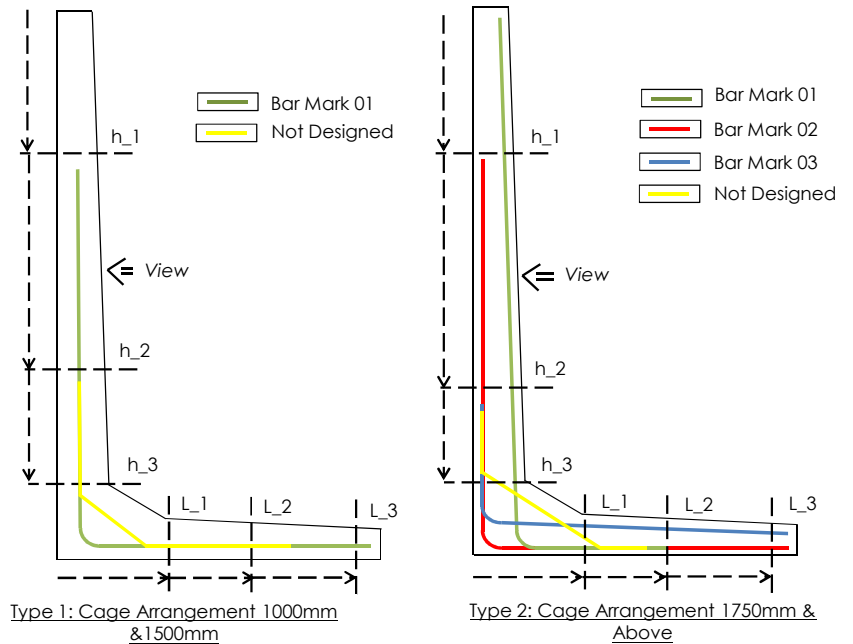
All the standard retaining walls have different reinforcement cages, however, they follow one of two patterns. The 1000mm and 1500mm are a type one and 1750mm and above are of a type 2, these are shown (right). A reinforcement check is then done on the three heights of the stem and three lengths of the base which are located to give the maximum moment and shear force with the minimum reinforcement.

Cage Provided

This retaining wall has a Type 1 cage.

Reinforcement Provided

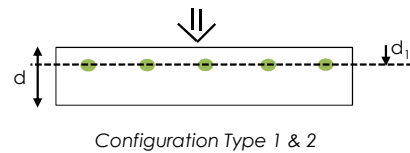
	Diameter	Spacing	As,prov
Bar Mark 1	10.00	200	393
Bar Mark 2	0.00	0	0
Bar Mark 3	0.00	0	0



6.1 Section Analysis

Analysis height 1 (500mm)

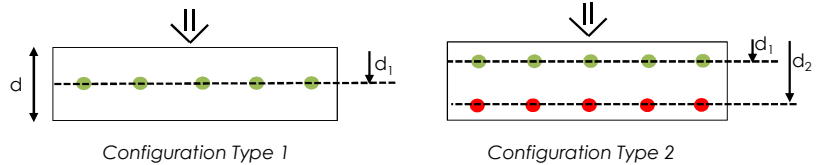
Depth @ S1 (hS1)	118 mm
hS1 - Depth to rein' (d1)	60 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	393	58	0	0
Front face in tension	393	60	0	0

Analysis height 2 (1030mm)

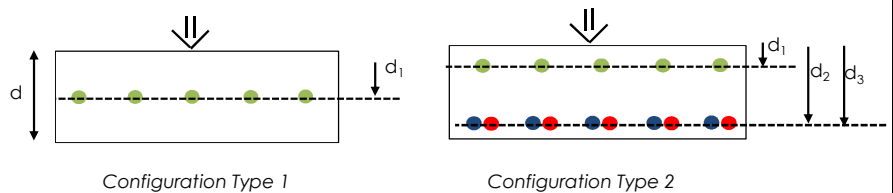
Depth @ S2 (hS2)	126 mm
hS2 - Depth to rein' (d1)	68 mm
hS2 - Depth to rein' (d2)	0 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	393	58	0	0
Front face in tension	393	68	0	0

Analysis height 3 (1270mm)

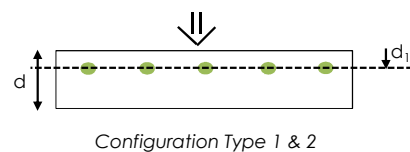
Depth @ S3 (hS3)	130 mm
hS3 - Depth to rein' (d1)	72 mm
hS3 - Depth to rein' (d2)	0 mm
hS3 - Depth to rein' (d3)	0 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	393	58	0	0
Front face in tension	393	72	0	0

Analysis height z (500mm)

Depth @ Sz (hSz)	118 mm
Depth to rein' (d1)	60 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	393	58	0	0
Front face in tension	393	60	0	0

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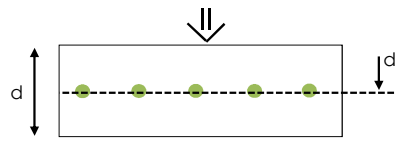
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CHK: C.B.

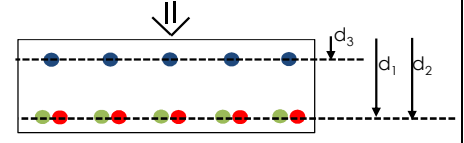
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Analysis length 1 (230mm)

Depth @ B1 (hB1)	130 mm
hB1 - Depth to rein' (d1)	72 mm
hB1 - Depth to rein' (d2)	0 mm
hB1 - Depth to rein' (d3)	0 mm



Configuration Type 1

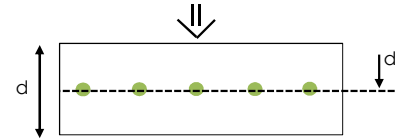


Configuration Type 2

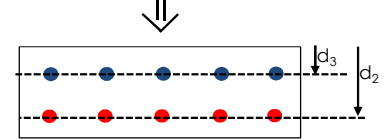
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	393	58	0	0
Bottom face in tension	393	72	0	0

Analysis length 2 (460mm)

Depth @ B2 (hB2)	121 mm
hB2 - Depth to rein' (d1)	63 mm
hB2 - Depth to rein' (d2)	0 mm
hB2 - Depth to rein' (d3)	0 mm



Configuration Type 1

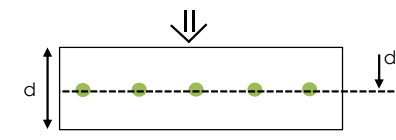


Configuration Type 2

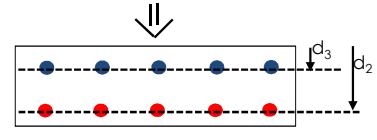
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	393	58	0	0
Bottom face in tension	393	63	0	0

Analysis length 3 (705mm)

Depth @ B3 (hB3)	112 mm
hB3 - Depth to rein' (d1)	54 mm
hB3 - Depth to rein' (d2)	0 mm
hB3 - Depth to rein' (d3)	0 mm



Configuration Type 1



Configuration Type 2

	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	393	58	0	0
Bottom face in tension	393	54	0	0

6.2 Concrete Properties

Concrete details & design

Concrete strength class
 Characteristic compressive cylinder strength
 Characteristic compressive cube strength
 Mean value of compressive cylinder strength
 Mean value of axial tensile strength
 5% fractile of axial tensile strength
 Secant modulus of elasticity
 Partial modulus of elasticity of concrete
 Compressive strength coefficient - cl.3.1.6(1)
 Design compressive concrete strength - cl.3.1.6(1)
 Maximum aggregate size
 Deviation
 Required concrete class
 Maximum concrete strut capacity
 Minimum concrete strut capacity

Pre-Cast

C45/55

$$\begin{aligned}
 f_{ck} &= 45 \text{ N/mm}^2 \\
 f_{ck,cube} &= 55 \text{ N/mm}^2 \\
 f_{cm} &= 53 \text{ N/mm}^2 \\
 f_{ctm} &= 4 \text{ N/mm}^2 \\
 f_{ctk,0.05} &= 3 \text{ N/mm}^2 \\
 E_{cm} &= 22 \cdot (f_{cm}/10)^{0.3} = 36283 \text{ N/mm}^2 \\
 \gamma_c &= 1.50 \\
 \alpha_{cc} &= 0.85 \\
 f_{cd} &= \alpha_{cc} \cdot f_{ck} / \gamma_c = 25.5 \text{ N/mm}^2 \\
 h_{agg} &= 20 \text{ mm} \\
 \Delta C_{dev} &= 5 \text{ mm} \\
 \text{Class} &= \mathbf{XC3/4} \\
 VRd, \max(\cot(\theta) = 2.5) &= 5.08 \\
 VRd, \max(\cot(\theta) = 1.0) &= 7.38
 \end{aligned}$$

Reinforcement details

Characteristic yield strength of reinforcement
 Modulus of elasticity of reinforcement
 Partial factor for reinforcing steel - Table 2.1N
 Design yield strength of reinforcement

$$\begin{aligned}
 f_{yk} &= 500 \text{ N/mm}^2 \\
 E_s &= 210000 \text{ N/mm}^2 \\
 \gamma_s &= 1.15 \\
 f_{yd} &= f_{yk} / \gamma_s = 435 \text{ N/mm}^2
 \end{aligned}$$

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6.3 Stem Reinforcement Design

Back face in Tension

<u>Moment</u>	h_1	h_2	h_3	h_Z
Moment capacity of section	7.9 kNm	7.9 kNm	7.9 kNm	7.9 kNm
Design Bending Moment	0.3 kNm	2.9 kNm	5.4 kNm	0.3 kNm
Area of tension reinforcement provided	393 mm ²	393 mm ²	393 mm ²	393 mm ²
Area of compression reinforcement provided	0 mm ²	0 mm ²	0 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	48 mm	48 mm	48 mm	48 mm
K Factor =M/(b•d _{n1} ² •fck);	0.003	0.028	0.052	0.003
Limiting k Factor = 0.5986-0.1862-0.21;	0.208	0.208	0.208	0.208
Lever arm (z) =Min(0.95•d _{n1} ,d _{n1} /2•(1+√(1-3.53k)));	46 mm	46 mm	46 mm	46 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	16 mm ²	143 mm ²	269 mm ²	16 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	95 mm ²	95 mm ²	95 mm ²	95 mm ²
where k>k' Lever arm (z) =d _{n1} /2•(1+√(1-3.53k'));				
Depth to compression reinforcement (d _{n2})=d-Δc;				
Compression Moment (M')=b•d _{n1} ² •f _{ck} •(k-K');				
Compression reinforcement reqd (A _{s'})=M'/(f _{yd} •(d _{n1} -d _{n2}));				
Tension reinforcement required (A _s) =(M-M')/f _{yd} •z+As';				
Tension reinforcement required at section (A _{s,req})	95 mm ²	143 mm ²	269 mm ²	95 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (4.1)	Pass (2.7)	Pass (1.4)	Pass (4.1)
<u>Shear</u>				
Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²
Effective Depth Factor (k) =min(2.0,1+√(200/dn1));	2.0000	2.0000	2.0000	2.0000
Reinforcement Ratio (ρ ₁) =min(0.02,A _s /b•d _{n1});	0.0080	0.0080	0.0080	0.0080
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	31.9 kN	31.9 kN	31.9 kN	31.9 kN
Shear resistance (V _{Rd,c,1}) = max(V _{Rd,c,min} ,C _{Rd,c} •k•(100•ρ ₁ •(f _{ck} /1))0.333•b•d _{n1});	38.0 kN	38.0 kN	38.0 kN	38.0 kN
Shear resistance required (V)	2.8 kN	7.9 kN	12.0 kN	1.9 kN
	Pass (9.9)	Pass (4.7)	Pass (3.1)	Pass (9.9)

Front face in Tension

<u>Moment</u>	h_1	h_2	h_3	h_Z
Moment capacity of section	8.0 kNm	9.4 kNm	10.1 kNm	8.0 kNm
Design Bending Moment	0.6 kNm	3.3 kNm	5.4 kNm	0.6 kNm
Area of tension reinforcement provided	393 mm ²	393 mm ²	393 mm ²	393 mm ²
Area of compression reinforcement provided	0 mm ²	0 mm ²	0 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	50 mm	58 mm	62 mm	50 mm
K Factor =M/(b•dn12•fck);	0.006	0.022	0.031	0.006
Limiting k Factor = 0.5986-0.1862-0.21;	0.208	0.208	0.208	0.208
Lever arm (z) =Min(0.95•d _{n1} ,d _{n1} /2•(1+√(1-3.53k)));	47 mm	55 mm	59 mm	47 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	32 mm ²	137 mm ²	211 mm ²	32 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	99 mm ²	115 mm ²	123 mm ²	99 mm ²
where k>k' Lever arm (z) =d _{n1} /2•(1+√(1-3.53k'));				
Depth to compression reinforcement (d _{n2})=d-Δc;				
Compression Moment (M')=b•d _{n1} ² •f _{ck} •(k-K');				
Compression reinforcement reqd (A _{s'})=M'/(f _{yd} •(d _{n1} -d _{n2}));				
Tension reinforcement required (A _s) =(M-M')/f _{yd} •z+As';				
Tension reinforcement required at section (A _{s,req})	99 mm ²	137 mm ²	211 mm ²	99 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (3.9)	Pass (2.8)	Pass (1.8)	Pass (3.9)
<u>Shear</u>				
Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²
Effective Depth Factor (k) =min(2.0,1+√(200/dn1));	2.0000	2.0000	2.0000	2.0000
Reinforcement Ratio (ρ ₁) =min(0.02,A _s /b•d _{n1});	0.0080	0.0070	0.0060	0.0080
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	33.1 kN	38.7 kN	41.2 kN	33.1 kN
Shear resistance (V _{Rd,c,1}) = max(V _{Rd,c,min} ,C _{Rd,c} •k•(100•ρ ₁ •(f _{ck} /1))0.333•b•d _{n1});	39.5 kN	44.1 kN	44.6 kN	39.5 kN
Shear resistance required (V)	2.8 kN	8.0 kN	12.1 kN	2.8 kN
	Pass (9.9)	Pass (5.5)	Pass (3.6)	Pass (9.9)

**1500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

SHEET: 20 of 20

6.4 Base Reinforcement Design

Top face in Tension

	L_1	L_2	L_3
<u>Moment</u>			
Moment capacity of section	7.9 kNm	7.9 kNm	7.9 kNm
Design Bending Moment	0.8 kNm	0.6 kNm	2.4 kNm
Area of tension reinforcement provided	393 mm ²	393 mm ²	393 mm ²
Area of compression reinforcement provided	0 mm ²	0 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	48 mm	48 mm	48 mm
K Factor =M/(b•dn1 ² •fck);	0.007	0.006	0.023
Limiting k Factor = 0.5986-0.1862-0.21;	0.208	0.208	0.208
Lever arm (z) =Min(0.95•d _{n1} ,d _{n1} /2•(1+√(1-3.53k)));	46 mm	46 mm	46 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	38 mm ²	31 mm ²	119 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	95 mm ²	95 mm ²	95 mm ²
where k>k' Lever arm (z) =d _{n1} /2•(1+√(1-3.53k'));			
Depth to compression reinforcement (d _{n2})=d-Δc;			
Compression Moment (M')=b•d _{n1} ² •f _{ck} •(k-K');			
Compression reinforcement reqd (A _{s'})=M'/(f _{yd} •(d _{n1} -d _{n2}));			
Tension reinforcement required (A _s) =(M-M')/f _{yd} •z+A _{s'} ;			

Tension reinforcement required at section (A_{s,req}) 95 mm² 95 mm² 119 mm²

Compression reinforcement required at section (A_{s',req}) 0 mm² 0 mm² 0 mm²

Pass (4.1) Pass (4.1) Pass (3.2)

Shear

Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²
Effective Depth Factor (k) =min(2.0,1+√(200/dn1));	2.0000	2.0000	2.0000
Reinforcement Ratio (ρ ₁) =min(0.02,A _s /b•d _{n1});	0.0080	0.0080	0.0080
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	31.9 kN	31.9 kN	31.9 kN
Shear resistance (V _{Rd,c,1}) = max(V _{Rd,c,min} ,C _{Rd,c} •k•(100•ρ ₁ •(f _{ck} /1))0.333•b•d _{n1});	38.0 kN	38.0 kN	38.0 kN
Shear resistance required (V)	5.3 kN	7.2 kN	7.2 kN
	Pass (7.1)	Pass (5.2)	Pass (5.2)

Bottom face in Tension

	L_1	L_2	L_3
Moment capacity of section	10.1 kNm	8.5 kNm	7.2 kNm
Design Bending Moment	0.0 kNm	0.0 kNm	0.0 kNm
Area of tension reinforcement provided	393 mm ²	393 mm ²	393 mm ²
Area of compression reinforcement provided	0 mm ²	0 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	62 mm	53 mm	44 mm
K Factor =M/(b•dn1 ² •fck);	0.000	0.000	0.000
Limiting k Factor = 0.5986-0.1862-0.21;	0.208	0.208	0.208
Lever arm (z) =Min(0.95•d _{n1} ,d _{n1} /2•(1+√(1-3.53k)));	59 mm	50 mm	42 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	0 mm ²	0 mm ²	0 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	123 mm ²	105 mm ²	86 mm ²

where k>k' Lever arm (z) =d_{n1}/2•(1+√(1-3.53k'));

Depth to compression reinforcement (d_{n2})=d-Δc;

Compression Moment (M')=b•d_{n1}²•f_{ck}•(k-K');

Compression reinforcement reqd (A_{s'})=M'/(f_{yd}•(d_{n1}-d_{n2}));

Tension reinforcement required (A_s) =(M-M')/f_{yd}•z+A_{s'};

Tension reinforcement required at section (A_{s,req}) 123 mm² 105 mm² 86 mm²

Compression reinforcement required at section (A_{s',req}) 0 mm² 0 mm² 0 mm²

Pass (3.1) Pass (3.7) Pass (4.5)

Shear

Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²
Effective Depth Factor (k) =min(2.0,1+√(200/dn1));	2.0000	2.0000	2.0000
Reinforcement Ratio (ρ ₁) =min(0.02,A _s /b•d _{n1});	0.0060	0.0070	0.0090
Minimum shear resistance (V _{Rd,c,min}) = 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	41.2 kN	35.3 kN	29.0 kN
Shear resistance (V _{Rd,c,1}) = max(V _{Rd,c,min} ,C _{Rd,c} •k•(100•ρ ₁ •(f _{ck} /1))0.333•b•d _{n1});	44.6 kN	40.2 kN	36.0 kN
Shear resistance required (V)	5.3 kN	7.2 kN	7.2 kN
	Pass (8.4)	Pass (5.5)	Pass (4.9)

Concrete section is sufficiently reinforced