

Calculations for the Design of Standard 3000mm 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

**3000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

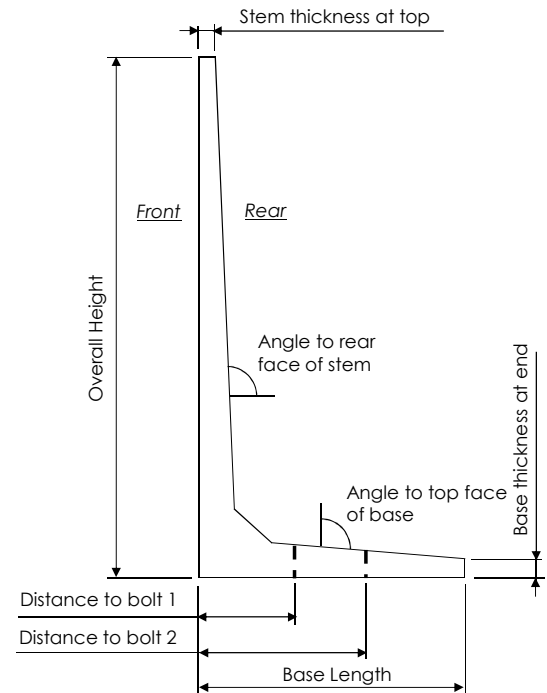
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1.0 Retaining Wall Design

Overall height (h)	3000 mm
Base length (L _{base})	1500 mm
Stem thickness at top (t _{stem_top})	110 mm
Base thickness at end (t _{base_min})	130 mm
Unit width (w _u)	1000 mm
Distance to bolt 1 (from face)	550 mm
Distance to bolt 2 (from face)	950 mm
Number of bolts / row (No.)	2 No.
Angle to rear face of stem (a1)	92.0°
Angle to top face of base (a2)	93.6°
Concrete Density (γ _c)	25.0 kN/m³
Average stem thickness (t _{stem})	160 mm
Average base thickness (t _{base})	178 mm
Stem height (h _{stem})	2822 mm
Toe length (L _{toe})	1340 mm

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

Height of retained soil (h _{ret})	3000 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);	0.312	0.284	0.349
Sloped backfill active pressure coefficient (k _a);	0.841	0.555	0.873

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})	3774 mm 3000 mm	3774 mm 3000 mm	3683 mm 3000 mm
Property A	4.60808m 2.598m	4.370m 2.409m	4.918m 2.844m
Property B	2.66047m 1.500m	2.523m 1.391m	2.839m 1.642m
Property C	2.66047m 1.500m	2.784m 1.535m	2.506m 1.450m
Property D	0.00000m 0.000m	-0.220m -0.121m	0.297m 0.172m
Property E	0.00000m 0.000m	-0.401m -0.221m	0.484m 0.280m
Property F	0.00000m 0.000m	-0.140m -0.077m	0.151m 0.087m
Area of Soil (A)	0.000 m² 0.000 m²	-0.599 m² -0.182 m²	0.769 m² 0.257 m²

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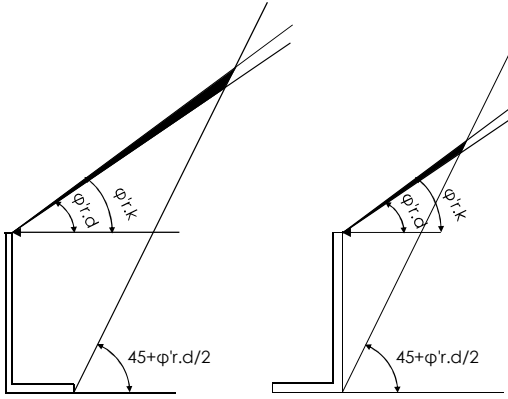
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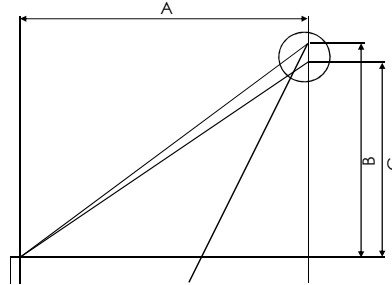
Additional Line Load

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

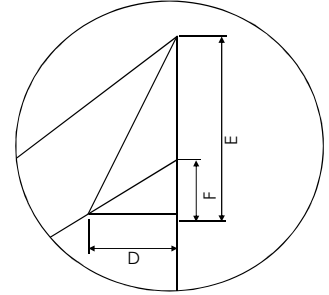


Sketch 1: Line load to rear of retaining wall

Sketch 2: Line load to front of retaining wall



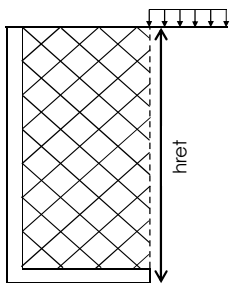
Primary Critical Dimensions



Secondary Critical Dimensions

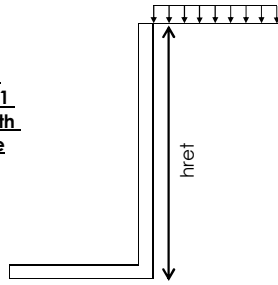
2.0 Retaining Wall Global Design

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.

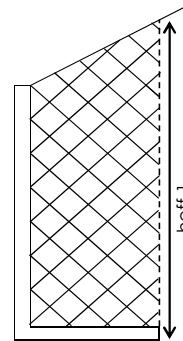


Backfill to rear of wall (A)

**Loading
condition 1
Level fill with
surcharge**

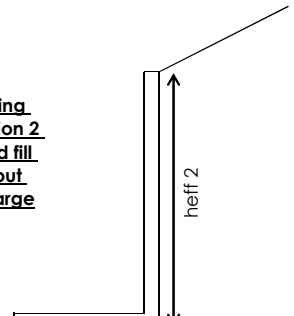


Backfill to front of wall (B)



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;

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

$$0.312 \cdot 0.928 \cdot 1.5 \cdot 10 \cdot 3 =$$

$$13.0 \text{ kN}$$

Lever Arm

Moment

$$1.500 \text{ m}$$

$$19.5 \text{ kNm}$$

Active Pressure;

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

$$1.1 \cdot 0.312 \cdot 0.928 \cdot 18 \cdot 3^2 / 2 =$$

$$25.8 \text{ kN}$$

$$1.000 \text{ m}$$

$$25.8 \text{ kNm}$$

Additional shear load acting at z;

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

$$0 \cdot 1.5 =$$

$$0.0 \text{ kN}$$

$$2.500 \text{ m}$$

$$0.0 \text{ kNm}$$

Horizontal Force (H):

$$38.8 \text{ kN}$$

M_H :

$$45.3 \text{ kNm}$$

Weight of wall stem;

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

$$0.9 \cdot 2.822 \cdot 0.16 \cdot 25 =$$

$$10.2 \text{ kN}$$

$$0.080 \text{ m}$$

$$0.8 \text{ kNm}$$

Weight of base;

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

$$0.9 \cdot 1.5 \cdot 0.178 \cdot 25 =$$

$$6.0 \text{ kN}$$

$$0.750 \text{ m}$$

$$4.5 \text{ kNm}$$

Retained Soil;

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

$$0.9 \cdot 2.822 \cdot 1.34 \cdot 18 =$$

$$61.3 \text{ kN}$$

$$0.830 \text{ m}$$

$$50.8 \text{ kNm}$$

Friction on virtual Back of wall;

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

$$0.9 \cdot 0.312 \cdot 0.34 \cdot 18 \cdot 3^2 / 2 =$$

$$7.7 \text{ kN}$$

$$1.500 \text{ m}$$

$$11.6 \text{ kNm}$$

Vertical Force (V):

$$85.2 \text{ kN}$$

M_V :

$$67.8 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ref}; \quad 0.312 \cdot 0.94 \cdot 1.5 \cdot 10 \cdot 3 = 13.2 \text{ kN} \quad 1.500 \text{ m} \quad 19.8 \text{ kNm}$$

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 1.1 \cdot 0.312 \cdot 0.94 \cdot 18 \cdot 3^2/2 = 26.1 \text{ kN} \quad 1.000 \text{ m} \quad 26.1 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 39.3 \text{ kN} \quad M_H; \quad 45.9 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 2.822 \cdot 0.16 \cdot 25 = 10.2 \text{ kN} \quad 1.420 \text{ m} \quad 14.4 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.0 \text{ kN} \quad 0.750 \text{ m} \quad 4.5 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\text{ frict}}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 0.9 \cdot 0.312 \cdot 0.34 \cdot 18 \cdot 3^2/2 = 7.7 \text{ kN} \quad 1.500 \text{ m} \quad 11.6 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 23.9 \text{ kN} \quad M_V; \quad 30.5 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d} \cdot (90-\alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 1.1 \cdot 0.841 \cdot 0.928 \cdot 18 \cdot 3.774^2/2 = 110.1 \text{ kN} \quad 1.258 \text{ m} \quad 138.4 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\varphi'_{r,d}) \cdot \cos(\varphi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = 0.0 \text{ kN} \quad 3.000 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 110.1 \text{ kN} \quad M_H; \quad 138.4 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 2.822 \cdot 0.16 \cdot 25 = 10.2 \text{ kN} \quad 0.080 \text{ m} \quad 0.8 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.0 \text{ kN} \quad 0.750 \text{ m} \quad 4.5 \text{ kNm}$$

Retained Soil;

$$F_{ret}=\gamma_{Gf} \cdot ((h_{ret} \cdot t_{base}) + (L_{toe} \cdot \tan(\beta)/2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 0.9 \cdot (2.822 + (1.34 \cdot 0.577/2)) \cdot 1.34 \cdot 18 = 69.7 \text{ kN} \quad 0.830 \text{ m} \quad 57.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\text{ frict}}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 0.9 \cdot 0.841 \cdot 0.34 \cdot 18 \cdot 3.774^2/2 = 33.0 \text{ kN} \quad 1.500 \text{ m} \quad 49.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 118.8 \text{ kN} \quad M_V; \quad 112.6 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 1.1 \cdot 0.841 \cdot 0.94 \cdot 18 \cdot 3^2/2 = 70.5 \text{ kN} \quad 1.000 \text{ m} \quad 70.5 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\varphi'_{r,d}) \cdot \cos(\varphi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = 0.0 \text{ kN} \quad 3.000 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 70.5 \text{ kN} \quad M_H; \quad 70.5 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 2.822 \cdot 0.16 \cdot 25 = 10.2 \text{ kN} \quad 1.420 \text{ m} \quad 14.4 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.0 \text{ kN} \quad 0.750 \text{ m} \quad 4.5 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\text{ frict}}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 0.9 \cdot 0.841 \cdot 0.34 \cdot 18 \cdot 3^2/2 = 20.9 \text{ kN} \quad 1.500 \text{ m} \quad 31.3 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 37.0 \text{ kN} \quad M_V; \quad 50.2 \text{ kNm}$$

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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;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.284 \cdot 0.916 \cdot 1.5 \cdot 10 \cdot 3 = 11.7 \text{ kN} \quad 1.500 \text{ m} \quad 17.6 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.284 \cdot 0.916 \cdot 18 \cdot 3^2 / 2 = 28.4 \text{ kN} \quad 1.000 \text{ m} \quad 28.4 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 40.1 \text{ kN} \quad M_{Ht}; \quad 46.0 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 0.080 \text{ m} \quad 0.9 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot (h_{ret} - t_{base}) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot 2.822 \cdot 1.34 \cdot 18 = 68.1 \text{ kN} \quad 0.830 \text{ m} \quad 56.5 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.284 \cdot 0.37 \cdot 18 \cdot 3^2 / 2 = 8.5 \text{ kN} \quad 1.500 \text{ m} \quad 12.8 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 94.5 \text{ kN} \quad M_{Vt}; \quad 75.2 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.284 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 3 = 11.9 \text{ kN} \quad 1.500 \text{ m} \quad 17.8 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.284 \cdot 0.929 \cdot 18 \cdot 3^2 / 2 = 28.9 \text{ kN} \quad 1.000 \text{ m} \quad 28.9 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 40.7 \text{ kN} \quad M_{Ht}; \quad 46.7 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 1.420 \text{ m} \quad 16.0 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.284 \cdot 0.37 \cdot 18 \cdot 3^2 / 2 = 8.5 \text{ kN} \quad 1.500 \text{ m} \quad 12.8 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 26.5 \text{ kN} \quad M_{Vt}; \quad 33.8 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1.35 \cdot 0.555 \cdot 0.916 \cdot 18 \cdot 3.774^2 / 2 = 88.0 \text{ kN} \quad 1.258 \text{ m} \quad 110.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.599 = -6.6 \text{ kN} \quad 3.000 \text{ m} \quad -19.8 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 81.4 \text{ kN} \quad M_{Ht}; \quad 90.9 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 0.080 \text{ m} \quad 0.9 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot ((h_{ret} - t_{base}) + (L_{toe} \cdot \tan(\beta) / 2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot (2.822 + (1.34 \cdot 0.577 / 2)) \cdot 1.34 \cdot 18 = 77.4 \text{ kN} \quad 0.830 \text{ m} \quad 64.2 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1 \cdot 0.555 \cdot 0.37 \cdot 18 \cdot 3.774^2 / 2 = 26.3 \text{ kN} \quad 1.500 \text{ m} \quad 39.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 121.7 \text{ kN} \quad M_{Vt}; \quad 109.6 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret},h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff}2}^2 / 2; \quad 1.35 \cdot 0.555 \cdot 0.929 \cdot 18 \cdot 3^2 / 2 = 56.4 \text{ kN} \quad 1.000 \text{ m} \quad 56.4 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.599 = -2.0 \text{ kN} \quad 3.000 \text{ m} \quad -6.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 54.4 \text{ kN} \quad M_{Ht}; \quad 50.4 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 1.420 \text{ m} \quad 16.0 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff}2}^2 / 2; \quad 1 \cdot 0.555 \cdot 0.37 \cdot 18 \cdot 3^2 / 2 = 16.6 \text{ kN} \quad 1.500 \text{ m} \quad 24.9 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 34.6 \text{ kN} \quad M_{Vt}; \quad 46.0 \text{ kNm}$$

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;

$$F_{\text{sur},h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{\text{ret}}; \quad 0.349 \cdot 0.942 \cdot 1.3 \cdot 10 \cdot 3 = 12.8 \text{ kN} \quad 1.500 \text{ m} \quad 19.2 \text{ kNm}$$

Active Pressure;

$$F_{\text{ret},h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.349 \cdot 0.942 \cdot 18 \cdot 3^2 / 2 = 26.6 \text{ kN} \quad 1.000 \text{ m} \quad 26.6 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 39.4 \text{ kN} \quad M_{Ht}; \quad 45.9 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 0.080 \text{ m} \quad 0.9 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = \gamma_{Gf} \cdot (h_{\text{ret}} - t_{\text{base}}) \cdot L_{\text{toe}} \cdot \gamma_{mr}; \quad 1 \cdot 2.822 \cdot 1.34 \cdot 18 = 68.1 \text{ kN} \quad 0.830 \text{ m} \quad 56.5 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.349 \cdot 0.303 \cdot 18 \cdot 3^2 / 2 = 8.6 \text{ kN} \quad 1.500 \text{ m} \quad 12.9 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 94.6 \text{ kN} \quad M_{Vt}; \quad 75.3 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{\text{sur},h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{\text{ret}}; \quad 0.349 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 3 = 13.0 \text{ kN} \quad 1.500 \text{ m} \quad 19.5 \text{ kNm}$$

Active Pressure;

$$F_{\text{ret},h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.349 \cdot 0.953 \cdot 18 \cdot 3^2 / 2 = 26.9 \text{ kN} \quad 1.000 \text{ m} \quad 26.9 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 39.9 \text{ kN} \quad M_{Ht}; \quad 46.4 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 1.420 \text{ m} \quad 16.0 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.349 \cdot 0.303 \cdot 18 \cdot 3^2 / 2 = 8.6 \text{ kN} \quad 1.500 \text{ m} \quad 12.9 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 26.5 \text{ kN} \quad M_{Vt}; \quad 33.9 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.873 \cdot 0.942 \cdot 18 \cdot 3.683^2 / 2 = 100.4 \text{ kN} \quad 1.228 \text{ m} \quad 123.2 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.769 = 5.6 \text{ kN} \quad 3.000 \text{ m} \quad 16.8 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 106.0 \text{ kN} \quad M_H: \quad 140.0 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 0.080 \text{ m} \quad 0.9 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = \gamma_{Gf} \cdot ((h_{\text{ret}} - t_{\text{base}}) + (L_{\text{toe}} \cdot \tan(\beta) / 2)) \cdot L_{\text{toe}} \cdot \gamma_{mr}; \quad 1 \cdot (2.822 + (1.34 \cdot 0.577 / 2)) \cdot 1.34 \cdot 18 = 77.4 \text{ kN} \quad 0.830 \text{ m} \quad 64.2 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.873 \cdot 0.303 \cdot 18 \cdot 3.683^2 / 2 = 32.3 \text{ kN} \quad 1.500 \text{ m} \quad 48.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 127.7 \text{ kN} \quad M_V: \quad 118.6 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.873 \cdot 0.953 \cdot 18 \cdot 3^2 / 2 = 67.4 \text{ kN} \quad 1.000 \text{ m} \quad 67.4 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.257 = 1.9 \text{ kN} \quad 3.000 \text{ m} \quad 5.6 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 69.3 \text{ kN} \quad M_H: \quad 73.0 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.822 \cdot 0.16 \cdot 25 = 11.3 \text{ kN} \quad 1.420 \text{ m} \quad 16.0 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.5 \cdot 0.178 \cdot 25 = 6.7 \text{ kN} \quad 0.750 \text{ m} \quad 5.0 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.873 \cdot 0.303 \cdot 18 \cdot 3^2 / 2 = 21.5 \text{ kN} \quad 1.500 \text{ m} \quad 32.2 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 39.4 \text{ kN} \quad M_V: \quad 53.2 \text{ kNm}$$

2.4 Summary of forces and moments on wall

Equilibrium	H	M _H	V	M _V
A: LC1 - Backfill to rear:	38.8 kN	45.3 kNm	85.2 kN	67.8 kNm
B: LC1 - Backfill to front:	39.3 kN	45.9 kNm	23.9 kN	30.5 kNm
C: LC2 - Backfill to rear:	110.1 kN	138.4 kNm	118.8 kN	112.6 kN
D: LC2 - Backfill to front:	70.5 kN	70.5 kNm	37.0 kN	50.2 kN
Combination 1	H	M _H	V	M _V
A: LC1 - Backfill to rear:	40.1 kN	46.0 kNm	94.5 kN	75.2 kNm
B: LC1 - Backfill to front:	40.7 kN	46.7 kNm	26.5 kN	33.8 kNm
C: LC2 - Backfill to rear:	81.4 kN	90.9 kNm	121.7 kN	109.6 kN
D: LC2 - Backfill to front:	54.4 kN	50.4 kNm	34.6 kN	46.0 kN
Combination 2	H	M _H	V	M _V
A: LC1 - Backfill to rear:	39.4 kN	45.9 kNm	94.6 kN	75.3 kNm
B: LC1 - Backfill to front:	39.9 kN	46.4 kNm	26.5 kN	33.9 kNm
C: LC2 - Backfill to rear:	106.0 kN	140.0 kNm	127.7 kN	118.6 kN
D: LC2 - Backfill to front:	69.3 kN	73.0 kNm	39.4 kN	53.2 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:	4.8 kN 0.88 ULS Ratio	2.3 kN 0.94 ULS Ratio	1.6 kN 0.96 ULS Ratio
	LC1 - Backfill to front:	29.8 kN 0.24 ULS Ratio	30.1 kN 0.26 ULS Ratio	29.3 kN 0.27 ULS Ratio
	LC2 - Backfill to rear:	62.5 kN 0.43 ULS Ratio	32.7 kN 0.60 ULS Ratio	54.9 kN 0.48 ULS Ratio
	LC2 - Backfill to front:	55.7 kN 0.21 ULS Ratio	40.6 kN 0.25 ULS Ratio	53.5 kN 0.23 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:	22.4 kNm 1.49 ULS Ratio	29.2 kNm 1.63 ULS Ratio	29.4 kNm 1.64 ULS Ratio
	LC1 - Backfill to front:	-15.4 kNm 0.66 ULS Ratio	-12.9 kNm 0.72 ULS Ratio	-12.5 kNm 0.73 ULS Ratio
	LC2 - Backfill to rear:	-25.8 kNm 0.81 ULS Ratio	18.7 kNm 1.21 ULS Ratio	-21.4 kNm 0.85 ULS Ratio
	LC2 - Backfill to front:	-20.2 kNm 0.71 ULS Ratio	-4.4 kNm 0.91 ULS Ratio	-19.8 kNm 0.73 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; 62.5 kN/m - Loading condition 2 (Backfill to the rear)
 Vertical load; 118.8 kN/m - Loading condition 2 (Backfill to the rear)
 Resultant destabilising moment; 25.8 kNm/m - Loading condition 2 (Backfill to the rear)

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

Resultant sliding force; 54.9 kN/m - Combination 2 with loading condition 2 (Backfill to the rear)
 Resultant anti-clockwise destabilising moment; 21.4 kNm/m - Combination 2 with loading condition 2 (Backfill to the rear)
 Resultant clockwise destabilising moment; 19.8 kNm/m - Combination 2 with loading condition 2 (Backfill to the front)

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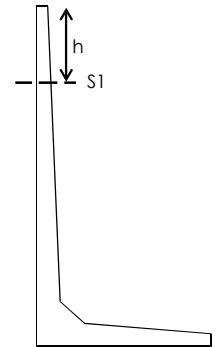
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3.1 Analysis Height 1

Analysis height 1 (S1) 650 mm
Soil depth at S1 650 mm



Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.522m	0.616m
Property B	0.301m	0.356m
Property C	0.332m	0.314m
Property D	-0.026m	0.037m
Property E	-0.048m	0.061m
Property F	-0.017m	0.019m
Area of Soil (A)	-0.009 m ²	0.012 m ²

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.916 \cdot 1.5 \cdot 10 \cdot 0.65 =$	2.5 kN	0.325 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.284 \cdot 0.916 \cdot 18 \cdot 0.65^2 / 2 =$	1.3 kN	0.217 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.9 kN	$M_H:$ 1.1 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.65 =$	2.6 kN	0.325 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.284 \cdot 0.929 \cdot 18 \cdot 0.65^2 / 2 =$	1.4 kN	0.217 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.9 kN	$M_H:$ 1.1 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.916 \cdot 18 \cdot 0.65^2 / 2 =$	2.6kN	0.217 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.009 =$	-0.1kN	0.650 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.5 kN	$M_H:$ 0.5 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.929 \cdot 18 \cdot 0.65^2 / 2 =$	2.6kN	0.217 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.009 =$	-0.1kN	0.650 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.5 kN	$M_H:$ 0.5 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.942 \cdot 1.3 \cdot 10 \cdot 0.65 =$	2.8 kN	0.325 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.349 \cdot 0.942 \cdot 18 \cdot 0.65^2 / 2 =$	1.2 kN	0.217 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	4.0 kN	$M_H:$ 1.2 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.65 =$	2.8 kN	0.325 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.349 \cdot 0.953 \cdot 18 \cdot 0.65^2 / 2 =$	1.3 kN	0.217 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	4.1 kN	$M_H:$ 1.2 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.942 \cdot 18 \cdot 0.65^2 / 2 =$	3.1kN	0.217 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.012 =$	0.1kN	0.650 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.2 kN	$M_H:$ 0.7 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.953 \cdot 18 \cdot 0.65^2 / 2 =$	3.2kN	0.217 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.012 =$	0.1kN	0.650 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.150 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.3 kN	$M_H:$ 0.7 kNm

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REV: 0

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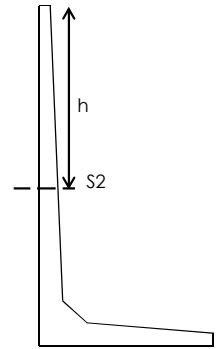
CHK: C.B.

SHEET: 10 of 20

3.2 Analysis Height 2

Analysis height 2 (S2) 1970 mm
Soil depth at S2 1970 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	1.582m	1.868m
Property B	0.913m	1.078m
Property C	1.008m	0.952m
Property D	-0.080m	0.113m
Property E	-0.145m	0.184m
Property F	-0.051m	0.057m
Area of Soil (A)	-0.078 m ²	0.111 m ²



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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.916 \cdot 1.5 \cdot 10 \cdot 1.97=$	7.7 kN	0.985 m	7.6 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.284 \cdot 0.916 \cdot 18 \cdot 1.97^2/2=$	12.3 kN	0.657 m	8.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	1.470 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):			19.9 kN	$M_H:$	15.6 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 1.97=$	7.8 kN	0.985 m	7.7 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.284 \cdot 0.929 \cdot 18 \cdot 1.97^2/2=$	12.4 kN	0.657 m	8.2 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	1.470 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):			20.2 kN	$M_H:$	15.9 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.916 \cdot 18 \cdot 1.97^2 / 2 =$	24.0kN	0.657 m	15.7 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.078 =$	-0.9kN	1.970 m	-1.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	1.470 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):			23.1 kN	$M_H:$	14.0 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.929 \cdot 18 \cdot 1.97^2 / 2 =$	24.3kN	0.657 m	16.0 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.078 =$	-0.9kN	1.970 m	-1.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	1.470 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):			23.5 kN	$M_H:$	14.3 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.942 \cdot 1.3 \cdot 10 \cdot 1.97=$	8.4 kN	0.985 m	8.3 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.349 \cdot 0.942 \cdot 18 \cdot 1.97^2/2=$	11.5 kN	0.657 m	7.5 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	1.470 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):			19.9 kN	$M_H:$	15.8 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 1.97=$	8.5 kN	0.985 m	8.4 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.349 \cdot 0.953 \cdot 18 \cdot 1.97^2/2=$	11.6 kN	0.657 m	7.6 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	1.470 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):			20.1 kN	$M_H:$	16.0 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.942 \cdot 18 \cdot 1.97^2 / 2 =$	28.7kN	0.657 m	18.9 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.111 =$	0.8kN	1.970 m	1.6 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	1.470 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):			29.5 kN	$M_H:$	20.5 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.953 \cdot 18 \cdot 1.97^2 / 2 =$	29.1 kN	0.657 m	19.1 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.111 =$	0.8 kN	1.970 m	1.6 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	1.470 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):			29.9 kN	$M_H:$	20.7 kNm

**3000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

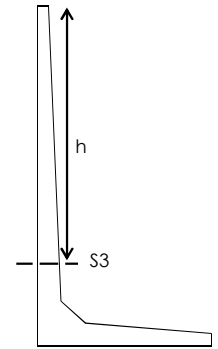
CHK: C.B.

SHEET: 11 of 20

3.3 Analysis Height 3

Analysis height 3 (S3) 2600 mm
Soil depth at S3 2600 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	2.088m	2.465m
Property B	1.205m	1.423m
Property C	1.330m	1.256m
Property D	-0.105m	0.149m
Property E	-0.192m	0.243m
Property F	-0.067m	0.076m
Area of Soil (A)	-0.137 m ²	0.193 m ²



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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.916 \cdot 1.5 \cdot 10 \cdot 2.6 =$	10.1 kN	1.300 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.284 \cdot 0.916 \cdot 18 \cdot 2.6^2 / 2 =$	21.4 kN	0.867 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		31.5 kN	$M_H:$	31.7 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 2.6 =$	10.3 kN	1.300 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.284 \cdot 0.929 \cdot 18 \cdot 2.6^2 / 2 =$	21.7 kN	0.867 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		32.0 kN	$M_H:$	32.2 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.916 \cdot 18 \cdot 2.6^2 / 2 =$	41.7kN	0.867 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.137 =$	-1.5kN	2.600 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		40.2 kN	$M_H:$	32.3 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.929 \cdot 18 \cdot 2.6^2 / 2 =$	42.4kN	0.867 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.137 =$	-1.5kN	2.600 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		40.8 kN	$M_H:$	32.8 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.942 \cdot 1.3 \cdot 10 \cdot 2.6 =$	11.1 kN	1.300 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.349 \cdot 0.942 \cdot 18 \cdot 2.6^2 / 2 =$	20.0 kN	0.867 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		31.1 kN	$M_H:$	31.8 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 2.6 =$	11.2 kN	1.300 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.349 \cdot 0.953 \cdot 18 \cdot 2.6^2 / 2 =$	20.2 kN	0.867 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		31.5 kN	$M_H:$	32.1 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.942 \cdot 18 \cdot 2.6^2 / 2 =$	50.0kN	0.867 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.193 =$	1.4kN	2.600 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		51.4 kN	$M_H:$	47.0 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.953 \cdot 18 \cdot 2.6^2 / 2 =$	50.6kN	0.867 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.193 =$	1.4kN	2.600 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.100 m
Moment at z	$M_z = M_z \cdot \gamma M_z$	$0.0 =$	0.0 kN	0.000 m
Horizontal Force (H):		52.0 kN	$M_H:$	47.5 kNm

**3000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

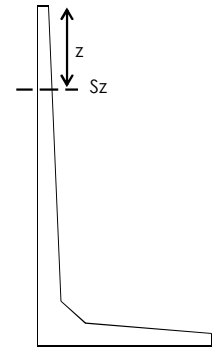
BY: S.J.H

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	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.916 \cdot 1.5 \cdot 10 \cdot 0.5 =$	2.0 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.284 \cdot 0.916 \cdot 18 \cdot 0.5^2 / 2 =$	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	0.0 kNm
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	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.284 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.5 =$	2.0 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.284 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	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	0.0 kNm
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 1) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.916 \cdot 18 \cdot 0.5^2 / 2 =$	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	0.0 kNm
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	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.555 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	1.6kN	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	0.0 kNm
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	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.942 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.349 \cdot 0.942 \cdot 18 \cdot 0.5^2 / 2 =$	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	0.0 kNm
Horizontal Force (H):		2.9 kN	$M_H:$	0.7 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.349 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.2 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.349 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	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	0.0 kNm
Horizontal Force (H):		2.9 kN	$M_H:$	0.7 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.942 \cdot 18 \cdot 0.5^2 / 2 =$	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	0.0 kNm
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	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.873 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	1.9kN	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	0.0 kNm
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.

	Analysis 1 @ 650		Analysis 2 @ 1970		Analysis 3 @ 2600		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Combination 1								
Rear level fill & surcharge (A)	3.9 kN	1.1 kNm	19.9 kN	15.6 kNm	31.5 kN	31.7 kNm	2.7 kN	0.6 kNm
Front level fill & surcharge (B)	3.9 kN	1.1 kNm	20.2 kN	15.9 kNm	32.0 kN	32.2 kNm	2.8 kN	0.6 kNm
Rear sloped fill without surcharge (C)	2.5 kN	0.5 kNm	23.1 kN	14.0 kNm	40.2 kN	32.3 kNm	1.5 kN	0.2 kNm
Front sloped fill without surcharge (D)	2.5 kN	0.5 kNm	23.5 kN	14.3 kNm	40.8 kN	32.8 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)	4.0 kN	1.2 kNm	19.9 kN	15.8 kNm	31.1 kN	31.8 kNm	2.9 kN	0.7 kNm
Front level fill & surcharge (B)	4.1 kN	1.2 kNm	20.1 kN	16.0 kNm	31.5 kN	32.1 kNm	2.9 kN	0.7 kNm
Rear sloped fill without surcharge (C)	3.2 kN	0.7 kNm	29.5 kN	20.5 kNm	51.4 kN	47.0 kNm	1.9 kN	0.3 kNm
Front sloped fill without surcharge (D)	3.3 kN	0.7 kNm	29.9 kN	20.7 kNm	52.0 kN	47.5 kNm	1.9 kN	0.3 kNm
	Analysis 1 @ 650		Analysis 2 @ 1970		Analysis 3 @ 2600		Analysis z @ 500	
Back face is in tension values	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	4.0 kN	0.7 kNm	29.5 kN	20.5 kNm	51.4 kN	47.0 kNm	1.9 kN	0.3 kNm
	Analysis 1 @ 650		Analysis 2 @ 1970		Analysis 3 @ 2600		Analysis z @ 500	
Front face is in tension values	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	4.1 kN	1.2 kNm	29.9 kN	20.7 kNm	52.0 kN	47.5 kNm	2.9 kN	0.7 kNm

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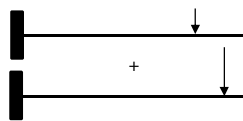
4.0 Wall Base Design

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

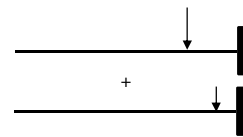
Analysis length 1 (B1)	400 mm
Analysis length 2 (B2)	1060 mm
Analysis length 3 (B3)	1455 mm

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: **2 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

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

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

$$FS_1 = lb_1 \cdot FS_2 / lb_2$$

Rearrange (2)

$$M = (lb_1^2) \cdot FS_2 / lb_2 + FS_2 \cdot lb_2$$

Substituting into (1)

$$FS_2 = M / [(lb_1^2) / lb_2 + lb_2]$$

Factorise & rearrange

4.1 Anchored Anticlockwise Rotation

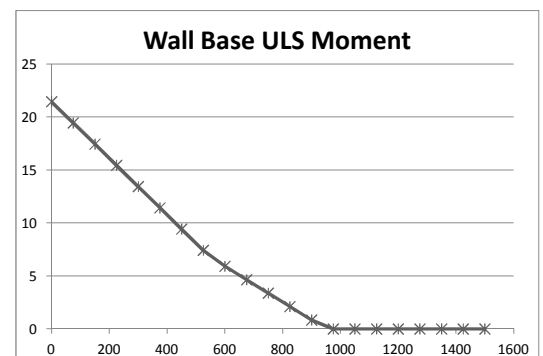
Maximum overturning moment	21.4 kNm
Lever arm to closest anchor (lb1)	550 mm (First Row)
Lever arm to furthest anchor (lb2)	950 mm (Second Row)

From the above equations:

Tension force in closest anchors (FS1)= 9.8 kN (First Row)

Tension force in furthest anchors (FS2)= 16.9 kN (Second Row)

X:	400mm	1060mm	1455mm
Tension Moment Top face:	10.8 kNm	0.0 kNm	0.0 kNm
Shear:	26.7 kN	0.0 kN	0.0 kN



4.2 Anchored Clockwise Rotation

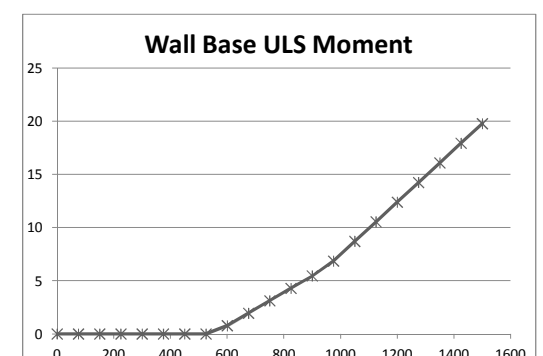
Maximum overturning moment	19.8 kNm
Lever arm to closest anchor (lb1)	550 mm (Second Row)
Lever arm to furthest anchor (lb2)	950 mm (First Row)

From the above equations:

Tension force in closest anchors (FS1)= 9.0 kN (Second Row)

Tension force in furthest anchors (FS2)= 15.6 kN (First Row)

X:	400mm	1060mm	1455mm
Tension Moment Top face:	0.0 kNm	8.9 kNm	18.7 kNm
Shear:	0.0 kN	24.6 kN	24.6 kN



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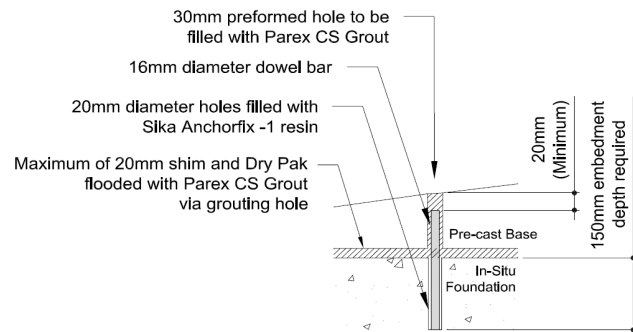
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5.0 Anchor Design

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)	300 mm
First Row: Effective Depth In Precast (h_{eff1});	130 mm
First Row: Effective Depth In Foundation (h_{eff2});	150 mm
Second Row: Dowel Bar Length (D_L)	300 mm
Second Row: Effective Depth In Precast (h_{eff1});	130 mm
Second Row: Effective Depth In Foundation (h_{eff2});	150 mm



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>
$N = \text{Max}\{\text{Clockwise Force, Anticlockwise Force}\} / \text{No.}$	$\text{Max}(9.8, 15.6) / 2 = 7.8 \text{ kN}$	$\text{Max}(16.9, 9) / 2 = 8.5 \text{ kN}$

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>
$\beta_N = N / N_{Rd,s}$	$7.8 / 96.1 = 0.08$	$8.5 / 96.1 = 0.09$

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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
 $\pi \cdot 16 \cdot 130 \cdot 12.3 = 80.4 \text{ kN}$

Second Row
 $\pi \cdot 16 \cdot 130 \cdot 12.3 = 80.4 \text{ kN}$

Design tension capacity of anchorage;

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

$80.4/3 = 26.8 \text{ kN}$

$80.4/3 = 26.8 \text{ kN}$

Ratio between design action and design resistance

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

$7.8/26.8 = 0.29$

$8.5/26.8 = 0.32$

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;

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

$54.9/(2 \cdot 2) = 13.7 \text{ kN}$

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;

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

$0.5 \cdot 201 \cdot 550 / 1000 = 55.3 \text{ kN}$

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

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

$55.3 / 1.15 = 48.1 \text{ kN}$

Ratio between design action and design resistance

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

First Row
 $13.7/48.1 = 0.28$

Second Row
 $13.7/48.1 = 0.28$

5.1.3 Resistance to combined tension and shear loads

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

First Row
0.18

Second Row
0.18

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

0.31

0.33

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

0.58

0.60

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;

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

$30/3 = 10.0 \text{ kN}$

Ratio between design action and design resistance

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

First Row
 $7.8/10 = 0.78$

Second Row
 $8.5/10 = 0.85$

Anchorage provided is adequate

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6.0 Reinforcement Design

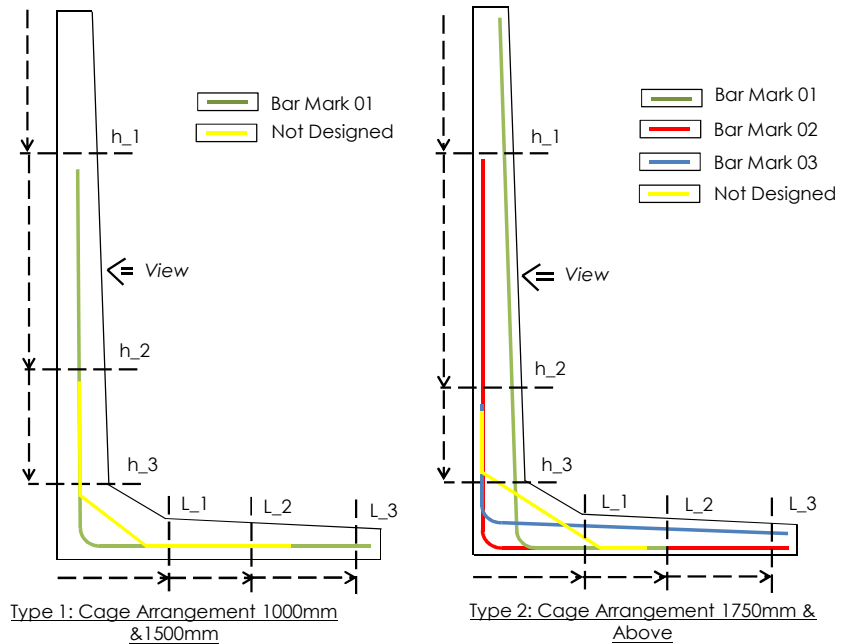
All the standard retaining walls have different reinforcement cages, however, they follow one of two patterns. The 1000mm and 1500mm are a type one and 1750mm and above are of a type 2, these are shown (right). A reinforcement check is then done on the three heights of the stem and three lengths of the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

Cage Provided

This retaining wall has a Type 2 cage.

Reinforcement Provided

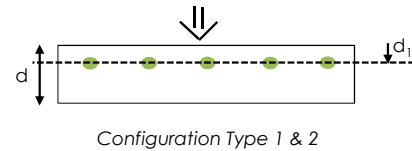
	Diameter	Spacing	As,prov
Bar Mark 1	16.00	200	1005
Bar Mark 2	16.00	200	1005
Bar Mark 3	16.00	200	1005



6.1 Section Analysis

Analysis height 1 (650mm)

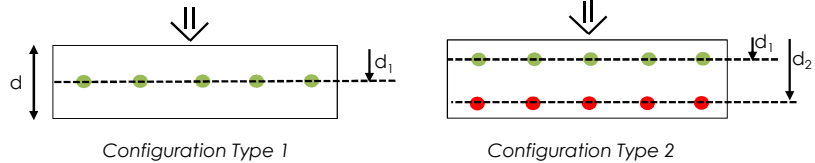
Depth @ S1 (hS1)	132 mm
hS1 - Depth to rein' (d1)	53 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1005	79	0	0
Front face in tension	1005	53	0	0

Analysis height 2 (1970mm)

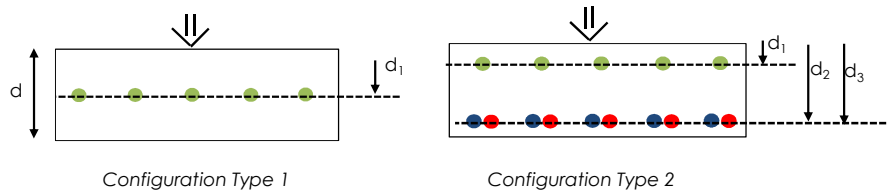
Depth @ S2 (hS2)	178 mm
hS2 - Depth to rein' (d1)	53 mm
hS2 - Depth to rein' (d2)	125 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1005	125	1005	53
Front face in tension	1005	125	1005	53

Analysis height 3 (2600mm)

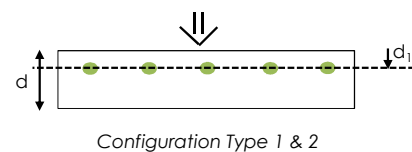
Depth @ S3 (hS3)	200 mm
hS3 - Depth to rein' (d1)	53 mm
hS3 - Depth to rein' (d2)	147 mm
hS3 - Depth to rein' (d3)	147 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1005	147	2011	53
Front face in tension	2011	147	1005	53

Analysis height z (500mm)

Depth @ Sz (hSz)	127 mm
Depth to rein' (d1)	48 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1005	79	0	0
Front face in tension	1005	48	0	0

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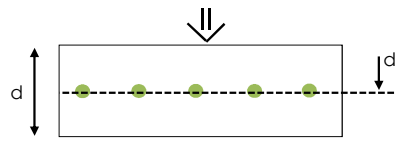
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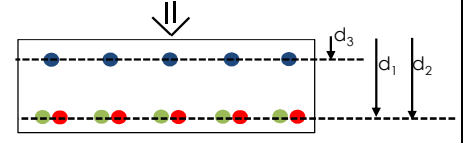
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Analysis length 1 (400mm)

Depth @ B1 (hB1)	200 mm
hB1 - Depth to rein' (d1)	147 mm
hB1 - Depth to rein' (d2)	147 mm
hB1 - Depth to rein' (d3)	53 mm



Configuration Type 1

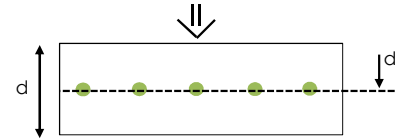


Configuration Type 2

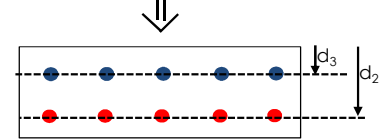
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	1005	147	2011	53
Bottom face in tension	2011	147	1005	53

Analysis length 2 (1060mm)

Depth @ B2 (hB2)	158 mm
hB2 - Depth to rein' (d1)	0 mm
hB2 - Depth to rein' (d2)	105 mm
hB2 - Depth to rein' (d3)	53 mm



Configuration Type 1

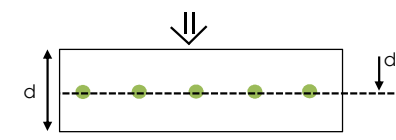


Configuration Type 2

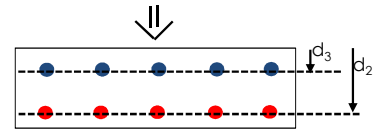
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	1005	105	1005	53
Bottom face in tension	1005	105	1005	53

Analysis length 3 (1455mm)

Depth @ B3 (hB3)	133 mm
hB3 - Depth to rein' (d1)	0 mm
hB3 - Depth to rein' (d2)	80 mm
hB3 - Depth to rein' (d3)	53 mm



Configuration Type 1



Configuration Type 2

	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	1005	80	1005	53
Bottom face in tension	1005	80	1005	53

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			
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	28.9 kNm	47.7 kNm	56.9 kNm	28.9 kNm
Design Bending Moment	0.7 kNm	20.5 kNm	47.0 kNm	0.3 kNm
Area of tension reinforcement provided	1005 mm ²	1005 mm ²	1005 mm ²	1005 mm ²
Area of compression reinforcement provided	0 mm ²	1005 mm ²	2011 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	69 mm	115 mm	137 mm	69 mm
K Factor =M/(b•d _{n1} ² •fck);	0.003	0.034	0.056	0.002
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)));	66 mm	109 mm	130 mm	66 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	26 mm ²	431 mm ²	831 mm ²	12 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	137 mm ²	228 mm ²	271 mm ²	137 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})	137 mm ²	431 mm ²	831 mm ²	137 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (7.3)	Pass (2.3)	Pass (1.2)	Pass (7.3)
Shear				
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});	0.0140	0.0090	0.0070	0.0140
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	46.2 kN	76.5 kN	91.0 kN	46.2 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});	66.3 kN	94.8 kN	103.7 kN	66.3 kN
Shear resistance required (V)	4.0 kN	29.5 kN	51.4 kN	1.9 kN
	Pass (9.9)	Pass (3.2)	Pass (2)	Pass (9.9)

	Front face in Tension			
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	17.9 kNm	47.7 kNm	113.7 kNm	15.7 kNm
Design Bending Moment	1.2 kNm	20.7 kNm	47.5 kNm	0.7 kNm
Area of tension reinforcement provided	1005 mm ²	1005 mm ²	2011 mm ²	1005 mm ²
Area of compression reinforcement provided	0 mm ²	1005 mm ²	1005 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	43 mm	115 mm	137 mm	38 mm
K Factor =M/(b•dn1 ² •fck);	0.014	0.035	0.056	0.010
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)));	41 mm	109 mm	130 mm	36 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	66 mm ²	436 mm ²	840 mm ²	42 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	85 mm ²	228 mm ²	271 mm ²	75 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})	85 mm ²	436 mm ²	840 mm ²	75 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (9.9)	Pass (2.3)	Pass (2.3)	Pass (9.9)
Shear				
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});	0.0200	0.0090	0.0150	0.0200
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	28.6 kN	76.5 kN	91.0 kN	25.1 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});	46.2 kN	94.8 kN	133.7 kN	40.6 kN
Shear resistance required (V)	4.1 kN	29.9 kN	52.0 kN	2.9 kN
	Pass (9.9)	Pass (3.1)	Pass (2.5)	Pass (9.9)

**3000mm 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
Moment	56.9 kNm	39.4 kNm	28.0 kNm
Moment capacity of section	10.8 kNm	8.9 kNm	18.7 kNm
Design Bending Moment	1005 mm ²	1005 mm ²	1005 mm ²
Area of tension reinforcement provided	2011 mm ²	1005 mm ²	1005 mm ²
Area of compression reinforcement provided	137 mm	95 mm	70 mm
Effective depth to tension rein' (d _{n1})=d-Δc;	0.013	0.022	0.085
K Factor =M/(b•dn1 ² •fck);	0.208	0.208	0.208
Limiting k Factor = 0.5986-0.1862-0.21;	130 mm	90 mm	64 mm
Lever arm (z) =Min(0.95•d _{n1} ,d _{n1} /2•(1+√(1-3.53k)));	190 mm ²	229 mm ²	670 mm ²
Area of rein' rqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	271 mm ²	188 mm ²	138 mm ²
Min area rqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;			
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 rqd (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})	271 mm ²	229 mm ²	670 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (3.7)	Pass (4.3)	Pass (1.5)
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});	0.0070	0.0110	0.0140
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	91.0 kN	63.1 kN	46.4 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});	103.7 kN	83.6 kN	66.6 kN
Shear resistance required (V)	26.7 kN	24.6 kN	24.6 kN
	Pass (3.8)	Pass (3.3)	Pass (2.7)

	Bottom face in Tension		
	L_1	L_2	L_3
Moment capacity of section	113.7 kNm	39.4 kNm	28.9 kNm
Design Bending Moment	0.0 kNm	0.0 kNm	0.0 kNm
Area of tension reinforcement provided	2011 mm ²	1005 mm ²	1005 mm ²
Area of compression reinforcement provided	1005 mm ²	1005 mm ²	1005 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	137 mm	95 mm	70 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)));	130 mm	90 mm	66 mm
Area of rein' rqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	0 mm ²	0 mm ²	0 mm ²
Min area rqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	271 mm ²	188 mm ²	138 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 rqd (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})	271 mm ²	188 mm ²	138 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (7.4)	Pass (5.3)	Pass (7.2)
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});	0.0150	0.0110	0.0140
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	91.0 kN	63.1 kN	46.4 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});	133.7 kN	83.6 kN	66.6 kN
Shear resistance required (V)	26.7 kN	24.6 kN	24.6 kN
	Pass (5)	Pass (3.3)	Pass (2.7)

Concrete section is sufficiently reinforced