

Calculations for the Design of Standard 1000mm 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

**1000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

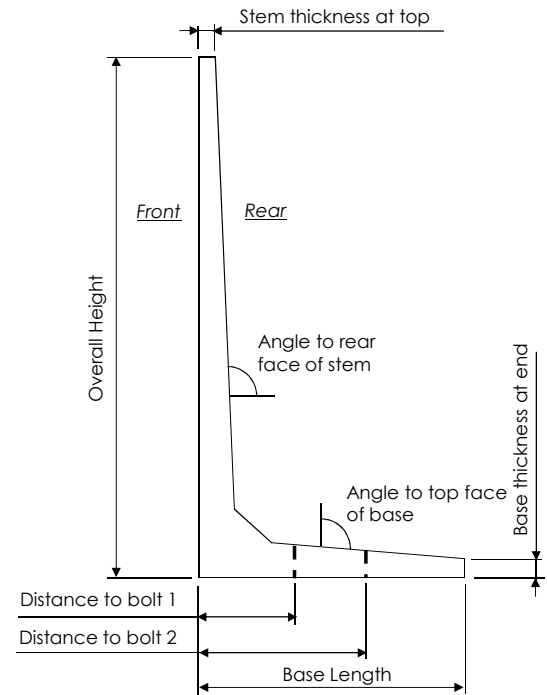
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1.0 Retaining Wall Design

Overall height (h)	1000 mm
Base length (L_{base})	500 mm
Stem thickness at top (t_{stem_top})	103 mm
Base thickness at end (t_{base_min})	104 mm
Unit width (w_u)	1000 mm
Distance to bolt 1 (from face)	315 mm
Distance to bolt 2 (from face)	N/A
Number of bolts / row (No.)	2 No.
Angle to rear face of stem (α_1)	91.3°
Angle to top face of base (α_2)	93.5°
Concrete Density (γ_c)	25.0 kN/m³
Average stem thickness (t_{stem})	113 mm
Average base thickness (t_{base})	119 mm
Stem height (h_{stem})	881 mm
Toe length (L_{toe})	387 mm

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

Height of retained soil (h_{ret})	1000 mm
Moist density (γ_{mr})	18.0 kN/m³
Char' eff' shear angle ($\phi'_{r,k}$)	32.5°
Char' wall friction angle ($\delta_{r,k}$)	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_γ)	1.00	1.00	1.00

Retained Soil Properties based on Coulomb	Equilibrium	Combination 1	Combination 2
Design eff' shear resistance angle ($\phi'_{r,d}$);	30.0°	32.5°	27.0°
Design wall friction angle ($\delta_{r,d}$);	19.9°	21.7°	17.7°
Level backfill active pressure coefficient (k_a);	0.307	0.279	0.343
Sloped backfill active pressure coefficient (k_a);	0.825	0.543	0.858

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})		1223 mm	1000 mm	1223 mm	1000 mm	1197 mm	1000 mm
Dimension properties (see diagram over page)	Property A	1.44653m	0.866m	1.369m	0.803m	1.547m	0.948m
	Property B	0.83515m	0.500m	0.791m	0.464m	0.893m	0.547m
	Property C	0.83515m	0.500m	0.872m	0.512m	0.788m	0.483m
	Property D	0.00000m	0.000m	-0.069m	-0.040m	0.093m	0.057m
	Property E	0.00000m	0.000m	-0.126m	-0.074m	0.152m	0.093m
	Property F	0.00000m	0.000m	-0.044m	-0.026m	0.048m	0.029m
Area of Soil (A)		0.000 m ²	0.000 m ²	-0.059 m ²	-0.020 m ²	0.076 m ²	0.029 m ²

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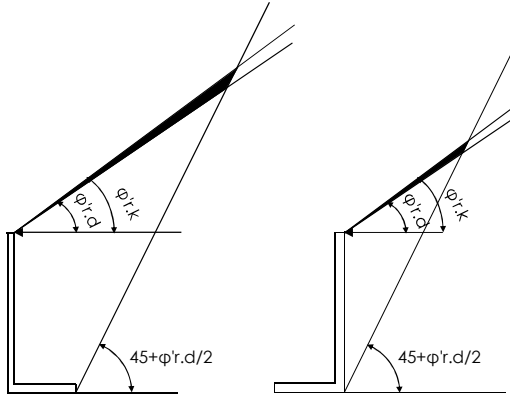
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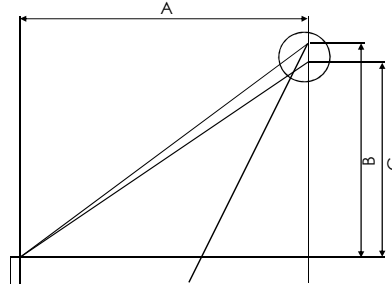
Additional Line Load

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

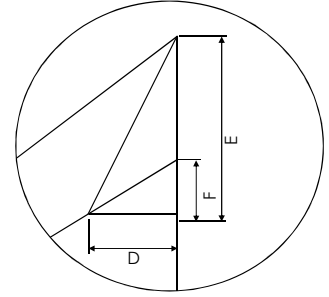


Sketch 1: Line load to rear of retaining wall

Sketch 2: Line load to front of retaining wall



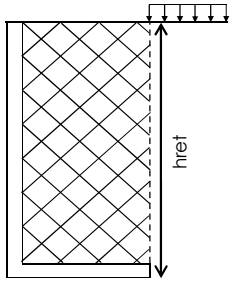
Primary Critical Dimensions



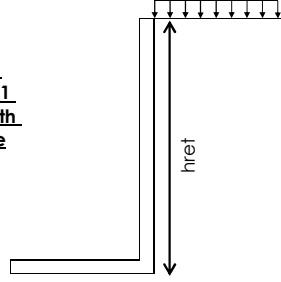
Secondary Critical Dimensions

2.0 Retaining Wall Global Design

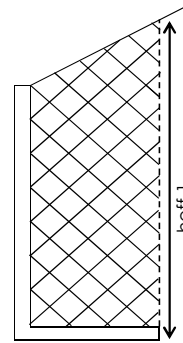
The global design determines a maximum overturning and sliding force on the retaining wall for each of the three combinations (EQU, Comb'1, Comb'2) in the two loading conditions (presented below) applied to the front and the back of the wall. All designs are done on a per/metre run basis.



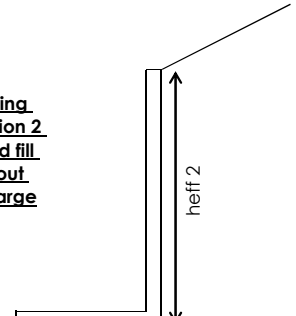
Backfill to rear of wall (A)



Backfill to front of wall (B)



Backfill to rear of wall (C)



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;

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

$$0.307 \cdot 0.933 \cdot 1.5 \cdot 10 \cdot 1 =$$

$$4.3 \text{ kN}$$

Lever Arm

Moment

Active Pressure;

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

$$1.1 \cdot 0.307 \cdot 0.933 \cdot 18 \cdot 1^2 / 2 =$$

$$2.8 \text{ kN}$$

$$0.333 \text{ m}$$

$$0.9 \text{ kNm}$$

Additional shear load acting at z;

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

$$0 \cdot 1.5 =$$

$$0.0 \text{ kN}$$

$$0.500 \text{ m}$$

$$0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):}$$

$$7.1 \text{ kN}$$

$$M_H;$$

$$3.1 \text{ kNm}$$

Weight of wall stem;

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

$$0.9 \cdot 0.881 \cdot 0.113 \cdot 25 =$$

$$2.2 \text{ kN}$$

$$0.057 \text{ m}$$

$$0.1 \text{ kNm}$$

Weight of base;

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

$$0.9 \cdot 0.5 \cdot 0.119 \cdot 25 =$$

$$1.3 \text{ kN}$$

$$0.250 \text{ m}$$

$$0.3 \text{ kNm}$$

Retained Soil;

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

$$0.9 \cdot 0.881 \cdot 0.387 \cdot 18 =$$

$$5.5 \text{ kN}$$

$$0.307 \text{ m}$$

$$1.7 \text{ kNm}$$

Friction on virtual Back of wall;

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

$$0.9 \cdot 0.307 \cdot 0.34 \cdot 18 \cdot 1^2 / 2 =$$

$$0.8 \text{ kN}$$

$$0.500 \text{ m}$$

$$0.4 \text{ kNm}$$

$$\text{Vertical Force (V):}$$

$$9.9 \text{ kN}$$

$$M_V;$$

$$2.6 \text{ kNm}$$

**1000mm Standard L-Wall
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Loading condition 1 -Backfill to front of wall with level fill and surcharge (B)

Lever Arm Moment

Surcharge Load;

$$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ref}; \quad 0.307 \cdot 0.94 \cdot 1.5 \cdot 10 \cdot 1 = \quad 4.3 \text{ kN} \quad 0.500 \text{ m} \quad 2.2 \text{ kNm}$$

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 1.1 \cdot 0.307 \cdot 0.94 \cdot 18 \cdot 1^2/2 = \quad 2.9 \text{ kN} \quad 0.333 \text{ m} \quad 1.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 7.2 \text{ kN} \quad M_H; \quad 3.1 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 0.881 \cdot 0.113 \cdot 25 = \quad 2.2 \text{ kN} \quad 0.444 \text{ m} \quad 1.0 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 0.5 \cdot 0.119 \cdot 25 = \quad 1.3 \text{ kN} \quad 0.250 \text{ m} \quad 0.3 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 0.9 \cdot 0.307 \cdot 0.34 \cdot 18 \cdot 1^2/2 = \quad 0.8 \text{ kN} \quad 0.500 \text{ m} \quad 0.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 4.4 \text{ kN} \quad M_V; \quad 1.8 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d} \cdot (90-\alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 1.1 \cdot 0.825 \cdot 0.933 \cdot 18 \cdot 1.223^2/2 = \quad 11.4 \text{ kN} \quad 0.408 \text{ m} \quad 4.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = \quad 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 11.4 \text{ kN} \quad M_H; \quad 4.6 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 0.881 \cdot 0.113 \cdot 25 = \quad 2.2 \text{ kN} \quad 0.057 \text{ m} \quad 0.1 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 0.5 \cdot 0.119 \cdot 25 = \quad 1.3 \text{ kN} \quad 0.250 \text{ m} \quad 0.3 \text{ kNm}$$

Retained Soil;

$$F_{ret}=\gamma_{Gf} \cdot ((h_{ret} \cdot t_{base}) + (L_{toe} \cdot \tan(\beta)/2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 0.9 \cdot (0.881 + (0.387 \cdot 0.577/2)) \cdot 0.387 \cdot 18 = \quad 6.2 \text{ kN} \quad 0.307 \text{ m} \quad 1.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 0.9 \cdot 0.825 \cdot 0.34 \cdot 18 \cdot 1.223^2/2 = \quad 3.4 \text{ kN} \quad 0.500 \text{ m} \quad 1.7 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 13.2 \text{ kN} \quad M_V; \quad 4.1 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 1.1 \cdot 0.825 \cdot 0.94 \cdot 18 \cdot 1^2/2 = \quad 7.7 \text{ kN} \quad 0.333 \text{ m} \quad 2.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = \quad 0.0 \text{ kN} \quad 1.000 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 7.7 \text{ kN} \quad M_H; \quad 2.6 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 0.881 \cdot 0.113 \cdot 25 = \quad 2.2 \text{ kN} \quad 0.444 \text{ m} \quad 1.0 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 0.5 \cdot 0.119 \cdot 25 = \quad 1.3 \text{ kN} \quad 0.250 \text{ m} \quad 0.3 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 0.9 \cdot 0.825 \cdot 0.34 \cdot 18 \cdot 1^2/2 = \quad 2.3 \text{ kN} \quad 0.500 \text{ m} \quad 1.1 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 5.9 \text{ kN} \quad M_V; \quad 2.5 \text{ kNm}$$

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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)

			<u>Lever Arm</u>	<u>Moment</u>
Surcharge Load;				
$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret};$	$0.279 \cdot 0.921 \cdot 1.5 \cdot 10 \cdot 1 =$	3.9 kN	0.500 m	1.9 kNm
Active Pressure;				
$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2;$	$1.35 \cdot 0.279 \cdot 0.921 \cdot 18 \cdot 1^2 / 2 =$	3.1 kN	0.333 m	1.0 kNm
Additional shear load acting at z;				
$F_z = V_z \cdot \gamma_{Vz}$	$0 \cdot 1.5 =$	0.0 kN	0.500 m	0.0 kNm
	Horizontal Force (H):	7.0 kN	$M_H:$	3.0 kNm
Weight of wall stem;				
$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$	$1 \cdot 0.881 \cdot 0.113 \cdot 25 =$	2.5kN	0.057 m	0.1 kNm
Weight of base;				
$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$	$1 \cdot 0.5 \cdot 0.119 \cdot 25 =$	1.5kN	0.250 m	0.4 kNm
Retained Soil;				
$F_{ret} = \gamma_{Gf} \cdot (h_{ret} - t_{base}) \cdot L_{toe} \cdot \gamma_{mr};$	$1 \cdot 0.881 \cdot 0.387 \cdot 18 =$	6.1kN	0.307 m	1.9 kNm
Friction on virtual Back of wall;				
$F_{wall\ friction} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2;$	$1 \cdot 0.279 \cdot 0.37 \cdot 18 \cdot 1^2 / 2 =$	0.9kN	0.500 m	0.5 kNm
	Vertical Force (V):	11.0 kN	$M_V:$	2.9 kNm

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

			<u>Lever Arm</u>	<u>Moment</u>
Surcharge Load;				
$F_{sur,h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret};$	$0.279 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 1 =$	3.9 kN	0.500 m	1.9 kNm
Active Pressure;				
$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2;$	$1.35 \cdot 0.279 \cdot 0.929 \cdot 18 \cdot 1^2 / 2 =$	3.1 kN	0.333 m	1.0 kNm
Additional shear load acting at z;				
$F_z = V_z \cdot \gamma_{Vz}$	$0 \cdot 1.5 =$	0.0 kN	0.500 m	0.0 kNm
	Horizontal Force (H):	7.0 kN	$M_H:$	3.0 kNm
Weight of wall stem;				
$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$	$1 \cdot 0.881 \cdot 0.113 \cdot 25 =$	2.5kN	0.444 m	1.1 kNm
Weight of base;				
$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$	$1 \cdot 0.5 \cdot 0.119 \cdot 25 =$	1.5kN	0.250 m	0.4 kNm
Friction on virtual Back of wall;				
$F_{wall\ friction} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2;$	$1 \cdot 0.279 \cdot 0.37 \cdot 18 \cdot 1^2 / 2 =$	0.9kN	0.500 m	0.5 kNm
	Vertical Force (V):	4.9 kN	$M_V:$	1.9 kNm

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

			<u>Lever Arm</u>	<u>Moment</u>
Active Pressure;				
$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.921 \cdot 18 \cdot 1.223^2 / 2 =$	9.1kN	0.408 m	3.7 kNm
Additional Point Load				
$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.059 =$	-0.6kN	1.000 m	-0.6 kNm
Additional shear load acting at z;				
$F_z = V_z \cdot \gamma_{Vz}$	$0 \cdot 1.5 =$	0.0 kN	0.500 m	0.0 kNm
	Horizontal Force (H):	8.4 kN	$M_H:$	3.1 kNm
Weight of wall stem;				
$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$	$1 \cdot 0.881 \cdot 0.113 \cdot 25 =$	2.5kN	0.057 m	0.1 kNm
Weight of base;				
$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$	$1 \cdot 0.5 \cdot 0.119 \cdot 25 =$	1.5kN	0.250 m	0.4 kNm
Retained Soil;				
$F_{ret} = \gamma_{Gf} \cdot ((h_{ret} - t_{base}) + (L_{toe} \cdot \tan(\beta) / 2)) \cdot L_{toe} \cdot \gamma_{mr};$	$1 \cdot (0.881 + (0.387 \cdot 0.577 / 2)) \cdot 0.387 \cdot 18 =$	6.9kN	0.307 m	2.1 kNm
Friction on virtual Back of wall;				
$F_{wall\ friction} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2;$	$1 \cdot 0.543 \cdot 0.37 \cdot 18 \cdot 1.223^2 / 2 =$	2.7kN	0.500 m	1.4 kNm
	Vertical Force (V):	13.6 kN	$M_V:$	4.0 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;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{eff2}^2 / 2; \quad 1.35 \cdot 0.543 \cdot 0.929 \cdot 18 \cdot 1^2 / 2 = \quad 6.1 \text{ kN} \quad 0.333 \text{ m} \quad 2.0 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.059 = \quad -0.2 \text{ kN} \quad 1.000 \text{ m} \quad -0.2 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 5.9 \text{ kN} \quad M_H; \quad 1.8 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 0.881 \cdot 0.113 \cdot 25 = \quad 2.5 \text{ kN} \quad 0.444 \text{ m} \quad 1.1 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 0.5 \cdot 0.119 \cdot 25 = \quad 1.5 \text{ kN} \quad 0.250 \text{ m} \quad 0.4 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff2}^2 / 2; \quad 1 \cdot 0.543 \cdot 0.37 \cdot 18 \cdot 1^2 / 2 = \quad 1.8 \text{ kN} \quad 0.500 \text{ m} \quad 0.9 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 5.8 \text{ kN} \quad M_V; \quad 2.4 \text{ kNm}$$

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;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.343 \cdot 0.946 \cdot 1.3 \cdot 10 \cdot 1 = \quad 4.2 \text{ kN} \quad 0.500 \text{ m} \quad 2.1 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.343 \cdot 0.946 \cdot 18 \cdot 1^2 / 2 = \quad 2.9 \text{ kN} \quad 0.333 \text{ m} \quad 1.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = \quad 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 7.1 \text{ kN} \quad M_H; \quad 3.1 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 0.881 \cdot 0.113 \cdot 25 = \quad 2.5 \text{ kN} \quad 0.057 \text{ m} \quad 0.1 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 0.5 \cdot 0.119 \cdot 25 = \quad 1.5 \text{ kN} \quad 0.250 \text{ m} \quad 0.4 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot (h_{ret} - t_{base}) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot 0.881 \cdot 0.387 \cdot 18 = \quad 6.1 \text{ kN} \quad 0.307 \text{ m} \quad 1.9 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.343 \cdot 0.303 \cdot 18 \cdot 1^2 / 2 = \quad 0.9 \text{ kN} \quad 0.500 \text{ m} \quad 0.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 11.0 \text{ kN} \quad M_V; \quad 2.9 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.343 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 1 = \quad 4.2 \text{ kN} \quad 0.500 \text{ m} \quad 2.1 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.343 \cdot 0.953 \cdot 18 \cdot 1^2 / 2 = \quad 2.9 \text{ kN} \quad 0.333 \text{ m} \quad 1.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = \quad 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 7.2 \text{ kN} \quad M_H; \quad 3.1 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 0.881 \cdot 0.113 \cdot 25 = \quad 2.5 \text{ kN} \quad 0.444 \text{ m} \quad 1.1 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 0.5 \cdot 0.119 \cdot 25 = \quad 1.5 \text{ kN} \quad 0.250 \text{ m} \quad 0.4 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.343 \cdot 0.303 \cdot 18 \cdot 1^2 / 2 = \quad 0.9 \text{ kN} \quad 0.500 \text{ m} \quad 0.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 4.9 \text{ kN} \quad M_V; \quad 1.9 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.858 \cdot 0.946 \cdot 18 \cdot 1.197^2 / 2 = 10.5 \text{ kN} \quad 0.399 \text{ m} \quad 4.2 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.076 = 0.6 \text{ kN} \quad 1.000 \text{ m} \quad 0.6 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 11.0 \text{ kN} \quad M_H; \quad 4.7 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 0.881 \cdot 0.113 \cdot 25 = 2.5 \text{ kN} \quad 0.057 \text{ m} \quad 0.1 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 0.5 \cdot 0.119 \cdot 25 = 1.5 \text{ kN} \quad 0.250 \text{ m} \quad 0.4 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = \gamma_{Gf} \cdot ((h_{\text{ret}} - t_{\text{base}}) + (L_{\text{toe}} \cdot \tan(\beta) / 2)) \cdot L_{\text{toe}} \cdot \gamma_{mr}; \quad 1 \cdot (0.881 + (0.387 \cdot 0.577 / 2)) \cdot 0.387 \cdot 18 = 6.9 \text{ kN} \quad 0.307 \text{ m} \quad 2.1 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.858 \cdot 0.303 \cdot 18 \cdot 1.197^2 / 2 = 3.4 \text{ kN} \quad 0.500 \text{ m} \quad 1.7 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 14.2 \text{ kN} \quad M_V; \quad 4.3 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.858 \cdot 0.953 \cdot 18 \cdot 1^2 / 2 = 7.4 \text{ kN} \quad 0.333 \text{ m} \quad 2.5 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.029 = 0.2 \text{ kN} \quad 1.000 \text{ m} \quad 0.2 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = 0.0 \text{ kN} \quad 0.500 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 7.6 \text{ kN} \quad M_H; \quad 2.7 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 0.881 \cdot 0.113 \cdot 25 = 2.5 \text{ kN} \quad 0.444 \text{ m} \quad 1.1 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 0.5 \cdot 0.119 \cdot 25 = 1.5 \text{ kN} \quad 0.250 \text{ m} \quad 0.4 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.858 \cdot 0.303 \cdot 18 \cdot 1^2 / 2 = 2.3 \text{ kN} \quad 0.500 \text{ m} \quad 1.2 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 6.3 \text{ kN} \quad M_V; \quad 2.6 \text{ kNm}$$

2.4 Summary of forces and moments on wall

Equilibrium	H	M _H	V	M _V
A: LC1 - Backfill to rear:	7.1 kN	3.1 kNm	9.9 kN	2.6 kNm
B: LC1 - Backfill to front:	7.2 kN	3.1 kNm	4.4 kN	1.8 kNm
C: LC2 - Backfill to rear:	11.4 kN	4.6 kNm	13.2 kN	4.1 kN
D: LC2 - Backfill to front:	7.7 kN	2.6 kNm	5.9 kN	2.5 kN
Combination 1	H	M _H	V	M _V
A: LC1 - Backfill to rear:	7.0 kN	3.0 kNm	11.0 kN	2.9 kNm
B: LC1 - Backfill to front:	7.0 kN	3.0 kNm	4.9 kN	1.9 kNm
C: LC2 - Backfill to rear:	8.4 kN	3.1 kNm	13.6 kN	4.0 kN
D: LC2 - Backfill to front:	5.9 kN	1.8 kNm	5.8 kN	2.4 kN
Combination 2	H	M _H	V	M _V
A: LC1 - Backfill to rear:	7.1 kN	3.1 kNm	11.0 kN	2.9 kNm
B: LC1 - Backfill to front:	7.2 kN	3.1 kNm	4.9 kN	1.9 kNm
C: LC2 - Backfill to rear:	11.0 kN	4.7 kNm	14.2 kN	4.3 kN
D: LC2 - Backfill to front:	7.6 kN	2.7 kNm	6.3 kN	2.6 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:	3.1 kN 0.56 ULS Ratio	2.6 kN 0.63 ULS Ratio	2.7 kN 0.62 ULS Ratio
	LC1 - Backfill to front:	5.4 kN 0.25 ULS Ratio	5.1 kN 0.28 ULS Ratio	5.2 kN 0.27 ULS Ratio
	LC2 - Backfill to rear:	6.1 kN 0.46 ULS Ratio	3.0 kN 0.64 ULS Ratio	5.3 kN 0.52 ULS Ratio
	LC2 - Backfill to front:	5.3 kN 0.30 ULS Ratio	3.6 kN 0.39 ULS Ratio	5.0 kN 0.33 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:	-0.5 kNm 0.83 ULS Ratio	-0.1 kNm 0.96 ULS Ratio	-0.2 kNm 0.94 ULS Ratio
	LC1 - Backfill to front:	-1.4 kNm 0.56 ULS Ratio	-1.1 kNm 0.65 ULS Ratio	-1.2 kNm 0.63 ULS Ratio
	LC2 - Backfill to rear:	-0.6 kNm 0.88 ULS Ratio	0.9 kNm 1.30 ULS Ratio	-0.4 kNm 0.91 ULS Ratio
	LC2 - Backfill to front:	-0.1 kNm 0.96 ULS Ratio	0.6 kNm 1.31 ULS Ratio	0.0 kNm 0.99 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;	6.1 kN/m	- Loading condition 2 (Backfill to the rear)
Vertical load;	13.2 kN/m	- Loading condition 2 (Backfill to the rear)
Resultant destabilising moment;	1.4 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;	5.3 kN/m	- Combination 2 with loading condition 2 (Backfill to the rear)
Resultant anti-clockwise destabilising moment;	0.4 kNm/m	- Combination 2 with loading condition 2 (Backfill to the rear)
Resultant clockwise destabilising moment;	1.2 kNm/m	- Combination 2 with loading condition 1 (Backfill to the front)

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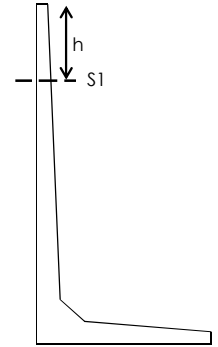
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3.1 Analysis Height 1

Analysis height 1 (S1) 333 mm
Soil depth at S1 333 mm



Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.267m	0.316m
Property B	0.154m	0.182m
Property C	0.170m	0.161m
Property D	-0.013m	0.019m
Property E	-0.025m	0.031m
Property F	-0.009m	0.010m
Area of Soil (A)	-0.002 m ²	0.003 m ²

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.921 \cdot 1.5 \cdot 10 \cdot 0.333=$	1.3 kN	0.167 m	0.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.279 \cdot 0.921 \cdot 18 \cdot 0.333^2/2=$	0.3 kN	0.111 m	0.0 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	-0.167 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):			1.6 kN	$M_H:$	0.3 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.333=$	1.3 kN	0.167 m	0.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.279 \cdot 0.929 \cdot 18 \cdot 0.333^2/2=$	0.3 kN	0.111 m	0.0 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	-0.167 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):			1.6 kN	$M_H:$	0.3 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.921 \cdot 18 \cdot 0.333^2 / 2 =$	0.7kN	0.111 m	0.1 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.002 =$	0.0kN	0.333 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	-0.167 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):			0.7 kN	$M_H:$	0.1 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.929 \cdot 18 \cdot 0.333^2 / 2 =$	0.7kN	0.111 m	0.1 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.002 =$	0.0kN	0.333 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	-0.167 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):			0.7 kN	$M_H:$	0.1 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.946 \cdot 1.3 \cdot 10 \cdot 0.333=$	1.4 kN	0.167 m	0.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.343 \cdot 0.946 \cdot 18 \cdot 0.333^2/2=$	0.3 kN	0.111 m	0.0 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	-0.167 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):			1.7 kN	$M_H:$	0.3 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.333=$	1.4 kN	0.167 m	0.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.343 \cdot 0.953 \cdot 18 \cdot 0.333^2/2=$	0.3 kN	0.111 m	0.0 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	-0.167 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):			1.7 kN	$M_H:$	0.3 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.946 \cdot 18 \cdot 0.333^2 / 2 =$	0.8kN	0.111 m	0.1 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.003 =$	0.0kN	0.333 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	-0.167 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):			0.8 kN	$M_H:$	0.1 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.953 \cdot 18 \cdot 0.333^2 / 2 =$	0.8kN	0.111 m	0.1 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.003 =$	0.0kN	0.333 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	-0.167 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):			0.8 kN	$M_H:$	0.1 kNm

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REV: 0

BY: S.J.H

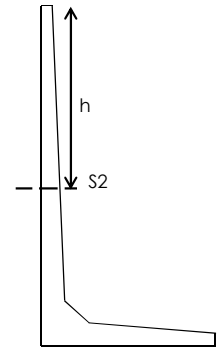
CHK: C.B.

SHEET: 10 of 20

3.2 Analysis Height 2

Analysis height 2 (S2) 530 mm
Soil depth at S2 530 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.426m	0.503m
Property B	0.246m	0.290m
Property C	0.271m	0.256m
Property D	-0.021m	0.030m
Property E	-0.039m	0.049m
Property F	-0.014m	0.015m
Area of Soil (A)	-0.006 m ²	0.008 m ²



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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.921 \cdot 1.5 \cdot 10 \cdot 0.53 =$	2.0 kN	0.265 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.279 \cdot 0.921 \cdot 18 \cdot 0.53^2 / 2 =$	0.9 kN	0.177 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
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 1) (B)

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.53 =$	2.1 kN	0.265 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.279 \cdot 0.929 \cdot 18 \cdot 0.53^2 / 2 =$	0.9 kN	0.177 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
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 1) (C)

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.921 \cdot 18 \cdot 0.53^2 / 2 =$	1.7kN	0.177 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.006 =$	-0.1kN	0.530 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.6 kN	$M_H:$	0.3 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.929 \cdot 18 \cdot 0.53^2 / 2 =$	1.7kN	0.177 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.006 =$	-0.1kN	0.530 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.7 kN	$M_H:$	0.3 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.946 \cdot 1.3 \cdot 10 \cdot 0.53 =$	2.2 kN	0.265 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.343 \cdot 0.946 \cdot 18 \cdot 0.53^2 / 2 =$	0.8 kN	0.177 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		3.1 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	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.53 =$	2.3 kN	0.265 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.343 \cdot 0.953 \cdot 18 \cdot 0.53^2 / 2 =$	0.8 kN	0.177 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		3.1 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	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.946 \cdot 18 \cdot 0.53^2 / 2 =$	2.1kN	0.177 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.008 =$	0.1kN	0.530 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.1 kN	$M_H:$	0.4 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.953 \cdot 18 \cdot 0.53^2 / 2 =$	2.1kN	0.177 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.008 =$	0.1kN	0.530 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.030 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.1 kN	$M_H:$	0.4 kNm

**1000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

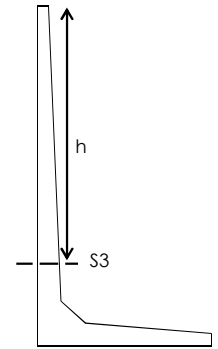
CHK: C.B.

SHEET: 11 of 20

3.3 Analysis Height 3

Analysis height 3 (S3) 760 mm
Soil depth at S3 760 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.610m	0.721m
Property B	0.352m	0.416m
Property C	0.389m	0.367m
Property D	-0.031m	0.043m
Property E	-0.056m	0.071m
Property F	-0.020m	0.022m
Area of Soil (A)	-0.012 m ²	0.017 m ²



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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.921 \cdot 1.5 \cdot 10 \cdot 0.76 =$	2.9 kN	0.380 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.279 \cdot 0.921 \cdot 18 \cdot 0.76^2 / 2 =$	1.8 kN	0.253 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		4.7 kN	$M_H:$	1.6 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.76 =$	3.0 kN	0.380 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.279 \cdot 0.929 \cdot 18 \cdot 0.76^2 / 2 =$	1.8 kN	0.253 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		4.8 kN	$M_H:$	1.6 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.921 \cdot 18 \cdot 0.76^2 / 2 =$	3.5kN	0.253 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.012 =$	-0.1kN	0.760 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		3.4 kN	$M_H:$	0.8 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.929 \cdot 18 \cdot 0.76^2 / 2 =$	3.5kN	0.253 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.012 =$	-0.1kN	0.760 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		3.4 kN	$M_H:$	0.8 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.946 \cdot 1.3 \cdot 10 \cdot 0.76 =$	3.2 kN	0.380 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.343 \cdot 0.946 \cdot 18 \cdot 0.76^2 / 2 =$	1.7 kN	0.253 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		4.9 kN	$M_H:$	1.6 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.76 =$	3.2 kN	0.380 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.343 \cdot 0.953 \cdot 18 \cdot 0.76^2 / 2 =$	1.7 kN	0.253 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		4.9 kN	$M_H:$	1.7 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.946 \cdot 18 \cdot 0.76^2 / 2 =$	4.2kN	0.253 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.017 =$	0.1kN	0.760 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		4.3 kN	$M_H:$	1.2 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.953 \cdot 18 \cdot 0.76^2 / 2 =$	4.3kN	0.253 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.017 =$	0.1kN	0.760 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.260 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		4.4 kN	$M_H:$	1.2 kNm

**1000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

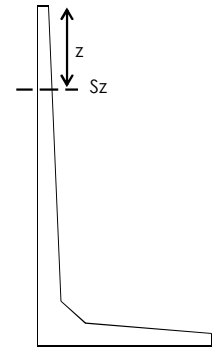
BY: S.J.H

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)

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.921 \cdot 1.5 \cdot 10 \cdot 0.5=$	1.9 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.279 \cdot 0.921 \cdot 18 \cdot 0.5^2/2=$	0.8 kN	0.167 m	0.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	0.000 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):			2.7 kN	$M_H:$	0.6 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.279 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.5=$	1.9 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.279 \cdot 0.929 \cdot 18 \cdot 0.5^2/2=$	0.8 kN	0.167 m	0.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	0.000 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):			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)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.921 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m	0.3 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 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):			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)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.543 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m	0.3 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 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):			1.5 kN	$M_H:$	0.2 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.946 \cdot 1.3 \cdot 10 \cdot 0.5=$	2.1 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.343 \cdot 0.946 \cdot 18 \cdot 0.5^2/2=$	0.7 kN	0.167 m	0.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	0.000 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):			2.8 kN	$M_H:$	0.6 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.343 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.5=$	2.1 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.343 \cdot 0.953 \cdot 18 \cdot 0.5^2/2=$	0.7 kN	0.167 m	0.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	0.000 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		<u>0.0 kN</u>	<u>0.000 m</u>	<u>0.0 kNm</u>
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)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.946 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m	0.3 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 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):			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)

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.858 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m	0.3 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m	0.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 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):			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 @ 333		Analysis 2 @ 530		Analysis 3 @ 760		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Rear level fill & surcharge (A)	1.6 kN	0.3 kNm	2.9 kN	0.7 kNm	4.7 kN	1.6 kNm	2.7 kN	0.6 kNm
Front level fill & surcharge (B)	1.6 kN	0.3 kNm	2.9 kN	0.7 kNm	4.8 kN	1.6 kNm	2.7 kN	0.6 kNm
Rear sloped fill without surcharge (C)	0.7 kN	0.1 kNm	1.6 kN	0.3 kNm	3.4 kN	0.8 kNm	1.5 kN	0.2 kNm
Front sloped fill without surcharge (D)	0.7 kN	0.1 kNm	1.7 kN	0.3 kNm	3.4 kN	0.8 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)	1.7 kN	0.3 kNm	3.1 kN	0.7 kNm	4.9 kN	1.6 kNm	2.8 kN	0.6 kNm
Front level fill & surcharge (B)	1.7 kN	0.3 kNm	3.1 kN	0.7 kNm	4.9 kN	1.7 kNm	2.9 kN	0.7 kNm
Rear sloped fill without surcharge (C)	0.8 kN	0.1 kNm	2.1 kN	0.4 kNm	4.3 kN	1.2 kNm	1.9 kN	0.3 kNm
Front sloped fill without surcharge (D)	0.8 kN	0.1 kNm	2.1 kN	0.4 kNm	4.4 kN	1.2 kNm	1.9 kN	0.3 kNm
Back face is in tension values	Analysis 1 @ 333		Analysis 2 @ 530		Analysis 3 @ 760		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	1.7 kN	0.1 kNm	2.1 kN	0.4 kNm	4.9 kN	1.2 kNm	1.9 kN	0.3 kNm
Front face is in tension values	Analysis 1 @ 333		Analysis 2 @ 530		Analysis 3 @ 760		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	1.7 kN	0.3 kNm	3.1 kN	0.7 kNm	4.9 kN	1.6 kNm	2.8 kN	0.6 kNm

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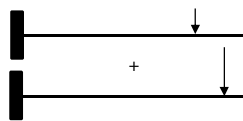
4.0 Wall Base Design

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

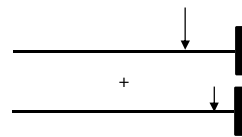
Analysis length 1 (B1)	240 mm
Analysis length 2 (B2)	333 mm
Analysis length 3 (B3)	455 mm

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

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

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

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

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

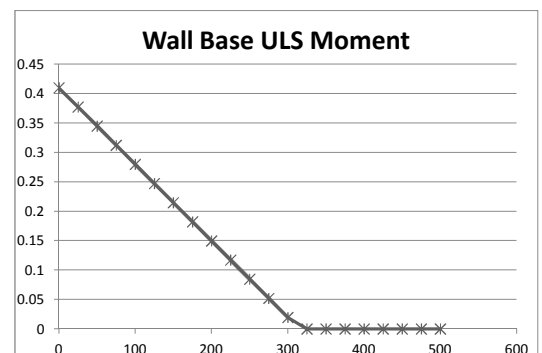
Maximum overturning moment	0.4 kNm
Lever arm to closest anchor (lb1)	315 mm
Lever arm to furthest anchor (lb2)	N/A

From the above equations:

$$\text{Tension force in closest anchors (FS1)} = 1.3 \text{ kN}$$

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

	X:	240mm	333mm	455mm
Tension Moment Top face:		0.1 kNm	0.0 kNm	0.0 kNm
Shear:		1.3 kN	0.0 kN	0.0 kN



4.2 Anchored Clockwise Rotation

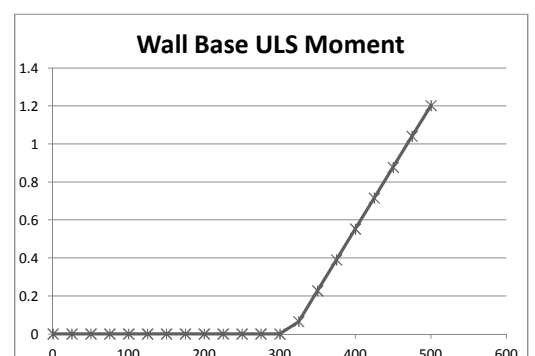
Maximum overturning moment	1.2 kNm
Lever arm to closest anchor (lb1)	185 mm
Lever arm to furthest anchor (lb2)	N/A

From the above equations:

$$\text{Tension force in closest anchors (FS1)} = 6.5 \text{ kN}$$

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

	X:	240mm	333mm	455mm
Tension Moment Top face:		0.0 kNm	0.1 kNm	0.9 kNm
Shear:		0.0 kN	6.5 kN	6.5 kN



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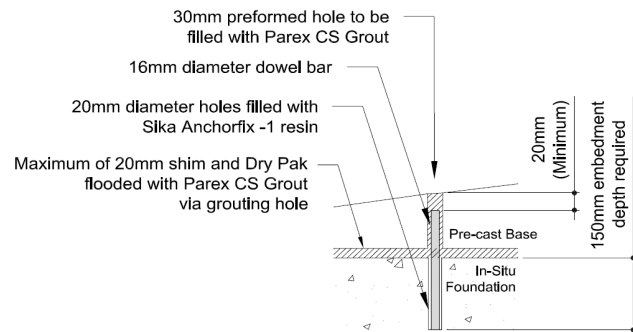
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5.0 Anchor Design

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);	First Row	Second Row
$N = \text{Max}\{\text{Clockwise Force, Anticlockwise Force}\} / \text{No.}$	$\text{Max}\{1.3, 0\} / 2 = 3.3 \text{ kN}$	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	First Row	Second Row
$\beta_N = N / N_{Rd,s}$	$3.3 / 96.1 = 0.03$	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

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

3.3/16.5 = 0.20

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;

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

5.3/(2 \cdot 1) = 2.7 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
2.7/48.1 = 0.06

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
0.02

Second Row
N/A

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

0.10

N/A

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

0.26

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
3.3/10 = 0.33

Second Row
N/A

Anchorage provided is adequate

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6.0 Reinforcement Design

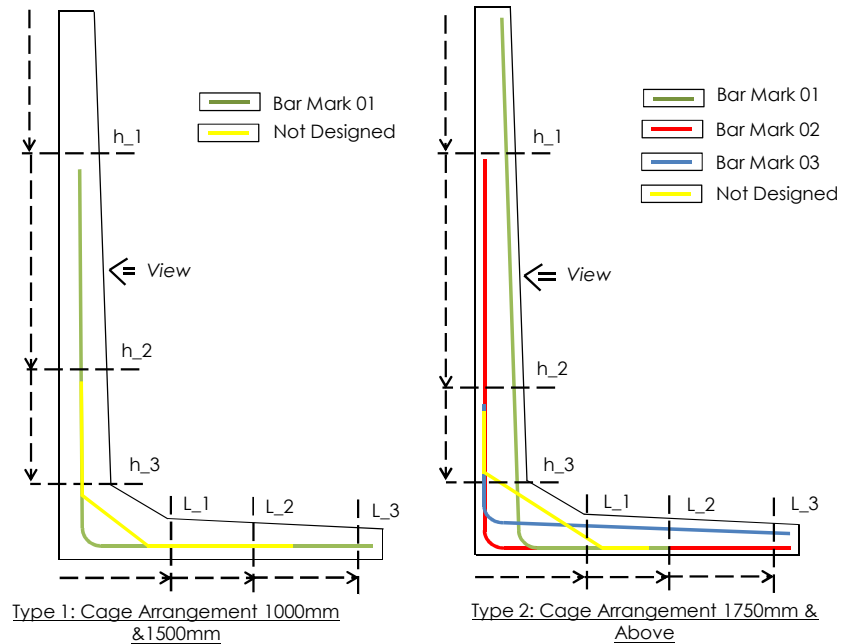
All the standard retaining walls have different reinforcement cages, however, they follow one of two patterns. The 1000mm and 1500mm are a type one and 1750mm and above are of a type 2, these are shown (right). A reinforcement check is then done on the three heights of the stem and three lengths of the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

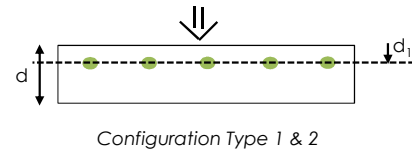
	Diameter	Spacing	As,prov
Bar Mark 1	8.00	200	251
Bar Mark 2	0.00	0	0
Bar Mark 3	0.00	0	0



6.1 Section Analysis

Analysis height 1 (333mm)

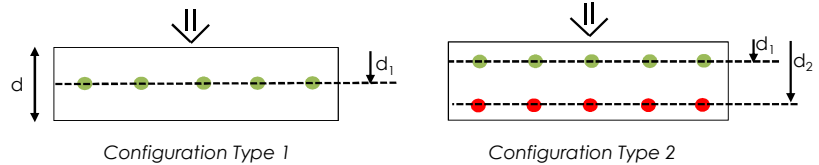
Depth @ S1 (hS1)	110 mm
hS1 - Depth to rein' (d1)	53 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	251	57	0	0
Front face in tension	251	53	0	0

Analysis height 2 (530mm)

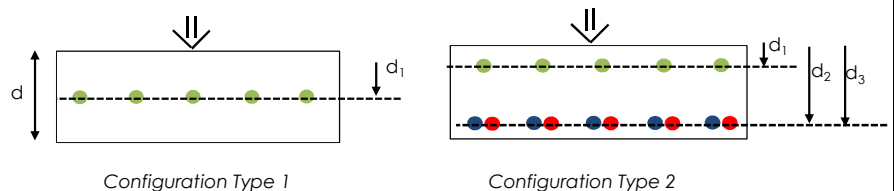
Depth @ S2 (hS2)	115 mm
hS2 - Depth to rein' (d1)	58 mm
hS2 - Depth to rein' (d2)	0 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	251	57	0	0
Front face in tension	251	58	0	0

Analysis height 3 (760mm)

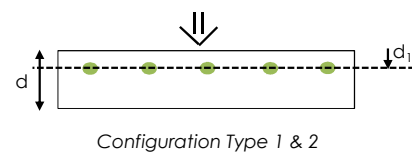
Depth @ S3 (hS3)	120 mm
hS3 - Depth to rein' (d1)	63 mm
hS3 - Depth to rein' (d2)	0 mm
hS3 - Depth to rein' (d3)	0 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	251	57	0	0
Front face in tension	251	63	0	0

Analysis height z (500mm)

Depth @ Sz (hSz)	114 mm
Depth to rein' (d1)	57 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	251	57	0	0
Front face in tension	251	57	0	0

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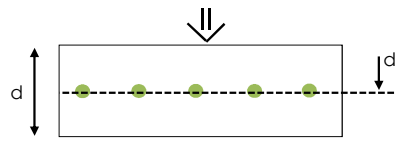
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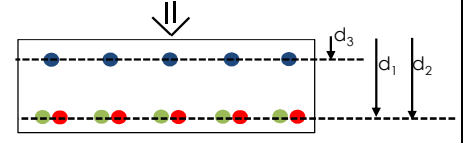
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Analysis length 1 (240mm)

Depth @ B1 (hB1)	120 mm
hB1 - Depth to rein' (d1)	63 mm
hB1 - Depth to rein' (d2)	0 mm
hB1 - Depth to rein' (d3)	0 mm



Configuration Type 1

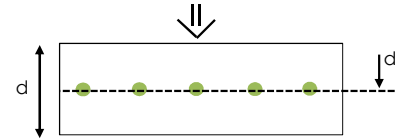


Configuration Type 2

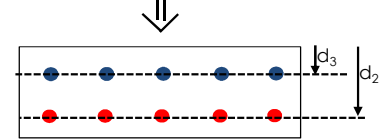
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	251	57	0	0
Bottom face in tension	251	63	0	0

Analysis length 2 (333mm)

Depth @ B2 (hB2)	114 mm
hB2 - Depth to rein' (d1)	57 mm
hB2 - Depth to rein' (d2)	0 mm
hB2 - Depth to rein' (d3)	0 mm



Configuration Type 1

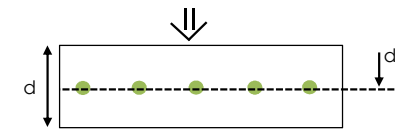


Configuration Type 2

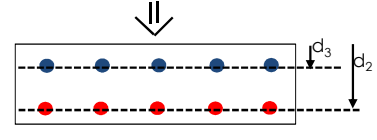
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	251	57	0	0
Bottom face in tension	251	57	0	0

Analysis length 3 (455mm)

Depth @ B3 (hB3)	107 mm
hB3 - Depth to rein' (d1)	50 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	251	57	0	0
Bottom face in tension	251	50	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

$$f_{ck} = 45 \text{ N/mm}^2$$

$$f_{ck,cube} = 55 \text{ N/mm}^2$$

$$f_{cm} = 53 \text{ N/mm}^2$$

$$f_{ctm} = 4 \text{ N/mm}^2$$

$$f_{ctk,0.05} = 3 \text{ N/mm}^2$$

$$E_{cm} = 22 \cdot (f_{cm}/10)^{0.3} = 36283 \text{ N/mm}^2$$

$$\gamma_c = 1.50$$

$$\alpha_{cc} = 0.85$$

$$f_{cd} = \alpha_{cc} \cdot f_{ck} / \gamma_c = 25.5 \text{ N/mm}^2$$

$$h_{agg} = 20 \text{ mm}$$

$$\Delta C_{dev} = 5 \text{ mm}$$

$$\text{Class} = \mathbf{XC3/4}$$

$$VRd,max(\cot(\theta) = 2.5) = 5.08$$

$$VRd,max(\cot(\theta) = 1.0) = 7.38$$

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

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

$$E_s = 210000 \text{ N/mm}^2$$

$$\gamma_s = 1.15$$

$$f_{yd} = f_{yk} / \gamma_s = 435 \text{ N/mm}^2$$

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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	4.9 kNm	4.9 kNm	4.9 kNm	4.9 kNm
Design Bending Moment	0.1 kNm	0.4 kNm	1.2 kNm	0.3 kNm
Area of tension reinforcement provided	251 mm ²	251 mm ²	251 mm ²	251 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;	47 mm	47 mm	47 mm	47 mm
K Factor =M/(b•d _{n1} ² •fck);	0.001	0.004	0.012	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)));	45 mm	45 mm	45 mm	45 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	5 mm ²	20 mm ²	59 mm ²	17 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	93 mm ²	93 mm ²	93 mm ²	93 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})	93 mm ²	93 mm ²	93 mm ²	93 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (2.7)	Pass (2.7)	Pass (2.7)	Pass (2.7)
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});	0.0050	0.0050	0.0050	0.0050
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	31.2 kN	31.2 kN	31.2 kN	31.2 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});	31.8 kN	31.8 kN	31.8 kN	31.8 kN
Shear resistance required (V)	1.7 kN	2.1 kN	4.9 kN	1.9 kN
	Pass (9.9)	Pass (9.9)	Pass (6.5)	Pass (9.9)

	Front face in Tension			
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	4.5 kNm	4.9 kNm	5.5 kNm	4.9 kNm
Design Bending Moment	0.3 kNm	0.7 kNm	1.6 kNm	0.6 kNm
Area of tension reinforcement provided	251 mm ²	251 mm ²	251 mm ²	251 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;	43 mm	48 mm	53 mm	47 mm
K Factor =M/(b•dn12•fck);	0.003	0.007	0.013	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)));	41 mm	45 mm	50 mm	45 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	15 mm ²	38 mm ²	76 mm ²	33 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	86 mm ²	95 mm ²	105 mm ²	93 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})	86 mm ²	95 mm ²	105 mm ²	93 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (2.9)	Pass (2.6)	Pass (2.3)	Pass (2.7)
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});	0.0060	0.0050	0.0050	0.0050
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	28.9 kN	31.8 kN	35.2 kN	31.3 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});	31.2 kN	32.4 kN	35.9 kN	31.9 kN
Shear resistance required (V)	1.7 kN	3.1 kN	4.9 kN	2.8 kN
	Pass (9.9)	Pass (9.9)	Pass (7.2)	Pass (9.9)

**1000mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

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6.4 Base Reinforcement Design

	Top face in Tension		
	L_1	L_2	L_3
<u>Moment</u>			
Moment capacity of section	4.9 kNm	4.9 kNm	4.9 kNm
Design Bending Moment	0.1 kNm	0.1 kNm	0.9 kNm
Area of tension reinforcement provided	251 mm ²	251 mm ²	251 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;	47 mm	47 mm	47 mm
K Factor =M/(b•dn1 ² •fck);	0.001	0.001	0.009
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)));	45 mm	45 mm	45 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	5 mm ²	6 mm ²	46 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	93 mm ²	93 mm ²	93 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})	93 mm ²	93 mm ²	93 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (2.7)	Pass (2.7)	Pass (2.7)
<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
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});	0.0050	0.0050	0.0050
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	31.2 kN	31.2 kN	31.2 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});	31.8 kN	31.8 kN	31.8 kN
Shear resistance required (V)	1.3 kN	6.5 kN	6.5 kN
	Pass (9.9)	Pass (4.8)	Pass (4.8)

	Bottom face in Tension		
	L_1	L_2	L_3
Moment capacity of section	5.5 kNm	4.9 kNm	4.2 kNm
Design Bending Moment	0.0 kNm	0.0 kNm	0.0 kNm
Area of tension reinforcement provided	251 mm ²	251 mm ²	251 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;	53 mm	47 mm	40 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)));	50 mm	45 mm	38 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} ;	105 mm ²	93 mm ²	79 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})	105 mm ²	93 mm ²	79 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (2.3)	Pass (2.7)	Pass (3.1)
<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
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});	0.0050	0.0050	0.0060
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	35.2 kN	31.4 kN	26.4 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});	35.9 kN	32.0 kN	28.6 kN
Shear resistance required (V)	1.3 kN	6.5 kN	6.5 kN
	Pass (9.9)	Pass (4.9)	Pass (4.4)

Concrete section is sufficiently reinforced