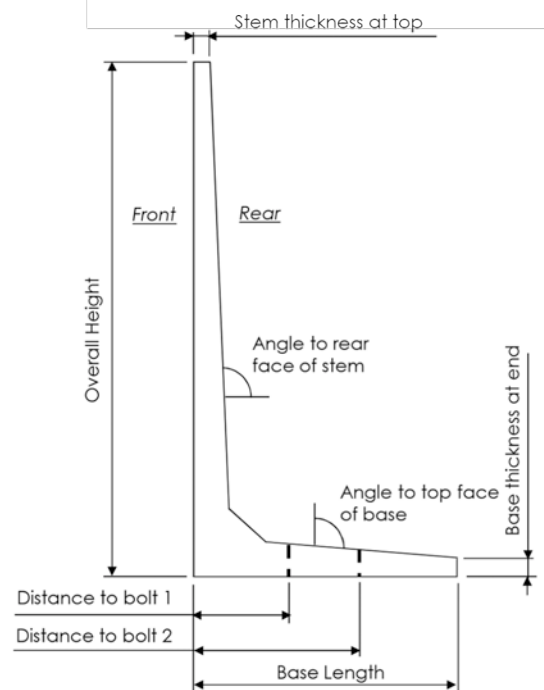


Rev	Description	By	Date

1.0 Retaining Wall Design

Overall height (h)	3750 mm
Base length (L_{base})	1875 mm
Stem thickness at top (t_{stem_top})	110 mm
Base thickness at end (t_{base_min})	135 mm
Unit width (w_u)	1000 mm
Distance to bolt 1 (from face)	662 mm
Distance to bolt 2 (from face)	1162 mm
Number of bolts / row (No.)	3 No.
Angle to rear face of stem ($\alpha 1$)	92.6°
Angle to top face of base ($\alpha 2$)	95.0°
Concrete Density (γ_c)	25.0 kN/m ³
Average stem thickness (t_{stem})	191 mm
Average base thickness (t_{base})	217 mm
Stem height (h_{stem})	3533 mm
Toe length (L_{toe})	1684 mm
Cover block (c)	45 mm
Cover deviation (Δc_{dev})	5 mm
Height of retained soil (h_{ret})	3750 mm
Moist density (γ_{mr})	18.0 kN/m ³
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 _Q)	10.0kN/m ²



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

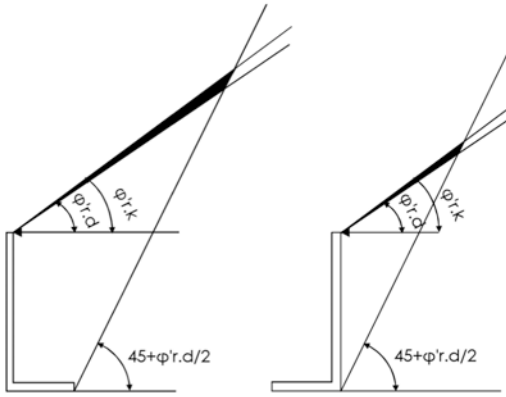
Partial Factors for Soil Parameters	Equilibrium (Table A.NA.2)	Comb' 1 (Table A.4)	Comb' 2 (Table A.4)
Angle of shearing resistance ($\gamma_{\phi'}$)	1.10	1.00	1.25
Effective cohesion (γ_c)	1.10	1.00	1.25
Weight density (γ_y)	1.00	1.00	1.00

Retained Soil Properties based on Coulomb	Equilibrium	Combination 1	Combination 2
Design eff' shear resistance angle ($\phi'_{r,d}$):	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):	0.316	0.288	0.353
Sloped backfill active pressure coefficient (k_a):	0.854	0.564	0.885

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})	4722 mm	3750 mm	4722 mm	3750 mm	4608 mm	3750 mm
Dimension properties (see diagram over page)						
Property A	5.77360m	3.248m	5.476m	3.011m	6.161m	3.556m
Property B	3.33339m	1.875m	3.161m	1.738m	3.557m	2.053m
Property C	3.33339m	1.875m	3.488m	1.918m	3.140m	1.812m
Property D	0.00000m	0.000m	-0.276m	-0.152m	0.372m	0.214m
Property E	0.00000m	0.000m	-0.503m	-0.276m	0.606m	0.350m
Property F	0.00000m	0.000m	-0.176m	-0.097m	0.189m	0.109m
Area of Soil (A)	0.000 m ²	0.000 m ²	-0.940 m ²	-0.284 m ²	1.207 m ²	0.402 m ²

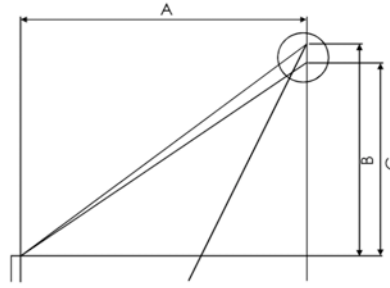
Additional Line Load

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

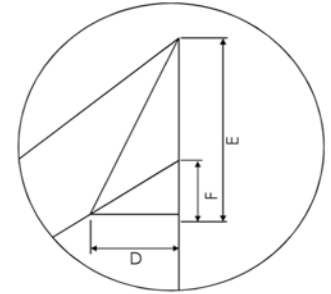


Sketch 1: Line load to rear of retaining wall

Sketch 2: Line load to front of retaining wall



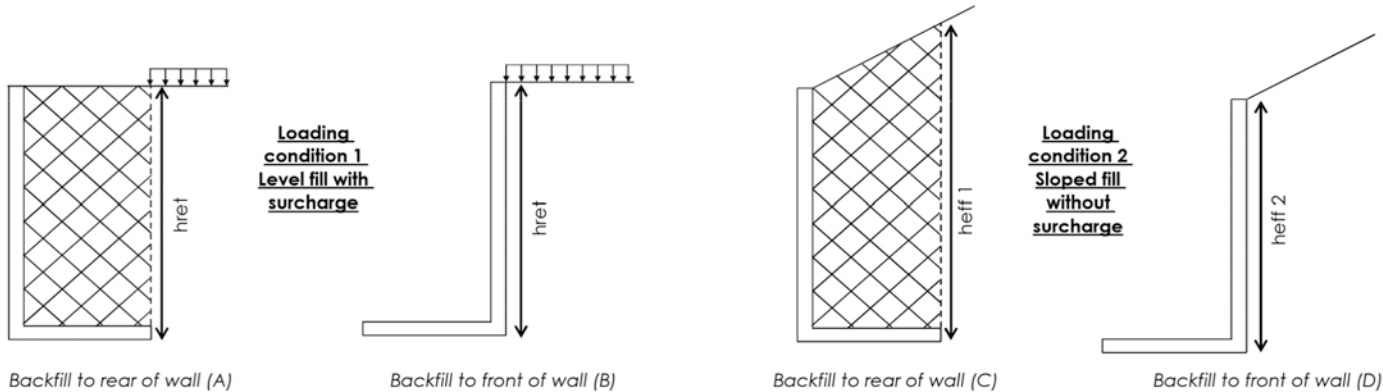
Primary Critical Dimensions



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.



2.1 Global Forces at EQU

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

Surcharge Load;

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

$$0.316 \cdot 0.924 \cdot 1.5 \cdot 10 \cdot 3.75 =$$

$$16.4 \text{ kN}$$

Lever Arm

Moment

Active Pressure;

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

$$1.1 \cdot 0.316 \cdot 0.924 \cdot 18 \cdot 3.75^2 / 2 =$$

$$40.7 \text{ kN}$$

$$1.250 \text{ m}$$

$$50.8 \text{ kNm}$$

Additional shear load acting at z;

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

$$0 \cdot 1.5 =$$

$$0.0 \text{ kN}$$

$$3.250 \text{ m}$$

$$0.0 \text{ kNm}$$

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

$$57.1 \text{ kN}$$

$$M_H;$$

$$81.6 \text{ kNm}$$

Weight of wall stem;

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

$$0.9 \cdot 3.533 \cdot 0.191 \cdot 25 =$$

$$15.2 \text{ kN}$$

$$0.096 \text{ m}$$

$$1.4 \text{ kNm}$$

Weight of base;

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

$$0.9 \cdot 1.875 \cdot 0.217 \cdot 25 =$$

$$9.2 \text{ kN}$$

$$0.938 \text{ m}$$

$$8.6 \text{ kNm}$$

Retained Soil;

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

$$0.9 \cdot 3.533 \cdot 1.684 \cdot 18 =$$

$$96.4 \text{ kN}$$

$$1.033 \text{ m}$$

$$99.6 \text{ kNm}$$

Friction on virtual Back of wall;

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

$$0.9 \cdot 0.316 \cdot 0.34 \cdot 18 \cdot 3.75^2 / 2 =$$

$$12.2 \text{ kN}$$

$$1.875 \text{ m}$$

$$23.0 \text{ kNm}$$

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

$$133.0 \text{ kN}$$

$$M_V;$$

$$132.6 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}) \cdot Y_G \cdot \text{Surcharge}_Q \cdot h_{rel};$ $0.316 \cdot 0.94 \cdot 1.5 \cdot 10 \cdot 3.75=$ 16.7 kN 1.875 m 31.3 kNm

Active Pressure;

$F_{ret,h}=Y_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot Y_{mr} \cdot h_{rel}^2/2;$ $1.1 \cdot 0.316 \cdot 0.94 \cdot 18 \cdot 3.75^2/2=$ 41.4 kN 1.250 m 51.7 kNm

Additional shear load acting at z;

$F_z=V_z \cdot Y_{Vz}$ $0 \cdot 1.5=$ 0.0 kN 3.250 m 0.0 kNm

Horizontal Force (H): 58.1 kN $M_H;$ 83.1 kNm

Weight of wall stem;

$F_{stem}=Y_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot Y_{stem};$ $0.9 \cdot 3.533 \cdot 0.191 \cdot 25=$ 15.2kN 1.780 m 27.0 kNm

Weight of base;

$F_{base}=Y_{Gf} \cdot L_{base} \cdot t_{base} \cdot Y_{base};$ $0.9 \cdot 1.875 \cdot 0.217 \cdot 25=$ 9.2kN 0.938 m 8.6 kNm

Friction on virtual Back of wall;

$F_{wall\ friction}=Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{rel}^2/2;$ $0.9 \cdot 0.316 \cdot 0.34 \cdot 18 \cdot 3.75^2/2=$ 12.2kN 1.875 m 23.0 kNm

Vertical Force (V): 36.6 kN $M_V;$ 58.6 kNm

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

Lever Arm Moment

Active Pressure;

$F_{ret,h}=Y_G \cdot K_a \cdot \cos(\delta_{r,d}-(90-a)) \cdot Y_{mr} \cdot h_{eff1}^2/2;$ $1.1 \cdot 0.854 \cdot 0.924 \cdot 18 \cdot 4.722^2/2=$ 174.2kN 1.574 m 274.2 kNm

Additional Point Load

$F_{x,h}=Y_G \cdot Y_{mr} \cdot \sin(\phi' \cdot r \cdot d) \cdot \cos(\phi' \cdot r \cdot d) \cdot A;$ $1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0=$ 0.0kN 3.750 m 0.0 kNm

Additional shear load acting at z;

$F_z=V_z \cdot Y_{Vz}$ $0 \cdot 1.5=$ 0.0 kN 3.250 m 0.0 kNm

Horizontal Force (H): 174.2 kN $M_H;$ 274.2 kNm

Weight of wall stem;

$F_{stem}=Y_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot Y_{stem};$ $0.9 \cdot 3.533 \cdot 0.191 \cdot 25=$ 15.2kN 0.096 m 1.4 kNm

Weight of base;

$F_{base}=Y_{Gf} \cdot L_{base} \cdot t_{base} \cdot Y_{base};$ $0.9 \cdot 1.875 \cdot 0.217 \cdot 25=$ 9.2kN 0.938 m 8.6 kNm

Retained Soil;

$F_{ret}=Y_{Gf} \cdot ((h_{ret}-t_{base})+(L_{toe} \cdot \tan(\beta)/2)) \cdot L_{toe} \cdot Y_{mr};$ $0.9 \cdot (3.533+(1.684 \cdot 0.577/2)) \cdot 1.684 \cdot 18=$ 109.6kN 1.033 m 113.3 kNm

Friction on virtual Back of wall;

$F_{wall\ friction}=Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{eff1}^2/2;$ $0.9 \cdot 0.854 \cdot 0.34 \cdot 18 \cdot 4.722^2/2=$ 52.5kN 1.875 m 98.4 kNm

Vertical Force (V): 186.5 kN $M_V;$ 221.7 kNm

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

Lever Arm Moment

Active Pressure;

$F_{ret,h}=Y_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot Y_{mr} \cdot h_{eff2}^2/2;$ $1.1 \cdot 0.854 \cdot 0.94 \cdot 18 \cdot 3.75^2/2=$ 111.8kN 1.250 m 139.8 kNm

Additional Point Load

$F_{x,h}=Y_G \cdot Y_{mr} \cdot \sin(\phi' \cdot r \cdot d) \cdot \cos(\phi' \cdot r \cdot d) \cdot A;$ $1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0=$ 0.0kN 3.750 m 0.0 kNm

Additional shear load acting at z;

$F_z=V_z \cdot Y_{Vz}$ $0 \cdot 1.5=$ 0.0 kN 3.250 m 0.0 kNm

Horizontal Force (H): 111.8 kN $M_H;$ 139.8 kNm

Weight of wall stem;

$F_{stem}=Y_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot Y_{stem};$ $0.9 \cdot 3.533 \cdot 0.191 \cdot 25=$ 15.2kN 1.780 m 27.0 kNm

Weight of base;

$F_{base}=Y_{Gf} \cdot L_{base} \cdot t_{base} \cdot Y_{base};$ $0.9 \cdot 1.875 \cdot 0.217 \cdot 25=$ 9.2kN 0.938 m 8.6 kNm

Friction on virtual Back of wall;

$F_{wall\ friction}=Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{eff2}^2/2;$ $0.9 \cdot 0.854 \cdot 0.34 \cdot 18 \cdot 3.75^2/2=$ 33.1kN 1.875 m 62.0 kNm

Vertical Force (V): 57.4 kN $M_V;$ 97.6 kNm

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;				
$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}-(90-\alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret};$	$0.288 \cdot 0.912 \cdot 1.5 \cdot 10 \cdot 3.75=$	14.8 kN	1.875 m	27.7 kNm
Active Pressure;				
$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}-(90-\alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2/2;$	$1.35 \cdot 0.288 \cdot 0.912 \cdot 18 \cdot 3.75^2/2=$	44.9 kN	1.250 m	56.1 kNm
Additional shear load acting at z;				
$F_z=V_z \cdot \gamma_{Vz}$	$0 \cdot 1.5=$	0.0 kN	3.250 m	0.0 kNm
	Horizontal Force (H):	59.6 kN	$M_{H;}$	83.8 kNm
Weight of wall stem;				
$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$	$1 \cdot 3.533 \cdot 0.191 \cdot 25=$	16.9kN	0.096 m	1.6 kNm
Weight of base;				
$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$	$1 \cdot 1.875 \cdot 0.217 \cdot 25=$	10.2kN	0.938 m	9.5 kNm
Retained Soil;				
$F_{ret}=\gamma_{Gf} \cdot (h_{ret}-t_{base}) \cdot L_{toe} \cdot \gamma_{mr};$	$1 \cdot 3.533 \cdot 1.684 \cdot 18=$	107.1kN	1.033 m	110.6 kNm
Friction on virtual Back of wall;				
$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2/2;$	$1 \cdot 0.288 \cdot 0.37 \cdot 18 \cdot 3.75^2/2=$	13.5kN	1.875 m	25.3 kNm
	Vertical Force (V):	147.6 kN	$M_{V;}$	147.0 kNm

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

			<u>Lever Arm</u>	<u>Moment</u>
Surcharge Load;				
$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret};$	$0.288 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 3.75=$	15.1 kN	1.875 m	28.2 kNm
Active Pressure;				
$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2/2;$	$1.35 \cdot 0.288 \cdot 0.929 \cdot 18 \cdot 3.75^2/2=$	45.7 kN	1.250 m	57.2 kNm
Additional shear load acting at z;				
$F_z=V_z \cdot \gamma_{Vz}$	$0 \cdot 1.5=$	0.0 kN	3.250 m	0.0 kNm
	Horizontal Force (H):	60.8 kN	$M_{H;}$	85.4 kNm
Weight of wall stem;				
$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$	$1 \cdot 3.533 \cdot 0.191 \cdot 25=$	16.9kN	1.780 m	30.0 kNm
Weight of base;				
$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$	$1 \cdot 1.875 \cdot 0.217 \cdot 25=$	10.2kN	0.938 m	9.5 kNm
Friction on virtual Back of wall;				
$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2/2;$	$1 \cdot 0.288 \cdot 0.37 \cdot 18 \cdot 3.75^2/2=$	13.5kN	1.875 m	25.3 kNm
	Vertical Force (V):	40.5 kN	$M_{V;}$	64.8 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;				
$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}-(90-\alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2/2;$	$1.35 \cdot 0.564 \cdot 0.912 \cdot 18 \cdot 4.722^2/2=$	139.3kN	1.574 m	219.3 kNm
Additional Point Load				
$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.94=$	-10.4kN	3.750 m	-38.8 kNm
Additional shear load acting at z;				
$F_z=V_z \cdot \gamma_{Vz}$	$0 \cdot 1.5=$	0.0 kN	3.250 m	0.0 kNm
	Horizontal Force (H):	129.0 kN	$M_{H;}$	180.5 kNm
Weight of wall stem;				
$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem};$	$1 \cdot 3.533 \cdot 0.191 \cdot 25=$	16.9kN	0.096 m	1.6 kNm
Weight of base;				
$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base};$	$1 \cdot 1.875 \cdot 0.217 \cdot 25=$	10.2kN	0.938 m	9.5 kNm
Retained Soil;				
$F_{ret}=\gamma_{Gf} \cdot ((h_{ret}-t_{base})+(L_{toe} \cdot \tan(\beta)/2)) \cdot L_{toe} \cdot \gamma_{mr};$	$1 \cdot (3.533+(1.684 \cdot 0.577/2)) \cdot 1.684 \cdot 18=$	121.8kN	1.033 m	125.8 kNm
Friction on virtual Back of wall;				
$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2/2;$	$1 \cdot 0.564 \cdot 0.37 \cdot 18 \cdot 4.722^2/2=$	41.8kN	1.875 m	78.5 kNm
	Vertical Force (V):	190.7 kN	$M_{V;}$	215.5 kNm

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;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_G \cdot \text{Surcharge}_G \cdot h_{ret}; \quad 0.288 \cdot 0.912 \cdot 1.5 \cdot 10 \cdot 3.75 = 14.8 \text{ kN} \quad 1.875 \text{ m} \quad 27.7 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.288 \cdot 0.912 \cdot 18 \cdot 3.75^2 / 2 = 44.9 \text{ kN} \quad 1.250 \text{ m} \quad 56.1 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 3.250 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 59.6 \text{ kN} \quad M_H: \quad 83.8 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 3.533 \cdot 0.191 \cdot 25 = 16.9 \text{ kN} \quad 0.096 \text{ m} \quad 1.6 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.875 \cdot 0.217 \cdot 25 = 10.2 \text{ kN} \quad 0.938 \text{ m} \quad 9.5 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot (h_{ret} - t_{base}) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot 3.533 \cdot 1.684 \cdot 18 = 107.1 \text{ kN} \quad 1.033 \text{ m} \quad 110.6 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.288 \cdot 0.37 \cdot 18 \cdot 3.75^2 / 2 = 13.5 \text{ kN} \quad 1.875 \text{ m} \quad 25.3 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 147.6 \text{ kN} \quad M_V: \quad 147.0 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_G \cdot \text{Surcharge}_G \cdot h_{ret}; \quad 0.288 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 3.75 = 15.1 \text{ kN} \quad 1.875 \text{ m} \quad 28.2 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.288 \cdot 0.929 \cdot 18 \cdot 3.75^2 / 2 = 45.7 \text{ kN} \quad 1.250 \text{ m} \quad 57.2 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 3.250 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 60.8 \text{ kN} \quad M_H: \quad 85.4 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 3.533 \cdot 0.191 \cdot 25 = 16.9 \text{ kN} \quad 1.780 \text{ m} \quad 30.0 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.875 \cdot 0.217 \cdot 25 = 10.2 \text{ kN} \quad 0.938 \text{ m} \quad 9.5 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.288 \cdot 0.37 \cdot 18 \cdot 3.75^2 / 2 = 13.5 \text{ kN} \quad 1.875 \text{ m} \quad 25.3 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 40.5 \text{ kN} \quad M_V: \quad 64.8 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1.35 \cdot 0.564 \cdot 0.912 \cdot 18 \cdot 4.722^2 / 2 = 139.3 \text{ kN} \quad 1.574 \text{ m} \quad 219.3 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_{Gf} \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.94 = -10.4 \text{ kN} \quad 3.750 \text{ m} \quad -38.8 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 3.250 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 129.0 \text{ kN} \quad M_H: \quad 180.5 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 3.533 \cdot 0.191 \cdot 25 = 16.9 \text{ kN} \quad 0.096 \text{ m} \quad 1.6 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.875 \cdot 0.217 \cdot 25 = 10.2 \text{ kN} \quad 0.938 \text{ m} \quad 9.5 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot ((h_{ret} - t_{base}) + (L_{toe} \cdot \tan(\beta) / 2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot (3.533 + (1.684 \cdot 0.577 / 2)) \cdot 1.684 \cdot 18 = 121.8 \text{ kN} \quad 1.033 \text{ m} \quad 125.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1 \cdot 0.564 \cdot 0.37 \cdot 18 \cdot 4.722^2 / 2 = 41.8 \text{ kN} \quad 1.875 \text{ m} \quad 78.5 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 190.7 \text{ kN} \quad M_V: \quad 215.5 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$F_{\text{ref},h} = Y_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot Y_{mr} \cdot h_{\text{eff}1}^2 / 2;$ $1 \cdot 0.885 \cdot 0.938 \cdot 18 \cdot 4.608^2 / 2 =$ 158.7kN 1.536 m 243.8 kNm

Additional Point Load

$F_{x,h} = Y_G \cdot Y_{mr} \cdot \sin(\phi' \cdot r \cdot d) \cdot \cos(\phi' \cdot r \cdot d) \cdot A;$ $1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 1.207 =$ 8.8kN 3.750 m 33.0 kNm

Additional shear load acting at z;

$F_z = V_z \cdot Y_{Vz}$ $0 \cdot 1.3 =$ 0.0 kN 3.250 m 0.0 kNm

Horizontal Force (H): 167.5 kN $M_H;$ 276.7 kNm

Weight of wall stem;

$F_{\text{stem}} = Y_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot Y_{\text{stem}};$ $1 \cdot 3.533 \cdot 0.191 \cdot 25 =$ 16.9kN 0.096 m 1.6 kNm

Weight of base;

$F_{\text{base}} = Y_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot Y_{\text{base}};$ $1 \cdot 1.875 \cdot 0.217 \cdot 25 =$ 10.2kN 0.938 m 9.5 kNm

Retained Soil;

$F_{\text{ret}} = Y_{Gf} \cdot ((h_{\text{ret}} \cdot t_{\text{base}}) + (L_{\text{toe}} \cdot \tan(\beta) / 2)) \cdot L_{\text{toe}} \cdot Y_{mr};$ $1 \cdot (3.533 + (1.684 \cdot 0.577 / 2)) \cdot 1.684 \cdot 18 =$ 121.8kN 1.033 m 125.8 kNm

Friction on virtual Back of wall;

$F_{\text{wall friction}} = Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{\text{eff}1}^2 / 2;$ $1 \cdot 0.885 \cdot 0.303 \cdot 18 \cdot 4.608^2 / 2 =$ 51.3kN 1.875 m 96.2 kNm

Vertical Force (V): 200.2 kN $M_V;$ 233.2 kNm

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

Lever Arm Moment

Active Pressure;

$F_{\text{ref},h} = Y_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot Y_{mr} \cdot h_{\text{eff}2}^2 / 2;$ $1 \cdot 0.885 \cdot 0.953 \cdot 18 \cdot 3.75^2 / 2 =$ 106.7kN 1.250 m 133.4 kNm

Additional Point Load

$F_{x,h} = Y_G \cdot Y_{mr} \cdot \sin(\phi' \cdot r \cdot d) \cdot \cos(\phi' \cdot r \cdot d) \cdot A;$ $1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.402 =$ 2.9kN 3.750 m 11.0 kNm

Additional shear load acting at z;

$F_z = V_z \cdot Y_{Vz}$ $0 \cdot 1.3 =$ 0.0 kN 3.250 m 0.0 kNm

Horizontal Force (H): 109.7 kN $M_H;$ 144.4 kNm

Weight of wall stem;

$F_{\text{stem}} = Y_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot Y_{\text{stem}};$ $1 \cdot 3.533 \cdot 0.191 \cdot 25 =$ 16.9kN 1.780 m 30.0 kNm

Weight of base;

$F_{\text{base}} = Y_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot Y_{\text{base}};$ $1 \cdot 1.875 \cdot 0.217 \cdot 25 =$ 10.2kN 0.938 m 9.5 kNm

Friction on virtual Back of wall;

$F_{\text{wall friction}} = Y_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot Y_{mr} \cdot h_{\text{eff}2}^2 / 2;$ $1 \cdot 0.885 \cdot 0.303 \cdot 18 \cdot 3.75^2 / 2 =$ 34.0kN 1.875 m 63.7 kNm

Vertical Force (V): 61.0 kN $M_V;$ 103.3 kNm

2.4 Summary of forces and moments on wall

Equilibrium	H	M_H	V	$M_V;$
A: LC1 - Backfill to rear:	57.1 kN	81.6 kNm	133.0 KN	132.6 kNm
B: LC1 - Backfill to front:	58.1 kN	83.1 kNm	36.6 KN	58.6 kNm
C: LC2 - Backfill to rear:	174.2 kN	274.2 kNm	186.5 KN	221.7 kN
D: LC2 - Backfill to front:	111.8 kN	139.8 kNm	57.4 KN	97.6 kN
Combination 1	H	M_H	V	$M_V;$
A: LC1 - Backfill to rear:	59.6 kN	83.8 kNm	147.6 KN	147.0 kNm
B: LC1 - Backfill to front:	60.8 kN	85.4 kNm	40.5 KN	64.8 kNm
C: LC2 - Backfill to rear:	129.0 kN	180.5 kNm	190.7 KN	215.5 kN
D: LC2 - Backfill to front:	86.4 kN	100.2 kNm	53.4 KN	89.0 kN
Combination 2	H	M_H	V	$M_V;$
A: LC1 - Backfill to rear:	58.1 kN	82.7 kNm	147.7 KN	147.2 kNm
B: LC1 - Backfill to front:	59.0 kN	84.0 kNm	40.6 KN	65.0 kNm
C: LC2 - Backfill to rear:	167.5 kN	276.7 kNm	200.2 KN	233.2 kN
D: LC2 - Backfill to front:	109.7 kN	144.4 kNm	61.0 KN	103.3 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:	3.9 kN 0.93 ULS Ratio	0.6 kN 0.99 ULS Ratio	0.0 kN 1.02 ULS Ratio
	LC1 - Backfill to front:	43.5 kN 0.25 ULS Ratio	44.6 kN 0.27 ULS Ratio	42.7 kN 0.28 ULS Ratio
	LC2 - Backfill to rear:	99.7 kN 0.43 ULS Ratio	52.7 kN 0.59 ULS Ratio	87.4 kN 0.48 ULS Ratio
	LC2 - Backfill to front	88.8 kN 0.21 ULS Ratio	65.0 kN 0.25 ULS Ratio	85.2 kN 0.22 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:	50.9 kNm 1.62 ULS Ratio	63.3 kNm 1.76 ULS Ratio	64.5 kNm 1.78 ULS Ratio
	LC1 - Backfill to front:	-24.5 kNm 0.71 ULS Ratio	-20.5 kNm 0.76 ULS Ratio	-19.0 kNm 0.77 ULS Ratio
	LC2 - Backfill to rear:	-52.6 kNm 0.81 ULS Ratio	35.0 kNm 1.19 ULS Ratio	-43.5 kNm 0.84 ULS Ratio
	LC2 - Backfill to front	-42.1 kNm 0.70 ULS Ratio	-11.1 kNm 0.89 ULS Ratio	-41.1 kNm 0.72 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; 99.7 kN/m - Loading condition 2 (Backfill to the rear)
Vertical load; 186.5 kN/m - Loading condition 2 (Backfill to the rear)
Resultant destabilising moment; 52.6 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; 87.4 kN/m - Combination 2 with loading condition 2 (Backfill to the rear)
Resultant anti-clockwise destabilising moment; 43.5 kNm/m - Combination 2 with loading condition 2 (Backfill to the rear)
Resultant clockwise destabilising moment; 41.1 kNm/m - Combination 2 with loading condition 2 (Backfill to the front)

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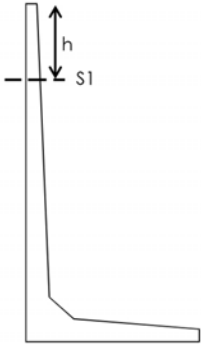
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3.1 Analysis Height 1

Analysis height 1 (S1)	700 mm
Soil depth at S1	700 mm



Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.562m	0.664m
Property B	0.325m	0.383m
Property C	0.358m	0.338m
Property D	-0.028m	0.040m
Property E	-0.052m	0.065m
Property F	-0.018m	0.020m
Area of Soil (A)	-0.010 m²	0.014 m²

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.912 \cdot 1.5 \cdot 10 \cdot 0.7 =$	2.8 kN	0.350 m	1.0 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.288 \cdot 0.912 \cdot 18 \cdot 0.7^2 / 2 =$	1.6 kN	0.233 m	0.4 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.200 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):			4.3 kN	$M_H:$	1.3 kNm

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.7 =$	2.8 kN	0.350 m	1.0 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.288 \cdot 0.929 \cdot 18 \cdot 0.7^2 / 2 =$	1.6 kN	0.233 m	0.4 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.200 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):			4.4 kN	$M_H:$	1.4 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.912 \cdot 18 \cdot 0.7^2 / 2 =$	3.1kN	0.233 m	0.7 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.01 =$	-0.1kN	0.700 m	-0.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.200 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):			3.0 kN	$M_H:$	0.6 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.929 \cdot 18 \cdot 0.7^2 / 2 =$	3.1kN	0.233 m	0.7 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.01 =$	-0.1kN	0.700 m	-0.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.200 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):			3.0 kN	$M_H:$	0.7 kNm

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.938 \cdot 1.3 \cdot 10 \cdot 0.7 =$	3.0 kN	0.350 m	1.1 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.353 \cdot 0.938 \cdot 18 \cdot 0.7^2 / 2 =$	1.5 kN	0.233 m	0.3 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.200 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):			4.5 kN	$M_H:$	1.4 kNm

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.7 =$	3.1 kN	0.350 m	1.1 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.353 \cdot 0.953 \cdot 18 \cdot 0.7^2 / 2 =$	1.5 kN	0.233 m	0.3 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.200 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):			4.5 kN	$M_H:$	1.4 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.938 \cdot 18 \cdot 0.7^2 / 2 =$	3.7kN	0.233 m	0.9 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.014 =$	0.1kN	0.700 m	0.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.200 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):			3.8 kN	$M_H:$	0.9 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.953 \cdot 18 \cdot 0.7^2 / 2 =$	3.7kN	0.233 m	0.9 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.014 =$	0.1kN	0.700 m	0.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.200 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):			3.8 kN	$M_H:$	0.9 kNm

3750mm Standard L-Wall
with Standard Design Parameters

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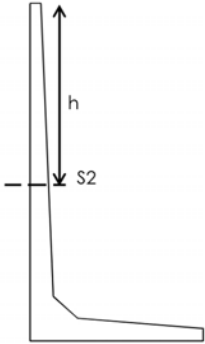
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3.2 Analysis Height 2

Analysis height 2 (S2)	2610 mm
Soil depth at S2	2610 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	2.096m	2.475m
Property B	1.210m	1.429m
Property C	1.335m	1.261m
Property D	-0.106m	0.149m
Property E	-0.192m	0.244m
Property F	-0.067m	0.076m
Area of Soil (A)	-0.138 m²	0.195 m²



Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 1) (A)				Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.912 \cdot 1.5 \cdot 10 \cdot 2.61 =$	10.3 kN	1.305 m	13.4 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.288 \cdot 0.912 \cdot 18 \cdot 2.61^2 / 2 =$	21.7 kN	0.870 m	18.9 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.110 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):				M_{H_i}	32.3 kNm
Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 1) (B)				Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 2.61 =$	10.5 kN	1.305 m	13.7 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.288 \cdot 0.929 \cdot 18 \cdot 2.61^2 / 2 =$	22.1 kN	0.870 m	19.3 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.110 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):				M_{H_i}	32.9 kNm
Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 1) (C)				Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.912 \cdot 18 \cdot 2.61^2 / 2 =$	42.6kN	0.870 m	37.0 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.138 =$	-1.5kN	2.610 m	-4.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.110 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):				M_{H_i}	33.1 kNm
Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 1) (D)				Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.929 \cdot 18 \cdot 2.61^2 / 2 =$	43.4kN	0.870 m	37.7 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.138 =$	-1.5kN	2.610 m	-4.0 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.110 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):				M_{H_i}	33.8 kNm
Loading condition 1 -Backfill to rear of wall with level fill and surcharge (combination 2) (A)				Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.938 \cdot 1.3 \cdot 10 \cdot 2.61 =$	11.2 kN	1.305 m	14.7 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.353 \cdot 0.938 \cdot 18 \cdot 2.61^2 / 2 =$	20.3 kN	0.870 m	17.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.110 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):				M_{H_i}	32.3 kNm
Loading condition 1 -Backfill to front of wall with level fill and surcharge (combination 2) (B)				Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 2.61 =$	11.4 kN	1.305 m	14.9 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.353 \cdot 0.953 \cdot 18 \cdot 2.61^2 / 2 =$	20.6 kN	0.870 m	17.9 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.110 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):				M_{H_i}	32.8 kNm
Loading condition 2 - Backfill to rear of wall with sloped fill and without surcharge (combination 2) (C)				Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.938 \cdot 18 \cdot 2.61^2 / 2 =$	50.9kN	0.870 m	44.3 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.195 =$	1.4kN	2.610 m	3.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.110 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):				M_{H_i}	48.0 kNm
Loading condition 2 - Backfill to front of wall with sloped fill and without surcharge (combination 2) (D)				Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.953 \cdot 18 \cdot 2.61^2 / 2 =$	51.7kN	0.870 m	45.0 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.195 =$	1.4kN	2.610 m	3.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.110 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):				M_{H_i}	48.7 kNm

3750mm Standard L-Wall
with Standard Design Parameters

REV: 0

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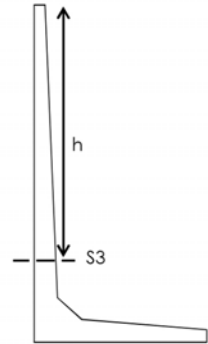
CHK: C.B.

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3.3 Analysis Height 3

Analysis height 3 (S3) 3250 mm
Soil depth at S3 3250 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	2.610m	3.081m
Property B	1.507m	1.779m
Property C	1.662m	1.570m
Property D	-0.131m	0.186m
Property E	-0.240m	0.303m
Property F	-0.084m	0.095m
Area of Soil (A)	-0.214 m ²	0.302 m ²



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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.912 \cdot 1.5 \cdot 10 \cdot 3.25=$	12.8 kN	1.625 m	20.8 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma_{mr} \cdot h^2/2;$	$1.35 \cdot 0.288 \cdot 0.912 \cdot 18 \cdot 3.25^2/2=$	33.7 kN	1.083 m	36.5 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	2.750 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):	46.5 kN	$M_H;$ 57.3 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 3.25=$	13.0 kN	1.625 m	21.2 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma mr \cdot h^2/2;$	$1.35 \cdot 0.288 \cdot 0.929 \cdot 18 \cdot 3.25^2/2=$	34.3 kN	1.083 m	37.2 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	2.750 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):	47.4 kN	$M_H;$ 58.4 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma_{mr} \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.912 \cdot 18 \cdot 3.25^2 / 2 =$	66.0kN	1.083 m	71.5 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma_{mr} \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.214 =$	-2.4kN	3.250 m	-7.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.750 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):	63.6 kN	$M_H;$ 63.8 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma_{mr} \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.929 \cdot 18 \cdot 3.25^2 / 2 =$	67.3kN	1.083 m	72.9 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma_{mr} \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.214 =$	-2.4kN	3.250 m	-7.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	2.750 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):	64.9 kN	$M_H;$ 65.2 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.938 \cdot 1.3 \cdot 10 \cdot 3.25=$	14.0 kN	1.625 m	22.7 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma_{mr} \cdot h^2/2;$	$1 \cdot 0.353 \cdot 0.938 \cdot 18 \cdot 3.25^2/2=$	31.5 kN	1.083 m	34.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	2.750 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):	45.5 kN	$M_H;$ 56.9 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 3.25=$	14.2 kN	1.625 m	23.1 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma_{mr} \cdot h^2/2;$	$1 \cdot 0.353 \cdot 0.953 \cdot 18 \cdot 3.25^2/2=$	32.0 kN	1.083 m	34.6 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	2.750 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):	46.2 kN	$M_H;$ 57.7 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma_{mr} \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.938 \cdot 18 \cdot 3.25^2 / 2 =$	78.9kN	1.083 m	85.5 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma_{mr} \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.302 =$	2.2kN	3.250 m	7.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.750 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):	81.1 kN	$M_H;$ 92.7 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\phi_r.d) \cdot \gamma_{mr} \cdot h^2/2;$	$1 \cdot 0.885 \cdot 0.953 \cdot 18 \cdot 3.25^2/2 =$	80.2kN	1.083 m	86.8 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma_{mr} \cdot \sin(\phi_r.d) \cdot \cos(\phi_r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.302 =$	2.2kN	3.250 m	7.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	2.750 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):	82.4 kN	$M_H;$ 94.0 kNm

3750mm Standard L-Wall
with Standard Design Parameters

REV: 0

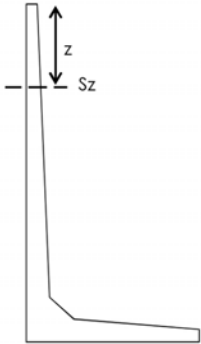
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3.3 Analysis Height Z

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 m²	0.007 m²

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.912 \cdot 1.5 \cdot 10 \cdot 0.5 =$	2.0 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.288 \cdot 0.912 \cdot 18 \cdot 0.5^2 / 2 =$	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):			2.8 kN	M_{H_i}	0.6 kNm

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.288 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.5 =$	2.0 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.288 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	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):			2.8 kN	M_{H_i}	0.6 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.912 \cdot 18 \cdot 0.5^2 / 2 =$	1.6kN	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_i}	0.2 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.564 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	1.6kN	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_i}	0.2 kNm

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.938 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.2 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.353 \cdot 0.938 \cdot 18 \cdot 0.5^2 / 2 =$	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):			2.9 kN	M_{H_i}	0.7 kNm

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

Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.353 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.2 kN	0.250 m	0.5 kNm
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.353 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m	0.1 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	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):			2.9 kN	M_{H_i}	0.7 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.938 \cdot 18 \cdot 0.5^2 / 2 =$	1.9kN	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_i}	0.3 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.885 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	1.9kN	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_i}	0.3 kNm

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 @ 700		Analysis 2 @ 2610		Analysis 3 @ 3250		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Rear level fill & surcharge (A)	4.3 kN	1.3 kNm	32.0 kN	32.3 kNm	46.5 kN	57.3 kNm	2.8 kN	0.6 kNm
Front level fill & surcharge (B)	4.4 kN	1.4 kNm	32.6 kN	32.9 kNm	47.4 kN	58.4 kNm	2.8 kN	0.6 kNm
Rear sloped fill without surcharge (C)	3.0 kN	0.6 kNm	41.0 kN	33.1 kNm	63.6 kN	63.8 kNm	1.5 kN	0.2 kNm
Front sloped fill without surcharge (D)	3.0 kN	0.7 kNm	41.9 kN	33.8 kNm	64.9 kN	65.2 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)	4.5 kN	1.4 kNm	31.5 kN	32.3 kNm	45.5 kN	56.9 kNm	2.9 kN	0.7 kNm
Front level fill & surcharge (B)	4.5 kN	1.4 kNm	32.0 kN	32.8 kNm	46.2 kN	57.7 kNm	2.9 kN	0.7 kNm
Rear sloped fill without surcharge (C)	3.8 kN	0.9 kNm	52.3 kN	48.0 kNm	81.1 kN	92.7 kNm	1.9 kN	0.3 kNm
Front sloped fill without surcharge (D)	3.8 kN	0.9 kNm	53.1 kN	48.7 kNm	82.4 kN	94.0 kNm	1.9 kN	0.3 kNm

Back face is in tension values	Analysis 1 @ 700		Analysis 2 @ 2610		Analysis 3 @ 3250		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	4.5 kN	0.9 kNm	52.3 kN	48.0 kNm	81.1 kN	92.7 kNm	1.9 kN	0.3 kNm

Front face is in tension values	Analysis 1 @ 700		Analysis 2 @ 2610		Analysis 3 @ 3250		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	4.5 kN	1.4 kNm	53.1 kN	48.7 kNm	82.4 kN	94.0 kNm	2.9 kN	0.7 kNm

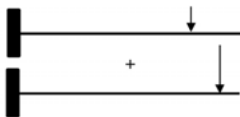
4.0 Wall Base Design

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

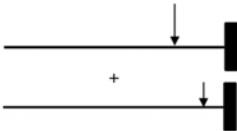
Analysis length 1 (B1)	500 mm
Analysis length 2 (B2)	1070 mm
Analysis length 3 (B3)	1825 mm

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

$M=FS1 \cdot lb1$

Forces in two row anchor system

$M=FS1 \cdot Lb1+FS2 \cdot lb2$ (1)

$FS1/LB1=FS2/lb2$ (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

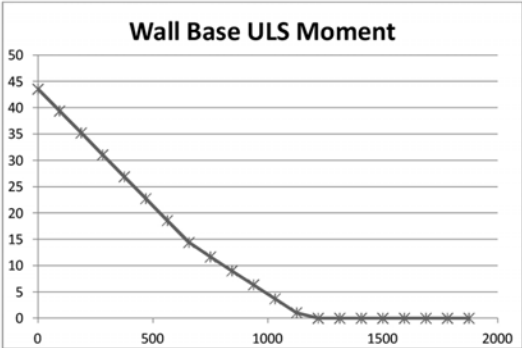
Maximum overturning moment	43.5 KNm
Lever arm to closest anchor (lb1)	662 mm (First Row)
Lever arm to furthest anchor (lb2)	1162mm (Second Row)

From the above equations:

Tension force in closest anchors (FS1)= 16.1 kN (First Row)

Tension force in furthest anchors (FS2)= 28.3 kN (Second Row)

X:	500mm	1070mm	1825mm
Tension Moment Top face:	21.3 kNm	2.6 kNm	0.0 kNm
Shear:	44.4 kN	28.3 kN	0.0 kN



4.2 Anchored Clockwise Rotation

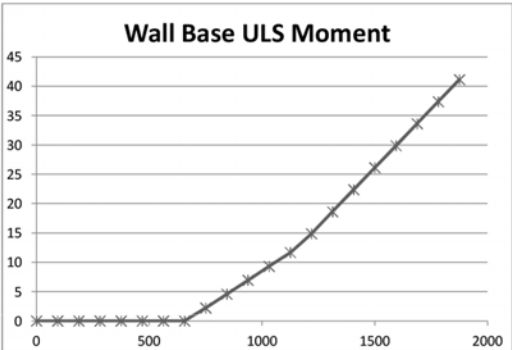
Maximum overturning moment	41.1 KNm
Lever arm to closest anchor (lb1)	713 mm (Second Row)
Lever arm to furthest anchor (lb2)	1213mm (First Row)

From the above equations:

Tension force in closest anchors (FS1)= 14.8 kN (Second Row)

Tension force in furthest anchors (FS2)= 25.2 kN (First Row)

X:	500mm	1070mm	1825mm
Tension Moment Top face:	0.0 kNm	10.3 kNm	39.1 kNm
Shear:	0.0 kN	25.2 kN	40.0 kN

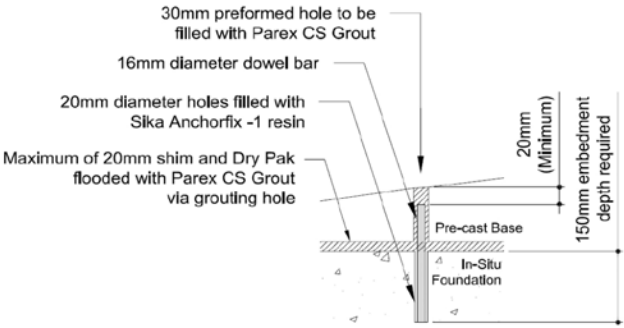


5.0 Anchor Design

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/mm ²
Dowel bar diameter(ϕ)	16 mm
Height of Shims	20 mm
Standard Embedment Length	150 mm
First Row: Dowel Bar Length (D_L)	325 mm
First Row: Effective Depth In Precast (h_{eff1}):	155 mm
First Row: Effective Depth In Foundation (h_{eff2}):	150 mm
Second Row: Dowel Bar Length (D_L)	325 mm
Second Row: Effective Depth In Precast (h_{eff1}):	155 mm
Second Row: Effective Depth In Foundation (h_{eff2}):	150 mm

Partial safety factor grout (γ_{grout})	3
Partial safety factor resin (γ_{resin})	3



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 resistace;
 $f_{bm}=N_{u,m}/A;$ 92.8/7540= 12.3 N/mm2

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
$N = \text{Max}(\text{Clockwise Force, Anticlockwise Force})/\text{No.}$	$\text{Max}\{16.1,25.2\}/3= 8.4 \text{ kN}$	$\text{Max}\{28.3,14.8\}/3= 9.4 \text{ kN}$

5.1.1.1 Steel Failure

Area of steel;
 $A_s=\pi \bullet \phi^2/4;$ $\pi \bullet 16^2/4= 201 \text{ mm}^2$
Characteristic resistance of an anchor in the case of steel failure;
 $N_{Rk,s}=A_s \bullet f_{uk};$ $201 \bullet 550/1000= 110.6 \text{ kN}$
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
$\beta_N=N/N_{Rd,s}$	$8.4/96.1= 0.09$	$9.4/96.1= 0.10$

3750mm Standard L-Wall with Standard Design Parameters	REV: 0		
	BY: S.J.H	CHK: C.B.	SHEET: 16 of 20

5.1.1.2 Pull-Out Failure to Pre-Cast Base

Characteristic resistance to pull-out;	<u>First Row</u>	<u>Second Row</u>
$N_{Rk,p}=\pi \cdot \varphi \cdot H_{eff1} \cdot f_{bm}$	$\pi \cdot 16 \cdot 155 \cdot 12.3= 95.8kN$	$\pi \cdot 16 \cdot 155 \cdot 12.3= 95.8kN$
Design tension capacity of anchorage;		
$N_{Rd,p}=N_{Rk,p}/\gamma_{grout};$	$95.8/3= 31.9kN$	$95.8/3= 31.9kN$
Ratio between design action and design resistance		
$\beta_N=N/N_{Rd,s}$	$8.4/31.9= 0.26$	$9.4/31.9= 0.29$

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;	
$V=Max\ Shear\ Force/No.\ Dowels$	$87.4/(3 \cdot 2)= 14.6kN$

5.1.2.1 Steel Failure, Shear Load without Lever Arm

Area of steel;	
$A_s=\pi \cdot \varphi^2/4;$	$\pi \cdot 16^2/4= 201\text{ mm}^2$
Characteristic resistance of an anchor in the case of steel failure;	
$V_{Rk,s}=0.5 \cdot A_s \cdot f_{uk};$	$0.5 \cdot 201 \cdot 550/1000= 55.3\text{ kN}$
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	<u>First Row</u>
$\beta_v=V/V_{Rd,s}$	$14.6/48.1= 0.30$

5.1.3 Resistance to combined tension and shear loads

	<u>First Row</u>	<u>Second Row</u>
$(N_{ED}/N_{RD,Dowel})^{1.5}+(V_{Ed}/V_{Rd,dowel})^{1.5} < 1.0;$	0.19	0.20
$(N_{ED}/N_{RD})^{1.5}+(V_{Ed}/V_{Rd})^{1.5} < 1.0;$	0.30	0.33
$(N_{ED}/N_{RD})+(V_{Ed}/V_{Rd}) < 1.2;$	0.57	0.60

5.1 Anchorage in Foundation

From Sika Technical information - Characteristic resistance to pull-out of deformed bar;		
$N_{Rk,p}=30kN$		30.0kN
Design tension capacity of anchorage;		
$N_{Rd,p}=N_{Rk,p}/\gamma_{resin};$		30/3= 10.0kN
Ratio between design action and design resistance		<u>First Row</u>
$\beta_N=N/N_{Rd,s}$		8.4/10= 0.84

Anchorage provided is adequate

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	142.8571429	1407
Bar Mark 2	16.00	142.8571429	1407
Bar Mark 3	16.00	142.8571429	1407

6.1 Section Analysis

Analysis height 1 (700mm)

Depth @ S1 (hS1)	141 mm
hS1 - Depth to rein' (d1)	53 mm

	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1407	88	0	0
Front face in tension	1407	53	0	0

Analysis height 2 (2610mm)

Depth @ S2 (hS2)	226 mm
hS2 - Depth to rein' (d1)	53 mm
hS2 - Depth to rein' (d2)	173 mm

	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1407	173	1407	53
Front face in tension	1407	173	1407	53

Analysis height 3 (3250mm)

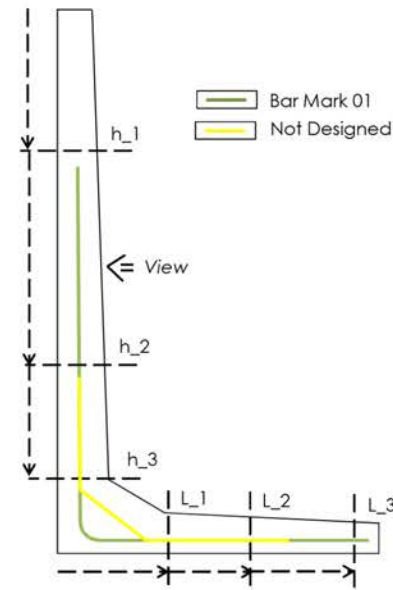
Depth @ S3 (hS3)	255 mm
hS3 - Depth to rein' (d1)	53 mm
hS3 - Depth to rein' (d2)	202 mm
hS3 - Depth to rein' (d3)	202 mm

	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1407	202	2815	53
Front face in tension	2815	202	1407	53

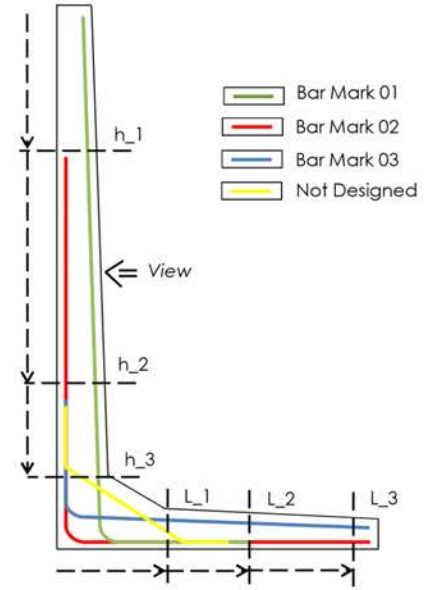
Analysis height z (500mm)

Depth @ Sz (hSz)	132 mm
Depth to rein' (d1)	44 mm

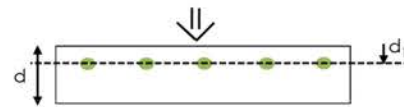
	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	1407	88	0	0
Front face in tension	1407	44	0	0



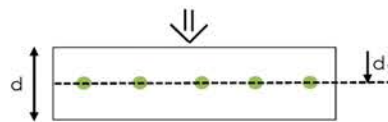
Type 1: Cage Arrangement 1000mm & 1500mm



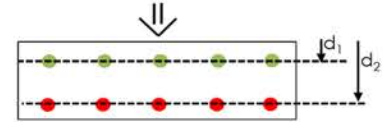
Type 2: Cage Arrangement 1750mm & Above



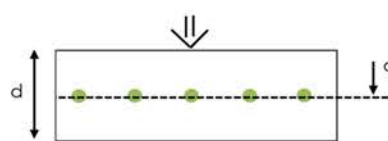
Configuration Type 1 & 2



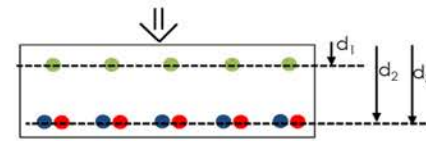
Configuration Type 1



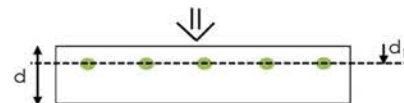
Configuration Type 2



Configuration Type 1



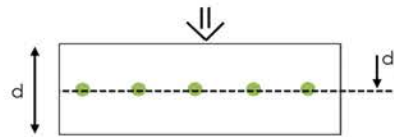
Configuration Type 2



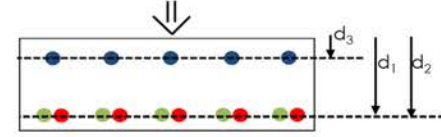
Configuration Type 1 & 2

Analysis length 1 (500mm)

Depth @ B1 (hB1)	255 mm
hB1 - Depth to rein' (d1)	202 mm
hB1 - Depth to rein' (d2)	202 mm
hB1 - Depth to rein' (d3)	53 mm



Configuration Type 1

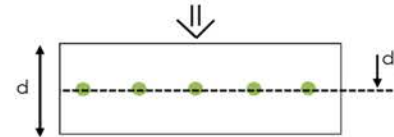


Configuration Type 2

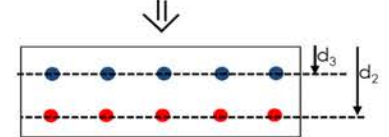
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	1407	202	2815	53
Bottom face in tension	2815	202	1407	53

Analysis length 2 (1070mm)

Depth @ B2 (hB2)	205 mm
hB2 - Depth to rein' (d1)	0 mm
hB2 - Depth to rein' (d2)	152 mm
hB2 - Depth to rein' (d3)	53 mm



Configuration Type 1

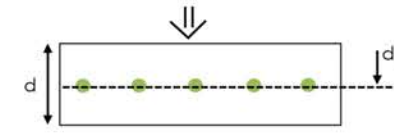


Configuration Type 2

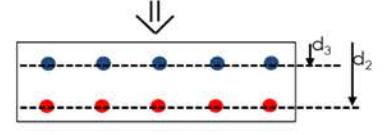
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	1407	152	1407	53
Bottom face in tension	1407	152	1407	53

Analysis length 3 (1825mm)

Depth @ B3 (hB3)	139 mm
hB3 - Depth to rein' (d1)	0 mm
hB3 - Depth to rein' (d2)	86 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	1407	86	1407	53
Bottom face in tension	1407	86	1407	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

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

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

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

6.3 Stem Reinforcement Design

	Back face in Tension			
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	45.3 kNm	94.9 kNm	111.4 kNm	45.3 kNm
Design Bending Moment	0.9 kNm	48.0 kNm	92.7 kNm	0.3 kNm
Area of tension reinforcement provided	1407 mm²	1407 mm²	1407 mm²	1407 mm²
Area of compression reinforcement provided	0 mm²	1407 mm²	2815 mm²	0 mm²
Effective depth to tension rein' (d _{n1})=d-Δc;	78 mm	163 mm	192 mm	78 mm
K Factor =M/(b•d _{n1} ² •f _{ck});	0.003	0.040	0.056	0.001
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)));	74 mm	155 mm	182 mm	74 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	29 mm²	712 mm²	1171 mm²	10 mm²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	155 mm²	323 mm²	379 mm²	155 mm²
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})	155 mm²	712 mm²	1171 mm²	155 mm²
Compression reinforcement required at section (A _{s',req})	0 mm²	0 mm²	0 mm²	0 mm²
	Pass (9)	Pass (1.9)	Pass (1.2)	Pass (9)
Shear				
Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm²	0.1N/mm²	0.1N/mm²	0.1N/mm²
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});	0.0180	0.0090	0.0070	0.0180
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	52.0 kN	108.5 kN	127.5 kN	52.0 kN
Shear resistance (V _{Rd,c,1}) = max(V _{Rd,c,min} ,C _{Rd,c} •k•(100•ρ ₁ •(f _{ck} /1)))0.333•b•d _{n1} ;	81.1 kN	134.5 kN	145.4 kN	81.1 kN
Shear resistance required (V)	4.5 kN	52.3 kN	81.1 kN	1.9 kN
	Pass (9.9)	Pass (2.5)	Pass (1.7)	Pass (9.9)
Front face in Tension				
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	25.1 kNm	94.9 kNm	222.9 kNm	19.6 kNm
Design Bending Moment	1.4 kNm	48.7 kNm	94.0 kNm	0.7 kNm
Area of tension reinforcement provided	1407 mm²	1407 mm²	2815 mm²	1407 mm²
Area of compression reinforcement provided	0 mm²	1407 mm²	1407 mm²	0 mm²
Effective depth to tension rein' (d _{n1})=d-Δc;	43 mm	163 mm	192 mm	34 mm
K Factor =M/(b•dn12•f _{ck});	0.017	0.040	0.057	0.013
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	155 mm	182 mm	32 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	78 mm²	722 mm²	1187 mm²	48 mm²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	85 mm²	323 mm²	379 mm²	67 mm²
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})	85 mm²	722 mm²	1187 mm²	67 mm²
Compression reinforcement required at section (A _{s',req})	0 mm²	0 mm²	0 mm²	0 mm²
	Pass (9.9)	Pass (1.9)	Pass (2.3)	Pass (9.9)
Shear				
Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm²	0.1N/mm²	0.1N/mm²	0.1N/mm²
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	108.5 kN	127.5 kN	22.6 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	134.5 kN	187.4 kN	36.6 kN
Shear resistance required (V)	4.5 kN	53.1 kN	82.4 kN	2.9 kN
	Pass (9.9)	Pass (2.5)	Pass (2.2)	Pass (9.9)

6.4 Base Reinforcement Design

	Top face in Tension		
Moment	L_1	L_2	L_3
Moment capacity of section	111.4 kNm	82.7 kNm	39.2 kNm
Design Bending Moment	21.3 kNm	10.3 kNm	39.1 kNm
Area of tension reinforcement provided	1407 mm ²	1407 mm ²	1407 mm ²
Area of compression reinforcement provided	2815 mm ²	1407 mm ²	1407 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	192 mm	142 mm	76 mm
K Factor =M/(b•dn1 ² •fck);	0.013	0.011	0.149
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)));	182 mm	135 mm	64 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	270 mm ²	175 mm ²	1405 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	379 mm ²	281 mm ²	151 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})	379 mm ²	281 mm ²	1405 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (3.7)	Pass (5)	Pass (1)
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	0.0100	0.0180
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	127.5 kN	94.5 kN	50.7 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});	145.4 kN	121.3 kN	79.2 kN
Shear resistance required (V)	44.4 kN	28.3 kN	40.0 kN
	Pass (3.2)	Pass (4.2)	Pass (1.9)

	Bottom face in Tension		
	L_1	L_2	L_3
Moment capacity of section	222.9 kNm	82.7 kNm	44.7 kNm
Design Bending Moment	0.0 kNm	0.0 kNm	0.0 kNm
Area of tension reinforcement provided	2815 mm ²	1407 mm ²	1407 mm ²
Area of compression reinforcement provided	1407 mm ²	1407 mm ²	1407 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	192 mm	142 mm	76 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)));	182 mm	135 mm	73 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} ;	379 mm ²	281 mm ²	151 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})	379 mm ²	281 mm ²	151 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (7.4)	Pass (5)	Pass (9.3)
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	0.0100	0.0180
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	127.5 kN	94.5 kN	50.7 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});	187.4 kN	121.3 kN	79.2 kN
Shear resistance required (V)	44.4 kN	28.3 kN	40.0 kN
	Pass (4.2)	Pass (4.2)	Pass (1.9)

Concrete section is sufficiently reinforced