

Calculations for the Design of Standard 2500mm 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

**2500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

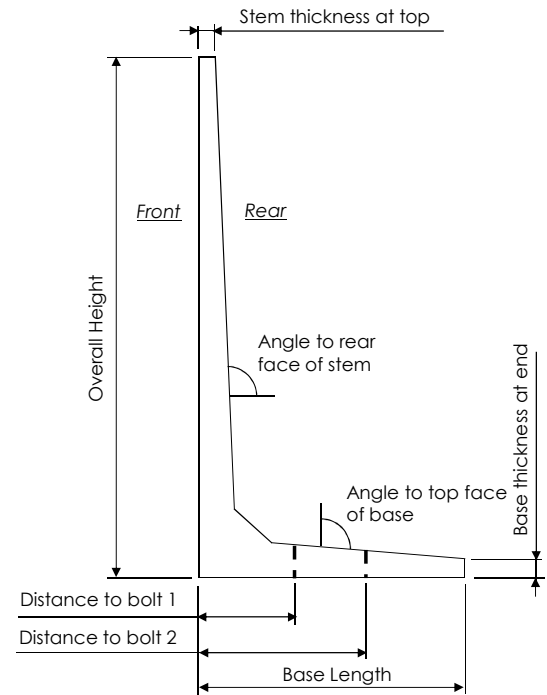
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1.0 Retaining Wall Design

Overall height (h)	2500 mm
Base length (L _{base})	1250 mm
Stem thickness at top (t _{stem_top})	110 mm
Base thickness at end (t _{base_min})	125 mm
Unit width (w _u)	1000 mm
Distance to bolt 1 (from face)	375 mm
Distance to bolt 2 (from face)	875 mm
Number of bolts / row (No.)	2 No.
Angle to rear face of stem (a1)	91.8°
Angle to top face of base (a2)	93.3°
Concrete Density (γ _c)	25.0 kN/m³
Average stem thickness (t _{stem})	148 mm
Average base thickness (t _{base})	161 mm
Stem height (h _{stem})	2339 mm
Toe length (L _{toe})	1102 mm

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

Height of retained soil (h _{ret})	2500 mm
Moist density (γ _{mr})	18.0 kN/m³
Char' eff' shear angle (φ' _{r,k})	32.5°
Char' wall friction angle (δ _{r,k})	21.7°
Angle of soil surface (β)	30.0°
Variable surcharge (Surcharge _G)	10.0 kN/m²



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

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

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

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

Retained Soil Properties based on Coulomb	Equilibrium	Combination 1	Combination 2
Design eff' shear resistance angle (φ' _{r,d});	30.0°	32.5°	27.0°
Design wall friction angle (δ _{r,d});	19.9°	21.7°	17.7°
Level backfill active pressure coefficient (k _a);	0.311	0.283	0.347
Sloped backfill active pressure coefficient (k _a);	0.837	0.552	0.870

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})	3136 mm 2500 mm	3136 mm 2500 mm	3062 mm 2500 mm
Property A	3.81806m 2.165m	3.620m 2.007m	4.076m 2.370m
Property B	2.20436m 1.250m	2.090m 1.159m	2.353m 1.369m
Property C	2.20436m 1.250m	2.306m 1.279m	2.077m 1.208m
Property D	0.00000m 0.000m	-0.182m -0.101m	0.246m 0.143m
Property E	0.00000m 0.000m	-0.332m -0.184m	0.401m 0.233m
Property F	0.00000m 0.000m	-0.116m -0.064m	0.125m 0.073m
Area of Soil (A)	0.000 m² 0.000 m²	-0.411 m² -0.126 m²	0.528 m² 0.179 m²

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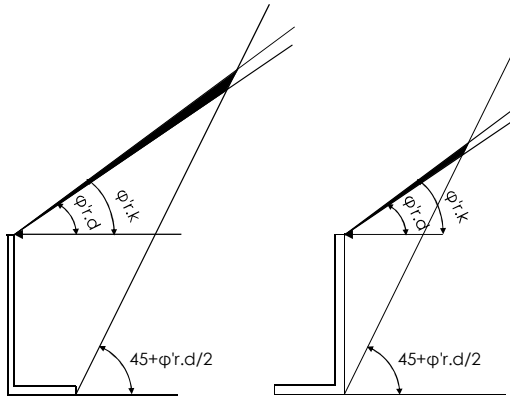
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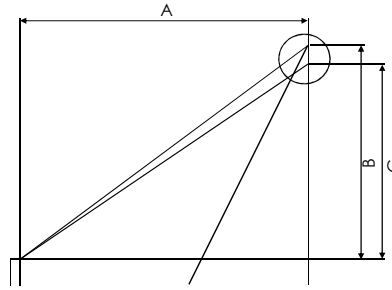
Additional Line Load

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

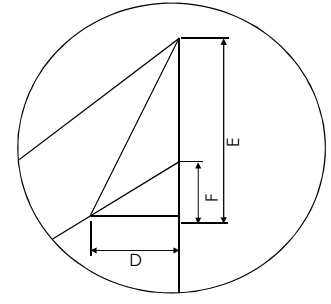


Sketch 1: Line load to rear of retaining wall

Sketch 2: Line load to front of retaining wall



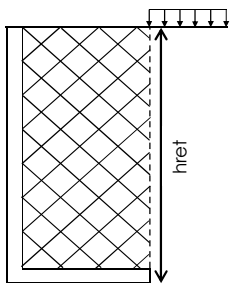
Primary Critical Dimensions



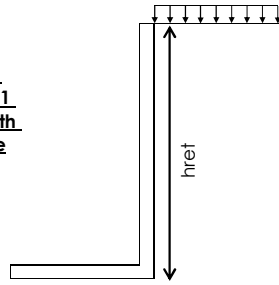
Secondary Critical Dimensions

2.0 Retaining Wall Global Design

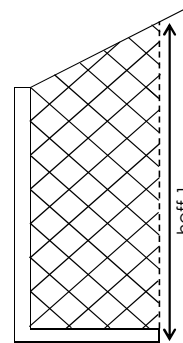
The global design determines a maximum overturning and sliding force on the retaining wall for each of the three combinations (EQU, Comb'1, Comb'2) in the two loading conditions (presented below) applied to the front and the back of the wall. All designs are done on a per/metre run basis.



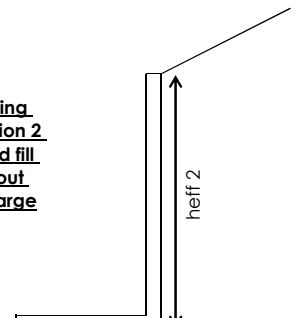
Backfill to rear of wall (A)



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;

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

$$0.311 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 2.5 =$$

$$10.8 \text{ kN}$$

Lever Arm

Moment

$$1.250 \text{ m}$$

$$13.5 \text{ kNm}$$

Active Pressure;

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

$$1.1 \cdot 0.311 \cdot 0.929 \cdot 18 \cdot 2.5^2 / 2 =$$

$$17.9 \text{ kN}$$

$$0.833 \text{ m}$$

$$14.9 \text{ kNm}$$

Additional shear load acting at z;

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

$$0 \cdot 1.5 =$$

$$0.0 \text{ kN}$$

$$2.000 \text{ m}$$

$$0.0 \text{ kNm}$$

Horizontal Force (H):

$$28.7 \text{ kN}$$

$$M_H;$$

$$28.4 \text{ kNm}$$

Weight of wall stem;

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

$$0.9 \cdot 2.339 \cdot 0.148 \cdot 25 =$$

$$7.8 \text{ kN}$$

$$0.074 \text{ m}$$

$$0.6 \text{ kNm}$$

Weight of base;

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

$$0.9 \cdot 1.25 \cdot 0.161 \cdot 25 =$$

$$4.5 \text{ kN}$$

$$0.625 \text{ m}$$

$$2.8 \text{ kNm}$$

Retained Soil;

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

$$0.9 \cdot 2.339 \cdot 1.102 \cdot 18 =$$

$$41.8 \text{ kN}$$

$$0.699 \text{ m}$$

$$29.2 \text{ kNm}$$

Friction on virtual Back of wall;

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

$$0.9 \cdot 0.311 \cdot 0.34 \cdot 18 \cdot 2.5^2 / 2 =$$

$$5.4 \text{ kN}$$

$$1.250 \text{ m}$$

$$6.7 \text{ kNm}$$

Vertical Force (V):

$$59.4 \text{ kN}$$

$$M_V;$$

$$39.3 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h}=K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ref}; \quad 0.311 \cdot 0.94 \cdot 1.5 \cdot 10 \cdot 2.5 = 11.0 \text{ kN} \quad 1.250 \text{ m} \quad 13.7 \text{ kNm}$$

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 1.1 \cdot 0.311 \cdot 0.94 \cdot 18 \cdot 2.5^2/2 = 18.1 \text{ kN} \quad 0.833 \text{ m} \quad 15.1 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 29.1 \text{ kN} \quad M_H; \quad 28.8 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 2.339 \cdot 0.148 \cdot 25 = 7.8 \text{ kN} \quad 1.176 \text{ m} \quad 9.2 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 1.25 \cdot 0.161 \cdot 25 = 4.5 \text{ kN} \quad 0.625 \text{ m} \quad 2.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{ref}^2/2; \quad 0.9 \cdot 0.311 \cdot 0.34 \cdot 18 \cdot 2.5^2/2 = 5.4 \text{ kN} \quad 1.250 \text{ m} \quad 6.7 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 17.7 \text{ kN} \quad M_V; \quad 18.7 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d} \cdot (90-\alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 1.1 \cdot 0.837 \cdot 0.929 \cdot 18 \cdot 3.136^2/2 = 75.7 \text{ kN} \quad 1.045 \text{ m} \quad 79.1 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\varphi'_{r,d}) \cdot \cos(\varphi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 75.7 \text{ kN} \quad M_H; \quad 79.1 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 2.339 \cdot 0.148 \cdot 25 = 7.8 \text{ kN} \quad 0.074 \text{ m} \quad 0.6 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 1.25 \cdot 0.161 \cdot 25 = 4.5 \text{ kN} \quad 0.625 \text{ m} \quad 2.8 \text{ kNm}$$

Retained Soil;

$$F_{ret}=\gamma_{Gf} \cdot ((h_{ret} \cdot t_{base}) + (L_{toe} \cdot \tan(\beta)/2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 0.9 \cdot (2.339 + (1.102 \cdot 0.577/2)) \cdot 1.102 \cdot 18 = 47.4 \text{ kN} \quad 0.699 \text{ m} \quad 33.2 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2/2; \quad 0.9 \cdot 0.837 \cdot 0.34 \cdot 18 \cdot 3.136^2/2 = 22.7 \text{ kN} \quad 1.250 \text{ m} \quad 28.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 82.4 \text{ kN} \quad M_V; \quad 64.9 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h}=\gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 1.1 \cdot 0.837 \cdot 0.94 \cdot 18 \cdot 2.5^2/2 = 48.7 \text{ kN} \quad 0.833 \text{ m} \quad 40.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h}=\gamma_G \cdot \gamma_{mr} \cdot \sin(\varphi'_{r,d}) \cdot \cos(\varphi'_{r,d}) \cdot A; \quad 1.1 \cdot 18 \cdot 0.5 \cdot 0.866 \cdot 0 = 0.0 \text{ kN} \quad 2.500 \text{ m} \quad 0.0 \text{ kNm}$$

Additional shear load acting at z;

$$F_z=V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 48.7 \text{ kN} \quad M_H; \quad 40.6 \text{ kNm}$$

Weight of wall stem;

$$F_{stem}=\gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 0.9 \cdot 2.339 \cdot 0.148 \cdot 25 = 7.8 \text{ kN} \quad 1.176 \text{ m} \quad 9.2 \text{ kNm}$$

Weight of base;

$$F_{base}=\gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 0.9 \cdot 1.25 \cdot 0.161 \cdot 25 = 4.5 \text{ kN} \quad 0.625 \text{ m} \quad 2.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall\ friction}=\gamma_{Gf} \cdot K_A \cdot \sin\delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff2}^2/2; \quad 0.9 \cdot 0.837 \cdot 0.34 \cdot 18 \cdot 2.5^2/2 = 14.4 \text{ kN} \quad 1.250 \text{ m} \quad 18.0 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 26.7 \text{ kN} \quad M_V; \quad 30.0 \text{ kNm}$$

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REV: 0

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2.2 Global Forces at Combination 1

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.283 \cdot 0.917 \cdot 1.5 \cdot 10 \cdot 2.5 = 9.7 \text{ kN} \quad 1.250 \text{ m} \quad 12.2 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.283 \cdot 0.917 \cdot 18 \cdot 2.5^2 / 2 = 19.7 \text{ kN} \quad 0.833 \text{ m} \quad 16.4 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 29.4 \text{ kN} \quad M_{Ht}; \quad 28.6 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = 8.7 \text{ kN} \quad 0.074 \text{ m} \quad 0.6 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot (h_{ret} \cdot t_{base}) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot 2.339 \cdot 1.102 \cdot 18 = 46.4 \text{ kN} \quad 0.699 \text{ m} \quad 32.4 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.283 \cdot 0.37 \cdot 18 \cdot 2.5^2 / 2 = 5.9 \text{ kN} \quad 1.250 \text{ m} \quad 7.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 66.0 \text{ kN} \quad M_{Vt}; \quad 43.6 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{sur,h} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{ret}; \quad 0.283 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 2.5 = 9.9 \text{ kN} \quad 1.250 \text{ m} \quad 12.3 \text{ kNm}$$

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1.35 \cdot 0.283 \cdot 0.929 \cdot 18 \cdot 2.5^2 / 2 = 20.0 \text{ kN} \quad 0.833 \text{ m} \quad 16.6 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 29.8 \text{ kN} \quad M_{Ht}; \quad 29.0 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = 8.7 \text{ kN} \quad 1.176 \text{ m} \quad 10.2 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{ret}^2 / 2; \quad 1 \cdot 0.283 \cdot 0.37 \cdot 18 \cdot 2.5^2 / 2 = 5.9 \text{ kN} \quad 1.250 \text{ m} \quad 7.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 19.6 \text{ kN} \quad M_{Vt}; \quad 20.7 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{ret,h} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1.35 \cdot 0.552 \cdot 0.917 \cdot 18 \cdot 3.136^2 / 2 = 60.5 \text{ kN} \quad 1.045 \text{ m} \quad 63.2 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.411 = -4.5 \text{ kN} \quad 2.500 \text{ m} \quad -11.3 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 55.9 \text{ kN} \quad M_{Ht}; \quad 51.9 \text{ kNm}$$

Weight of wall stem;

$$F_{stem} = \gamma_{Gf} \cdot h_{stem} \cdot t_{stem} \cdot \gamma_{stem}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = 8.7 \text{ kN} \quad 0.074 \text{ m} \quad 0.6 \text{ kNm}$$

Weight of base;

$$F_{base} = \gamma_{Gf} \cdot L_{base} \cdot t_{base} \cdot \gamma_{base}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Retained Soil;

$$F_{ret} = \gamma_{Gf} \cdot ((h_{ret} \cdot t_{base}) + (L_{toe} \cdot \tan(\beta) / 2)) \cdot L_{toe} \cdot \gamma_{mr}; \quad 1 \cdot (2.339 + (1.102 \cdot 0.577 / 2)) \cdot 1.102 \cdot 18 = 52.7 \text{ kN} \quad 0.699 \text{ m} \quad 36.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{wall \text{ frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{eff1}^2 / 2; \quad 1 \cdot 0.552 \cdot 0.37 \cdot 18 \cdot 3.136^2 / 2 = 18.1 \text{ kN} \quad 1.250 \text{ m} \quad 22.6 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 84.5 \text{ kN} \quad M_{Vt}; \quad 63.2 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff}2}^2 / 2; \quad 1.35 \cdot 0.552 \cdot 0.929 \cdot 18 \cdot 2.5^2 / 2 = \quad 38.9 \text{ kN} \quad 0.833 \text{ m} \quad 32.5 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.411 = \quad -1.4 \text{ kN} \quad 2.500 \text{ m} \quad -3.5 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.5 = \quad 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 37.6 \text{ kN} \quad M_{Ht}; \quad 29.0 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = \quad 8.7 \text{ kN} \quad 1.176 \text{ m} \quad 10.2 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = \quad 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff}2}^2 / 2; \quad 1 \cdot 0.552 \cdot 0.37 \cdot 18 \cdot 2.5^2 / 2 = \quad 11.5 \text{ kN} \quad 1.250 \text{ m} \quad 14.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 25.2 \text{ kN} \quad M_{Vt}; \quad 27.7 \text{ kNm}$$

2.3 Global Forces at Combination 2

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

Lever Arm Moment

Surcharge Load;

$$F_{\text{sur,h}} = K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{\text{ret}}; \quad 0.347 \cdot 0.943 \cdot 1.3 \cdot 10 \cdot 2.5 = \quad 10.6 \text{ kN} \quad 1.250 \text{ m} \quad 13.3 \text{ kNm}$$

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} - (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.347 \cdot 0.943 \cdot 18 \cdot 2.5^2 / 2 = \quad 18.4 \text{ kN} \quad 0.833 \text{ m} \quad 15.3 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = \quad 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 29.0 \text{ kN} \quad M_{Ht}; \quad 28.6 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = \quad 8.7 \text{ kN} \quad 0.074 \text{ m} \quad 0.6 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = \quad 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = \gamma_{Gf} \cdot (h_{\text{ret}} - t_{\text{base}}) \cdot L_{\text{toe}} \cdot \gamma_{mr}; \quad 1 \cdot 2.339 \cdot 1.102 \cdot 18 = \quad 46.4 \text{ kN} \quad 0.699 \text{ m} \quad 32.4 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.347 \cdot 0.303 \cdot 18 \cdot 2.5^2 / 2 = \quad 5.9 \text{ kN} \quad 1.250 \text{ m} \quad 7.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 66.0 \text{ kN} \quad M_{Vt}; \quad 43.6 \text{ kNm}$$

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

Lever Arm Moment

Surcharge Load;

$$F_{\text{sur,h}} = K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_Q \cdot \text{Surcharge}_Q \cdot h_{\text{ret}}; \quad 0.347 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 2.5 = \quad 10.7 \text{ kN} \quad 1.250 \text{ m} \quad 13.4 \text{ kNm}$$

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.347 \cdot 0.953 \cdot 18 \cdot 2.5^2 / 2 = \quad 18.6 \text{ kN} \quad 0.833 \text{ m} \quad 15.5 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = \quad 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 29.3 \text{ kN} \quad M_{Ht}; \quad 28.9 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = \quad 8.7 \text{ kN} \quad 1.176 \text{ m} \quad 10.2 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = \quad 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall friction}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{ret}}^2 / 2; \quad 1 \cdot 0.347 \cdot 0.303 \cdot 18 \cdot 2.5^2 / 2 = \quad 5.9 \text{ kN} \quad 1.250 \text{ m} \quad 7.4 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 19.6 \text{ kN} \quad M_{Vt}; \quad 20.7 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d} \cdot (90 - \alpha)) \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.87 \cdot 0.943 \cdot 18 \cdot 3.062^2 / 2 = \quad 69.2 \text{ kN} \quad 1.021 \text{ m} \quad 70.6 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.528 = \quad 3.8 \text{ kN} \quad 2.500 \text{ m} \quad 9.6 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = \quad 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 73.1 \text{ kN} \quad M_H: \quad 80.3 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = \quad 8.7 \text{ kN} \quad 0.074 \text{ m} \quad 0.6 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = \quad 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Retained Soil;

$$F_{\text{ret}} = \gamma_{Gf} \cdot ((h_{\text{ret}} \cdot t_{\text{base}}) + (L_{\text{toe}} \cdot \tan(\beta) / 2)) \cdot L_{\text{toe}} \cdot \gamma_{mr}; \quad 1 \cdot (2.339 + (1.102 \cdot 0.577 / 2)) \cdot 1.102 \cdot 18 = \quad 52.7 \text{ kN} \quad 0.699 \text{ m} \quad 36.8 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff1}}^2 / 2; \quad 1 \cdot 0.87 \cdot 0.303 \cdot 18 \cdot 3.062^2 / 2 = \quad 22.3 \text{ kN} \quad 1.250 \text{ m} \quad 27.8 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 88.7 \text{ kN} \quad M_V: \quad 68.5 \text{ kNm}$$

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

Lever Arm Moment

Active Pressure;

$$F_{\text{ret,h}} = \gamma_G \cdot K_a \cdot \cos(\delta_{r,d}) \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.87 \cdot 0.953 \cdot 18 \cdot 2.5^2 / 2 = \quad 46.6 \text{ kN} \quad 0.833 \text{ m} \quad 38.9 \text{ kNm}$$

Additional Point Load

$$F_{x,h} = \gamma_G \cdot \gamma_{mr} \cdot \sin(\phi'_{r,d}) \cdot \cos(\phi'_{r,d}) \cdot A; \quad 1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.179 = \quad 1.3 \text{ kN} \quad 2.500 \text{ m} \quad 3.3 \text{ kNm}$$

Additional shear load acting at z;

$$F_z = V_z \cdot \gamma_{Vz} \quad 0 \cdot 1.3 = \quad 0.0 \text{ kN} \quad 2.000 \text{ m} \quad 0.0 \text{ kNm}$$

$$\text{Horizontal Force (H):} \quad 47.9 \text{ kN} \quad M_H: \quad 42.1 \text{ kNm}$$

Weight of wall stem;

$$F_{\text{stem}} = \gamma_{Gf} \cdot h_{\text{stem}} \cdot t_{\text{stem}} \cdot \gamma_{\text{stem}}; \quad 1 \cdot 2.339 \cdot 0.148 \cdot 25 = \quad 8.7 \text{ kN} \quad 1.176 \text{ m} \quad 10.2 \text{ kNm}$$

Weight of base;

$$F_{\text{base}} = \gamma_{Gf} \cdot L_{\text{base}} \cdot t_{\text{base}} \cdot \gamma_{\text{base}}; \quad 1 \cdot 1.25 \cdot 0.161 \cdot 25 = \quad 5.0 \text{ kN} \quad 0.625 \text{ m} \quad 3.1 \text{ kNm}$$

Friction on virtual Back of wall;

$$F_{\text{wall frict}} = \gamma_{Gf} \cdot K_A \cdot \sin \delta_{r,d} \cdot \gamma_{mr} \cdot h_{\text{eff2}}^2 / 2; \quad 1 \cdot 0.87 \cdot 0.303 \cdot 18 \cdot 2.5^2 / 2 = \quad 14.8 \text{ kN} \quad 1.250 \text{ m} \quad 18.6 \text{ kNm}$$

$$\text{Vertical Force (V):} \quad 28.5 \text{ kN} \quad M_V: \quad 31.9 \text{ kNm}$$

2.4 Summary of forces and moments on wall

Equilibrium	H	M _H	V	M _V
A: LC1 - Backfill to rear:	28.7 kN	28.4 kNm	59.4 kN	39.3 kNm
B: LC1 - Backfill to front:	29.1 kN	28.8 kNm	17.7 kN	18.7 kNm
C: LC2 - Backfill to rear:	75.7 kN	79.1 kNm	82.4 kN	64.9 kN
D: LC2 - Backfill to front:	48.7 kN	40.6 kNm	26.7 kN	30.0 kN
Combination 1	H	M _H	V	M _V
A: LC1 - Backfill to rear:	29.4 kN	28.6 kNm	66.0 kN	43.6 kNm
B: LC1 - Backfill to front:	29.8 kN	29.0 kNm	19.6 kN	20.7 kNm
C: LC2 - Backfill to rear:	55.9 kN	51.9 kNm	84.5 kN	63.2 kN
D: LC2 - Backfill to front:	37.6 kN	29.0 kNm	25.2 kN	27.7 kN
Combination 2	H	M _H	V	M _V
A: LC1 - Backfill to rear:	29.0 kN	28.6 kNm	66.0 kN	43.6 kNm
B: LC1 - Backfill to front:	29.3 kN	28.9 kNm	19.6 kN	20.7 kNm
C: LC2 - Backfill to rear:	73.1 kN	80.3 kNm	88.7 kN	68.5 kN
D: LC2 - Backfill to front:	47.9 kN	42.1 kNm	28.5 kN	31.9 kN

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2.5 Resultant actions

Sliding force

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

		<u>Equilibrium</u>	<u>Combination 1</u>	<u>Combination 2</u>
V• μ -H	LC1 - Backfill to rear:	4.9 kN 0.83 ULS Ratio	3.0 kN 0.90 ULS Ratio	2.6 kN 0.91 ULS Ratio
	LC1 - Backfill to front:	22.0 kN 0.24 ULS Ratio	22.0 kN 0.26 ULS Ratio	21.5 kN 0.27 ULS Ratio
	LC2 - Backfill to rear:	42.7 kN 0.44 ULS Ratio	22.2 kN 0.60 ULS Ratio	37.6 kN 0.49 ULS Ratio
	LC2 - Backfill to front:	38.0 kN 0.22 ULS Ratio	27.5 kN 0.27 ULS Ratio	36.5 kN 0.24 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:	10.8 kNm 1.38 ULS Ratio	15.0 kNm 1.52 ULS Ratio	15.0 kNm 1.52 ULS Ratio
	LC1 - Backfill to front:	-10.1 kNm 0.65 ULS Ratio	-8.3 kNm 0.71 ULS Ratio	-8.2 kNm 0.72 ULS Ratio
	LC2 - Backfill to rear:	-14.2 kNm 0.82 ULS Ratio	11.3 kNm 1.22 ULS Ratio	-11.8 kNm 0.85 ULS Ratio
	LC2 - Backfill to front:	-10.6 kNm 0.74 ULS Ratio	-1.3 kNm 0.95 ULS Ratio	-10.2 kNm 0.76 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; 42.7 kN/m - Loading condition 2 (Backfill to the rear)
 Vertical load; 82.4 kN/m - Loading condition 2 (Backfill to the rear)
 Resultant destabilising moment; 14.2 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; 37.6 kN/m - Combination 2 with loading condition 2 (Backfill to the rear)
 Resultant anti-clockwise destabilising moment; 11.8 kNm/m - Combination 2 with loading condition 2 (Backfill to the rear)
 Resultant clockwise destabilising moment; 10.2 kNm/m - Combination 2 with loading condition 2 (Backfill to the front)

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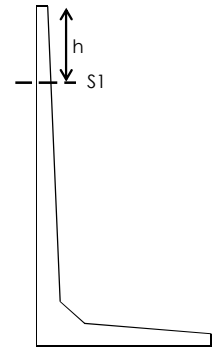
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3.1 Analysis Height 1

Analysis height 1 (S1) 660 mm
Soil depth at S1 660 mm



Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	0.530m	0.626m
Property B	0.306m	0.361m
Property C	0.338m	0.319m
Property D	-0.027m	0.038m
Property E	-0.049m	0.062m
Property F	-0.017m	0.019m
Area of Soil (A)	-0.009 m ²	0.012 m ²

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.917 \cdot 1.5 \cdot 10 \cdot 0.66 =$	2.6 kN	0.330 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.283 \cdot 0.917 \cdot 18 \cdot 0.66^2 / 2 =$	1.4 kN	0.220 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.9 kN	$M_H:$ 1.1 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.66 =$	2.6 kN	0.330 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.283 \cdot 0.929 \cdot 18 \cdot 0.66^2 / 2 =$	1.4 kN	0.220 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	4.0 kN	$M_H:$ 1.2 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.917 \cdot 18 \cdot 0.66^2 / 2 =$	2.7kN	0.220 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.009 =$	-0.1kN	0.660 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.6 kN	$M_H:$ 0.5 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.929 \cdot 18 \cdot 0.66^2 / 2 =$	2.7kN	0.220 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.009 =$	-0.1kN	0.660 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	2.6 kN	$M_H:$ 0.5 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.943 \cdot 1.3 \cdot 10 \cdot 0.66 =$	2.8 kN	0.330 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.347 \cdot 0.943 \cdot 18 \cdot 0.66^2 / 2 =$	1.3 kN	0.220 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	4.1 kN	$M_H:$ 1.2 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.66 =$	2.8 kN	0.330 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.347 \cdot 0.953 \cdot 18 \cdot 0.66^2 / 2 =$	1.3 kN	0.220 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	4.1 kN	$M_H:$ 1.2 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.943 \cdot 18 \cdot 0.66^2 / 2 =$	3.2kN	0.220 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.012 =$	0.1kN	0.660 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.3 kN	$M_H:$ 0.8 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.953 \cdot 18 \cdot 0.66^2 / 2 =$	3.3kN	0.220 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.012 =$	0.1kN	0.660 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.160 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
		Horizontal Force (H):	3.3 kN	$M_H:$ 0.8 kNm

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with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

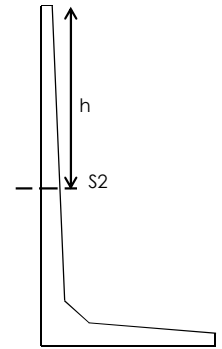
CHK: C.B.

SHEET: 10 of 20

3.2 Analysis Height 2

Analysis height 2 (S2) 1490 mm
Soil depth at S2 1490 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	1.196m	1.413m
Property B	0.691m	0.816m
Property C	0.762m	0.720m
Property D	-0.060m	0.085m
Property E	-0.110m	0.139m
Property F	-0.038m	0.043m
Area of Soil (A)	-0.045 m ²	0.063 m ²



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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.917 \cdot 1.5 \cdot 10 \cdot 1.49=$	5.8 kN	0.745 m	4.3 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.283 \cdot 0.917 \cdot 18 \cdot 1.49^2/2=$	7.0 kN	0.497 m	3.5 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	0.990 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):			12.8 kN	$M_{H:}$	7.8 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 1.49=$	5.9 kN	0.745 m	4.4 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.283 \cdot 0.929 \cdot 18 \cdot 1.49^2/2=$	7.1 kN	0.497 m	3.5 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	0.990 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):			13.0 kN	$M_{H:}$	7.9 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.917 \cdot 18 \cdot 1.49^2 / 2 =$	13.7kN	0.497 m	6.8 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.045 =$	-0.5kN	1.490 m	-0.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.990 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):			13.2 kN	$M_{H:}$	6.0 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.929 \cdot 18 \cdot 1.49^2 / 2 =$	13.8kN	0.497 m	6.9 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.045 =$	-0.5kN	1.490 m	-0.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.990 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):			13.3 kN	$M_{H:}$	6.1 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.943 \cdot 1.3 \cdot 10 \cdot 1.49=$	6.3 kN	0.745 m	4.7 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-\alpha)) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.347 \cdot 0.943 \cdot 18 \cdot 1.49^2/2=$	6.5 kN	0.497 m	3.2 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	0.990 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):			12.9 kN	$M_{H:}$	8.0 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 1.49=$	6.4 kN	0.745 m	4.8 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.347 \cdot 0.953 \cdot 18 \cdot 1.49^2/2=$	6.6 kN	0.497 m	3.3 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	0.990 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):			13.0 kN	$M_{H:}$	8.1 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - \alpha)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.943 \cdot 18 \cdot 1.49^2 / 2 =$	16.4kN	0.497 m	8.1 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.063 =$	0.5kN	1.490 m	0.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.990 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):			16.8 kN	$M_{H:}$	8.8 kNm

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

Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.953 \cdot 18 \cdot 1.49^2 / 2 =$	16.6kN	0.497 m	8.2 kNm
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.063 =$	0.5kN	1.490 m	0.7 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.990 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):			17.0 kN	$M_{H:}$	8.9 kNm

**2500mm Standard L-Wall
with Standard Design Parameters**

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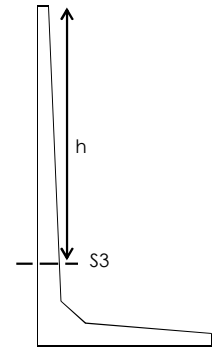
CHK: C.B.

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3.3 Analysis Height 3

Analysis height 3 (S3) 2195 mm
Soil depth at S3 2195 mm

Area Related to Additional Line Load	Comb' 1	Comb' 2
Property A	1.762m	2.081m
Property B	1.018m	1.202m
Property C	1.123m	1.061m
Property D	-0.089m	0.126m
Property E	-0.162m	0.205m
Property F	-0.057m	0.064m
Area of Soil (A)	-0.097 m ²	0.138 m ²



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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.917 \cdot 1.5 \cdot 10 \cdot 2.195=$	8.5 kN	1.098 m	9.4 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.283 \cdot 0.917 \cdot 18 \cdot 2.195^2/2=$	15.2 kN	0.732 m	11.1 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	1.695 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			23.7 kN	$M_H:$	20.5 kNm

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

Surcharge Load	$F_{sur,h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 2.195=$	8.7 kN	1.098 m	9.5 kNm
Active Pressure	$F_{ret,h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1.35 \cdot 0.283 \cdot 0.929 \cdot 18 \cdot 2.195^2/2=$	15.4 kN	0.732 m	11.3 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.5=$	0.0 kN	1.695 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):			24.0 kN	$M_H:$	20.8 kNm

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

Active Pressure	$F_{ret,h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.917 \cdot 18 \cdot 2.195^2 / 2 =$	29.6kN	0.732 m	21.7 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.097 =$	-1.1kN	2.195 m	-2.3 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	1.695 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):			28.6 kN	$M_H:$	19.3 kNm

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

Active Pressure	$F_{ret,h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.929 \cdot 18 \cdot 2.195^2 / 2 =$	30.0kN	0.732 m	22.0 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.097 =$	-1.1kN	2.195 m	-2.3 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	1.695 m	0.0 kNm
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			29.0 kN	$M_H:$	19.6 kNm

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

Surcharge Load	$F_{sur,h}=K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.943 \cdot 1.3 \cdot 10 \cdot 2.195=$	9.3 kN	1.098 m	10.2 kNm
Active Pressure	$F_{ret,h}=\gamma G \cdot K_a \cdot \cos(\delta r.d-(90-a)) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.347 \cdot 0.943 \cdot 18 \cdot 2.195^2/2=$	14.2 kN	0.732 m	10.4 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	1.695 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			23.5 kN	$M_H:$	20.6 kNm

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

Surcharge Load	$F_{sur_h}=K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 2.195=$	9.4 kN	1.098 m	10.4 kNm
Active Pressure	$F_{ret_h}=\gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2/2;$	$1 \cdot 0.347 \cdot 0.953 \cdot 18 \cdot 2.195^2/2=$	14.3 kN	0.732 m	10.5 kNm
Shear at z	$F_z=V_z \cdot \gamma V_z$	$0 \cdot 1.3=$	0.0 kN	1.695 m	0.0 kNm
Moment at z	$M_z=M_z \cdot \gamma M_z$		0.0 kN	0.000 m	0.0 kNm
Horizontal Force (H):			23.8 kN	$M_H:$	20.8 kNm

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

Active Pressure	$F_{ret,h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90-a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.943 \cdot 18 \cdot 2.195^2 / 2 =$	35.6kN	0.732 m	26.0 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.138 =$	1.0kN	2.195 m	2.2 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	1.695 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):			36.6 kN	$M_H:$	28.2 kNm

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

Active Pressure	$F_{ret,h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.953 \cdot 18 \cdot 2.195^2 / 2 =$	35.9kN	0.732 m	26.3 kNm
Additional Point Load	$F_{x,h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.138 =$	1.0kN	2.195 m	2.2 kNm
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	1.695 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):			37.0 kN	$M_H:$	28.5 kNm

**2500mm Standard L-Wall
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REV: 0

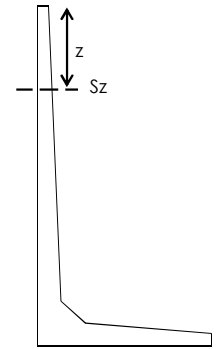
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SHEET: 12 of 20

3.3 Analysis Height Z

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



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

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.917 \cdot 1.5 \cdot 10 \cdot 0.5 =$	1.9 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.283 \cdot 0.917 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.7 kN	$M_H:$	0.6 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.283 \cdot 0.929 \cdot 1.5 \cdot 10 \cdot 0.5 =$	2.0 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.283 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	0.8 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.8 kN	$M_H:$	0.6 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.917 \cdot 18 \cdot 0.5^2 / 2 =$	1.5kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.5 kN	$M_H:$	0.2 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1.35 \cdot 0.552 \cdot 0.929 \cdot 18 \cdot 0.5^2 / 2 =$	1.6kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1.35 \cdot 18 \cdot 0.537 \cdot 0.843 \cdot -0.005 =$	-0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.5 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.5 kN	$M_H:$	0.2 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.943 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.347 \cdot 0.943 \cdot 18 \cdot 0.5^2 / 2 =$	0.7 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.9 kN	$M_H:$	0.7 kNm

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

			Lever Arm	Moment
Surcharge Load	$F_{sur_h} = K_a \cdot \cos(\delta r.d) \cdot \gamma Q \cdot \text{Surcharge} Q \cdot h;$	$0.347 \cdot 0.953 \cdot 1.3 \cdot 10 \cdot 0.5 =$	2.1 kN	0.250 m
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.347 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	0.7 kN	0.167 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		2.9 kN	$M_H:$	0.7 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d - (90 - a)) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.943 \cdot 18 \cdot 0.5^2 / 2 =$	1.8kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
Horizontal Force (H):		1.9 kN	$M_H:$	0.3 kNm

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

			Lever Arm	Moment
Active Pressure	$F_{ret_h} = \gamma G \cdot K_a \cdot \cos(\delta r.d) \cdot \gamma m r \cdot h^2 / 2;$	$1 \cdot 0.87 \cdot 0.953 \cdot 18 \cdot 0.5^2 / 2 =$	1.9kN	0.167 m
Additional Point Load	$F_{x_h} = \gamma G \cdot \gamma m r \cdot \sin(\phi' r.d) \cdot \cos(\phi' r.d) \cdot A;$	$1 \cdot 18 \cdot 0.454 \cdot 0.891 \cdot 0.007 =$	0.1kN	0.500 m
Shear at z	$F_z = V_z \cdot \gamma V_z$	$0 \cdot 1.3 =$	0.0 kN	0.000 m
Moment at z	$M_z = M_z \cdot \gamma M_z$		0.0 kN	0.000 m
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 @ 660		Analysis 2 @ 1490		Analysis 3 @ 2195		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Rear level fill & surcharge (A)	3.9 kN	1.1 kNm	12.8 kN	7.8 kNm	23.7 kN	20.5 kNm	2.7 kN	0.6 kNm
Front level fill & surcharge (B)	4.0 kN	1.2 kNm	13.0 kN	7.9 kNm	24.0 kN	20.8 kNm	2.8 kN	0.6 kNm
Rear sloped fill without surcharge (C)	2.6 kN	0.5 kNm	13.2 kN	6.0 kNm	28.6 kN	19.3 kNm	1.5 kN	0.2 kNm
Front sloped fill without surcharge (D)	2.6 kN	0.5 kNm	13.3 kN	6.1 kNm	29.0 kN	19.6 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)	4.1 kN	1.2 kNm	12.9 kN	8.0 kNm	23.5 kN	20.6 kNm	2.9 kN	0.7 kNm
Front level fill & surcharge (B)	4.1 kN	1.2 kNm	13.0 kN	8.1 kNm	23.8 kN	20.8 kNm	2.9 kN	0.7 kNm
Rear sloped fill without surcharge (C)	3.3 kN	0.8 kNm	16.8 kN	8.8 kNm	36.6 kN	28.2 kNm	1.9 kN	0.3 kNm
Front sloped fill without surcharge (D)	3.3 kN	0.8 kNm	17.0 kN	8.9 kNm	37.0 kN	28.5 kNm	1.9 kN	0.3 kNm

Back face is in tension values	Analysis 1 @ 660		Analysis 2 @ 1490		Analysis 3 @ 2195		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	4.1 kN	0.8 kNm	16.8 kN	8.8 kNm	36.6 kN	28.2 kNm	1.9 kN	0.3 kNm

Front face is in tension values	Analysis 1 @ 660		Analysis 2 @ 1490		Analysis 3 @ 2195		Analysis z @ 500	
	H	M _H	H	M _H	H	M _H	H	M _H
Max sloped & horizontal comb' 1 & 2	4.1 kN	1.2 kNm	17.0 kN	8.9 kNm	37.0 kN	28.5 kNm	2.9 kN	0.7 kNm

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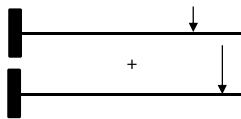
4.0 Wall Base Design

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

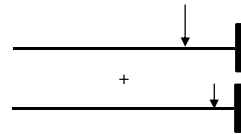
Analysis length 1 (B1)	305 mm
Analysis length 2 (B2)	770 mm
Analysis length 3 (B3)	1205 mm

The number of rows of bolts will determine how the forces are distributed in the base.
This design is done on the basis of an anchor system using: **2 rows of bolts**

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



Anti-Clockwise rotation (two Anchor system)



Clockwise rotation (two Anchor system)

Forces in single row anchor system

$$M = FS_1 \cdot lb_1$$

Forces in two row anchor system

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

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

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

Rearrange (2)

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

Substituting into (1)

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

Factorise & rearrange

4.1 Anchored Anticlockwise Rotation

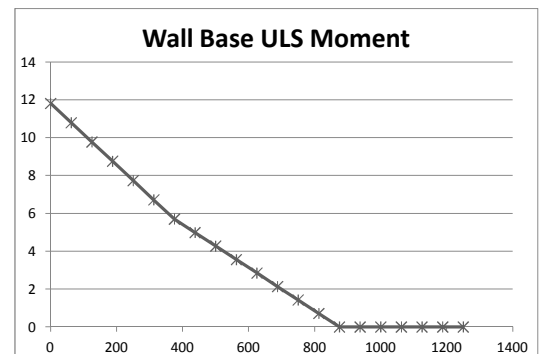
Maximum overturning moment	11.8 kNm
Lever arm to closest anchor (lb1)	375 mm (First Row)
Lever arm to furthest anchor (lb2)	875mm (Second Row)

From the above equations:

$$\text{Tension force in closest anchors (FS1)} = 4.9 \text{ kN (First Row)}$$

$$\text{Tension force in furthest anchors (FS2)} = 11.4 \text{ kN (Second Row)}$$

X:	305mm	770mm	1205mm
Tension Moment Top face:	6.8 kNm	1.2 kNm	0.0 kNm
Shear:	16.3 kN	11.4 kN	0.0 kN



4.2 Anchored Clockwise Rotation

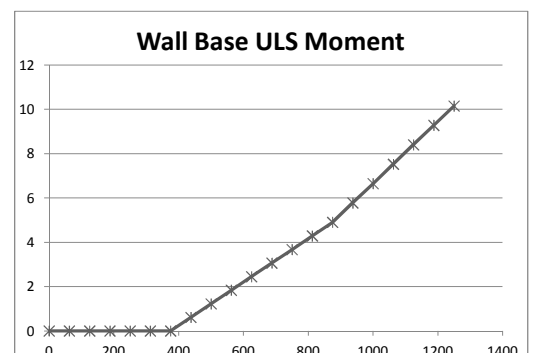
Maximum overturning moment	10.2 kNm
Lever arm to closest anchor (lb1)	375 mm (Second Row)
Lever arm to furthest anchor (lb2)	875mm (First Row)

From the above equations:

$$\text{Tension force in closest anchors (FS1)} = 4.2 \text{ kN (Second Row)}$$

$$\text{Tension force in furthest anchors (FS2)} = 9.8 \text{ kN (First Row)}$$

X:	305mm	770mm	1205mm
Tension Moment Top face:	0.0 kNm	3.9 kNm	9.5 kNm
Shear:	0.0 kN	9.8 kN	14.0 kN



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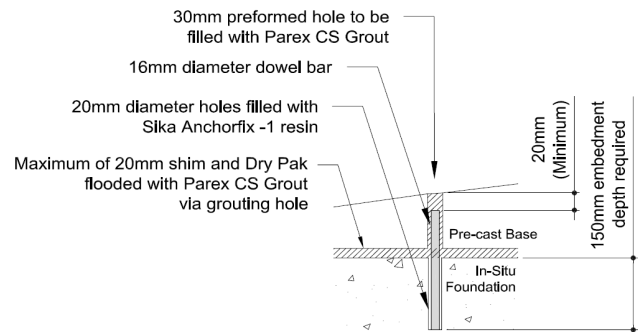
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5.0 Anchor Design

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)	275 mm
First Row: Effective Depth In Precast (h_{eff1});	105 mm
First Row: Effective Depth In Foundation (h_{eff2});	150 mm
Second Row: Dowel Bar Length (D_L)	275 mm
Second Row: Effective Depth In Precast (h_{eff1});	105 mm
Second Row: Effective Depth In Foundation (h_{eff2});	150 mm



Determination of the bond resistance of grout

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

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

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

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

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

5.1 Anchorage in Precast

5.1.1 Resistance to Tension Loads

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

Maximum Tensile Load per Anchor (N);	First Row	Second Row
$N = \text{Max}\{\text{Clockwise Force, Anticlockwise Force}\} / \text{No.}$	$\text{Max}\{4.9, 9.8\} / 2 = 4.9 \text{ kN}$	$\text{Max}\{11.4, 4.2\} / 2 = 5.7 \text{ kN}$

5.1.1.1 Steel Failure

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

Ratio between design action and design resistance	First Row	Second Row
$\beta_N = N / N_{Rd,s}$	$4.9 / 96.1 = 0.05$	$5.7 / 96.1 = 0.06$

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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
 $\pi \cdot 16 \cdot 105 \cdot 12.3 = 64.9 \text{ kN}$

Second Row
 $\pi \cdot 16 \cdot 105 \cdot 12.3 = 64.9 \text{ kN}$

Design tension capacity of anchorage;

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

$64.9/3 = 21.6 \text{ kN}$

$64.9/3 = 21.6 \text{ kN}$

Ratio between design action and design resistance

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

$4.9/21.6 = 0.23$

$5.7/21.6 = 0.26$

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;

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

$37.6 / (2 \cdot 2) = 9.4 \text{ kN}$

5.1.2.1 Steel Failure, Shear Load without Lever Arm

Area of steel;

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

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

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

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

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

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

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

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

Ratio between design action and design resistance

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

First Row
 $9.4 / 48.1 = 0.20$

Second Row
 $9.4 / 48.1 = 0.20$

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
0.10

Second Row
0.10

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

0.19

0.22

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

0.42

0.46

5.1 Anchorage in Foundation

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

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

30.0 kN

Design tension capacity of anchorage;

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

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

Ratio between design action and design resistance

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

First Row
 $4.9/10 = 0.49$

Second Row
 $5.7/10 = 0.57$

Anchorage provided is adequate

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6.0 Reinforcement Design

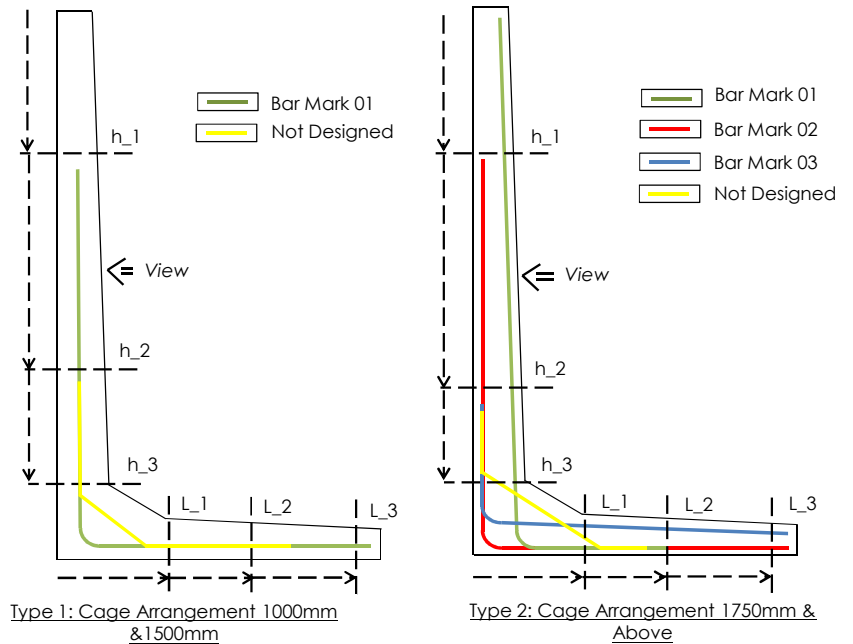
All the standard retaining walls have different reinforcement cages, however, they follow one of two patterns. The 1000mm and 1500mm are a type one and 1750mm and above are of a type 2, these are shown (right). A reinforcement check is then done on the three heights of the stem and three lengths of the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

Cage Provided

This retaining wall has a Type 2 cage.

Reinforcement Provided

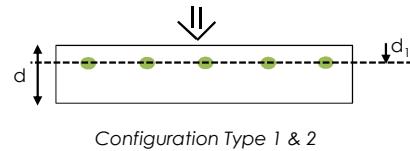
	Diameter	Spacing	As,prov
Bar Mark 1	14.14	200	785
Bar Mark 2	14.14	200	785
Bar Mark 3	14.14	200	785



6.1 Section Analysis

Analysis height 1 (660mm)

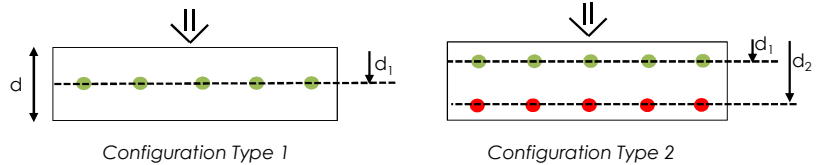
Depth @ S1 (hS1)	131 mm
hS1 - Depth to rein' (d1)	52 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	785	79	0	0
Front face in tension	785	52	0	0

Analysis height 2 (1490mm)

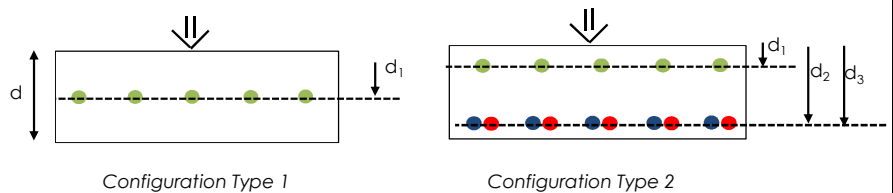
Depth @ S2 (hS2)	158 mm
hS2 - Depth to rein' (d1)	52 mm
hS2 - Depth to rein' (d2)	105 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	785	105	785	52
Front face in tension	785	105	785	52

Analysis height 3 (2195mm)

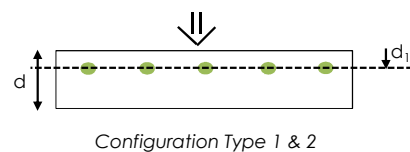
Depth @ S3 (hS3)	180 mm
hS3 - Depth to rein' (d1)	52 mm
hS3 - Depth to rein' (d2)	128 mm
hS3 - Depth to rein' (d3)	128 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	785	128	1571	52
Front face in tension	1571	128	785	52

Analysis height z (500mm)

Depth @ Sz (hSz)	126 mm
Depth to rein' (d1)	47 mm



	As,prov	Eff' Depth	As',prov	Eff' Depth
Back face in tension	785	79	0	0
Front face in tension	785	47	0	0

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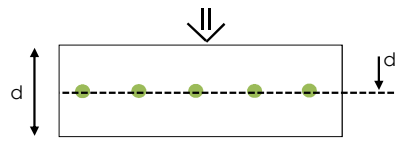
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CHK: C.B.

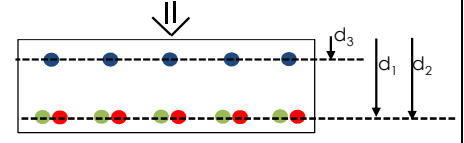
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Analysis length 1 (305mm)

Depth @ B1 (hB1)	180 mm
hB1 - Depth to rein' (d1)	128 mm
hB1 - Depth to rein' (d2)	128 mm
hB1 - Depth to rein' (d3)	52 mm



Configuration Type 1

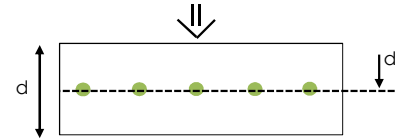


Configuration Type 2

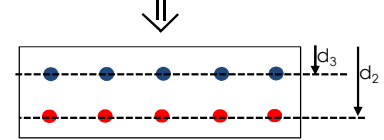
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	785	128	1571	52
Bottom face in tension	1571	128	785	52

Analysis length 2 (770mm)

Depth @ B2 (hB2)	153 mm
hB2 - Depth to rein' (d1)	0 mm
hB2 - Depth to rein' (d2)	101 mm
hB2 - Depth to rein' (d3)	52 mm



Configuration Type 1

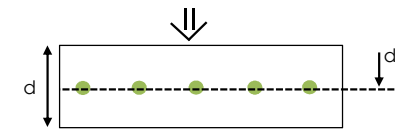


Configuration Type 2

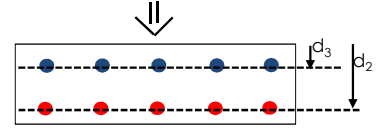
	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	785	101	785	52
Bottom face in tension	785	101	785	52

Analysis length 3 (1205mm)

Depth @ B3 (hB3)	128 mm
hB3 - Depth to rein' (d1)	0 mm
hB3 - Depth to rein' (d2)	76 mm
hB3 - Depth to rein' (d3)	52 mm



Configuration Type 1



Configuration Type 2

	As,prov	Eff' Depth	As',prov	Eff' Depth
Top face in tension	785	76	785	52
Bottom face in tension	785	76	785	52

6.2 Concrete Properties

Concrete details & design

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

Pre-Cast

C45/55

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

Reinforcement details

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

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

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6.3 Stem Reinforcement Design

	Back face in Tension			
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	22.5 kNm	31.1 kNm	38.3 kNm	22.5 kNm
Design Bending Moment	0.8 kNm	8.8 kNm	28.2 kNm	0.3 kNm
Area of tension reinforcement provided	785 mm ²	785 mm ²	785 mm ²	785 mm ²
Area of compression reinforcement provided	0 mm ²	785 mm ²	1571 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	69 mm	95 mm	118 mm	69 mm
K Factor =M/(b•d _{n1} ² •fck);	0.004	0.022	0.045	0.002
Limiting k Factor = 0.5986-0.1862-0.21;	0.208	0.208	0.208	0.208
Lever arm (z) =Min(0.95•d _{n1} ,d _{n1} /2•(1+√(1-3.53k)));	66 mm	91 mm	112 mm	66 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	27 mm ²	223 mm ²	579 mm ²	12 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	136 mm ²	189 mm ²	233 mm ²	136 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})	136 mm ²	223 mm ²	579 mm ²	136 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (5.7)	Pass (3.5)	Pass (1.3)	Pass (5.7)
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});	0.0110	0.0080	0.0070	0.0110
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	45.8 kN	63.4 kN	78.3 kN	45.8 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});	60.7 kN	75.5 kN	89.3 kN	60.7 kN
Shear resistance required (V)	4.1 kN	16.8 kN	36.6 kN	1.9 kN
	Pass (9.9)	Pass (4.4)	Pass (2.4)	Pass (9.9)

	Front face in Tension			
Moment	h_1	h_2	h_3	h_Z
Moment capacity of section	13.7 kNm	31.1 kNm	76.5 kNm	12.0 kNm
Design Bending Moment	1.2 kNm	8.9 kNm	28.5 kNm	0.7 kNm
Area of tension reinforcement provided	785 mm ²	785 mm ²	1571 mm ²	785 mm ²
Area of compression reinforcement provided	0 mm ²	785 mm ²	785 mm ²	0 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	42 mm	95 mm	118 mm	37 mm
K Factor =M/(b•dn1 ² •fck);	0.015	0.022	0.046	0.011
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)));	40 mm	91 mm	112 mm	35 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	69 mm ²	225 mm ²	585 mm ²	43 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	83 mm ²	189 mm ²	233 mm ²	73 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})	83 mm ²	225 mm ²	585 mm ²	73 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²	0 mm ²
	Pass (9.4)	Pass (3.4)	Pass (2.6)	Pass (9.9)
Shear				
Shear resistance constant (C _{Rd,c}) =0.18/γ _c ;	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²	0.1N/mm ²
Effective Depth Factor (k) =min(2.0,1+√(200/dn1));	2.0000	2.0000	2.0000	2.0000
Reinforcement Ratio (ρ ₁) =min(0.02,A _s /b•d _{n1});	0.0190	0.0080	0.0130	0.0200
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	27.9 kN	63.4 kN	78.3 kN	24.5 kN
Shear resistance (V _{Rd,c,1}) = max(V _{Rd,c,min} ,C _{Rd,c} •k•(100•ρ ₁ •(f _{ck} /1))0.333•b•d _{n1});	44.4 kN	75.5 kN	109.7 kN	39.7 kN
Shear resistance required (V)	4.1 kN	17.0 kN	37.0 kN	2.9 kN
	Pass (9.9)	Pass (4.4)	Pass (2.9)	Pass (9.9)

**2500mm Standard L-Wall
with Standard Design Parameters**

06-Jan-17

REV: 0

BY: S.J.H

CHK: C.B.

SHEET: 20 of 20

6.4 Base Reinforcement Design

	Top face in Tension		
	L_1	L_2	L_3
<u>Moment</u>			
Moment capacity of section	38.3 kNm	29.4 kNm	21.2 kNm
Design Bending Moment	6.8 kNm	3.9 kNm	9.5 kNm
Area of tension reinforcement provided	785 mm ²	785 mm ²	785 mm ²
Area of compression reinforcement provided	1571 mm ²	785 mm ²	785 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	118 mm	91 mm	66 mm
K Factor =M/(b•dn1 ² •fck);	0.011	0.010	0.049
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)));	112 mm	86 mm	62 mm
Area of rein' reqd for bending (A _{s,req,b}) =M/(f _{yd} •z);	140 mm ²	103 mm ²	353 mm ²
Min area reqd (A _{s,min}) = max(0.26•(f _{ctm} /f _{yk}),0.0013)•b•d _{n1} ;	233 mm ²	180 mm ²	130 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})	233 mm ²	180 mm ²	353 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (3.3)	Pass (4.3)	Pass (2.2)
<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});	0.0070	0.0090	0.0120
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	78.3 kN	60.3 kN	43.5 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} ;	89.3 kN	74.8 kN	59.4 kN
Shear resistance required (V)	16.3 kN	11.4 kN	14.0 kN
	Pass (5.4)	Pass (6.5)	Pass (4.2)
	Bottom face in Tension		
	L_1	L_2	L_3
Moment capacity of section	76.5 kNm	29.4 kNm	21.2 kNm
Design Bending Moment	0.0 kNm	0.0 kNm	0.0 kNm
Area of tension reinforcement provided	1571 mm ²	785 mm ²	785 mm ²
Area of compression reinforcement provided	785 mm ²	785 mm ²	785 mm ²
Effective depth to tension rein' (d _{n1})=d-Δc;	118 mm	91 mm	66 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)));	112 mm	86 mm	62 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} ;	233 mm ²	180 mm ²	130 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})	233 mm ²	180 mm ²	130 mm ²
Compression reinforcement required at section (A _{s',req})	0 mm ²	0 mm ²	0 mm ²
	Pass (6.7)	Pass (4.3)	Pass (6)
<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});	0.0130	0.0090	0.0120
Minimum shear resistance (V _{Rd,c,min})= 0.035•k ^{1.5} •f _{ck} ^{0.5} •b•d _{n1} ;	78.3 kN	60.3 kN	43.5 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} ;	109.7 kN	74.8 kN	59.4 kN
Shear resistance required (V)	16.3 kN	11.4 kN	14.0 kN
	Pass (6.7)	Pass (6.5)	Pass (4.2)

Concrete section is sufficiently reinforced