

SHANAWAY

RETAINING WALL ASSESSMENT



Document Information

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1 Executive Summary

Andrew Waring Associates were engaged by Mr A. Howden, to undertake a structural assessment of an existing 2m high masonry retaining wall at Shanaway and to develop strengthening options should the existing wall prove to be inadequate.

AWA undertook a site visit on the 22nd Dec 2025 to establish the geometry and understand the make-up of the existing wall. Calculations were undertaken on the existing wall using derived soil properties from the latest best practice guidance. The wall was found to be inadequate.

Two options for strengthening were then developed which could be installed in front of the existing wall to provide long term stability to the retaining structure.

- 1) Stepoc retaining wall with RC base
- 2) Mass concrete gravity retaining wall

Full calculations have been presented in the appendix.

2 Brief

Andrew Waring Associates were engaged by Mr A. Howden, to conduct a site visit and undertake a structural assessment of an existing masonry retaining wall at Shanaway, Maple Drive, Firsdown, Salisbury, Wiltshire, SP5 1SY.

On assessment, should the existing arrangement be found to be inadequate, AWA were requested to put forward proposals for strengthening the wall and provide structural calculations for the strengthening options.

3 Disclaimer

Our inspection was visual in nature only and did not include any intrusive investigations unless specifically noted otherwise. Where reasonably practicable we have attempted to access and inspect all safely accessible areas.

Our inspection did not include any parts which were inaccessible or not visible and therefore we can provide no comment on the condition of any such uninspected parts of the structure.

All external observations of the structure are made from ground level only.

No testing or enquiries as to the presence of or susceptibility to pollution contamination, radiation, methane, radon and toxic mould, fungus or spore or other hazardous substances has been carried out.

Our inspection concerned structural aspects only and no comment or guarantee can be made on the condition of services, architectural finishes or decorations.

No responsibility is accepted to any third party for the whole or part of the contents of this report, which has been exclusively compiled for the use of our client.

The Client should also note that liability to the Client, whether in Contract or Tort, shall not exceed the amount, if any, recoverable by way of indemnity insurance taken out by Andrew Waring Associates at the time we received instruction from the Client.

4 Visit

The site was inspected by on December 22.12.2025.

Weather conditions at the time of survey were fine. The inspection was carried out from ground level. No intrusive works were undertaken.

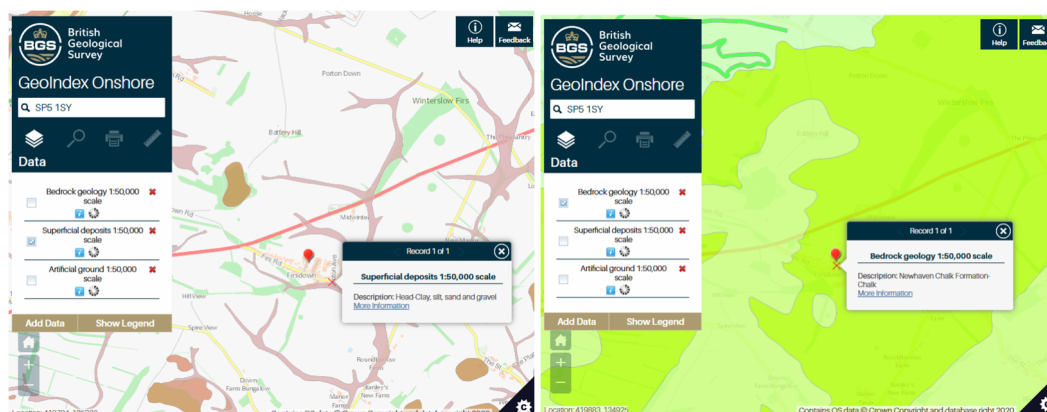
5 Site and Ground Conditions

The site is located at:

Shanaway,
Maple Drive,
Firsdawn,
Salisbury,
Wiltshire,
SP5 1SY.

The site is in a residential cul-de-sac surrounded by other residential properties. The site is elevated on a sloping site.

Interrogation of the British Geological Survey shows that the site is located on Newhaven Chalk.



5.1 Soil Properties

In the absence of any formal Site Investigation the properties of the soil have been derived from the latest best practice guidance Ciria Guidance C574 Engineering Chalk. The chalk is assumed to be a high density structured chalk.

Table 3.2 *Intact dry density scales of chalk (based on Mortimore et al, 1990 and Matthews et al, 1993)*

Density scale	Intact dry density γ_d (Mg/m ³)	Porosity n*	Saturation moisture content*
Low density	< 1.55	> 0.43	> 27.5%
Medium density	1.55–1.70	0.43–0.37	27.5–21.8%
High density	1.70–1.95	0.37–0.28	21.8–14.3%
Very high density	> 1.95	< 0.28	< 14.3%

* Based on the specific gravity of calcite $G_s = 2.70$ (see Section 4.2)

As discussed in Section 4.4.1, “moderately conservative” strength parameters for structured chalk have been found to be $c' = 20 \text{ kN/m}^2$, $\phi' = 39^\circ$, with “worst credible” parameters of $c' = 0$, $\phi' = 34^\circ$.

6 Existing Structure

The existing retaining wall has been formed from 215mm solid concrete block laid and faced with a 102mm brick.

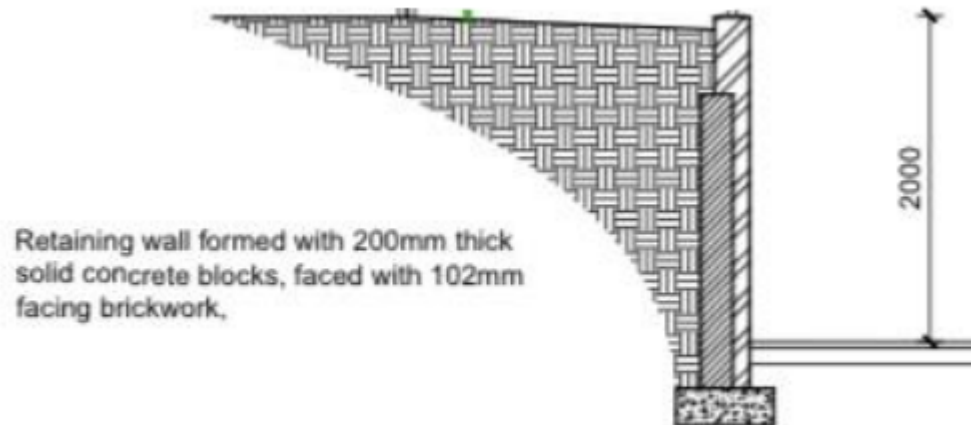


Figure 1: Sketch showing the existing structure

This was confirmed from photos taken by the client at the time of construction.



Figure 2: Sketch showing images taken during the construction of the wall

7 Proximity of Retaining Structure to Adjacent Building

The neighbouring property is reasonably close to the excavated area formed by the retaining structure therefore it is necessary to consider how the weight of the neighbouring property impacts on the retaining structure and if there is any risk of undermining the adjacent property resulting from the level of excavation.

The neighbouring property is minimum 3m away from the retaining structure and the retaining structure is 2m high. Assuming a 300mm build up in soil in the adjacent garden and assuming that the footing of the neighbouring property goes down 300mm (conservative), then the loaded area does not extend to the retaining wall therefore there is no need to consider the weight of the adjacent property on the retaining wall and there is no risk that the adjacent structure will be undermined.

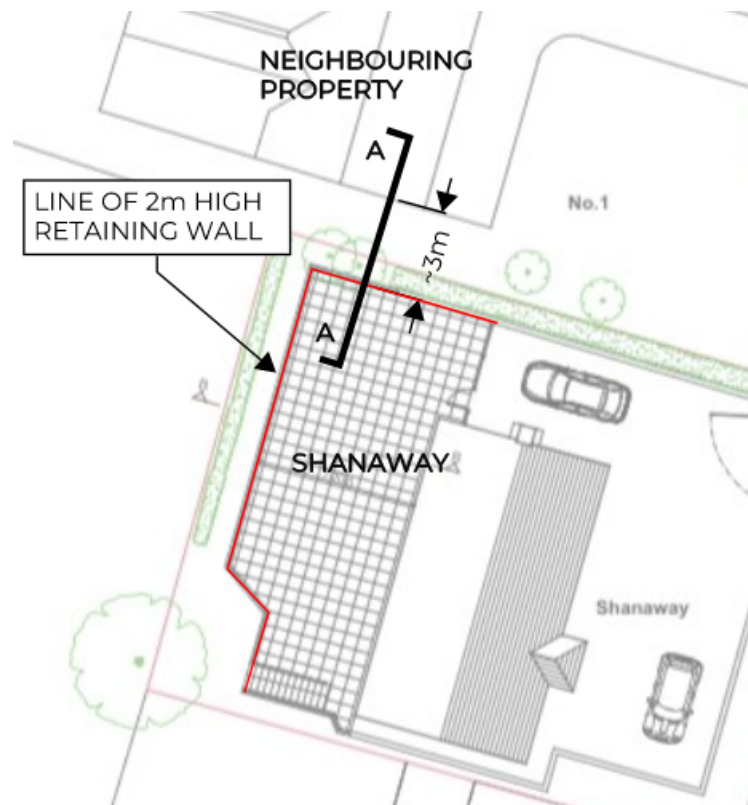


Figure 3: Plan drawing of Shanaway and neighbouring property

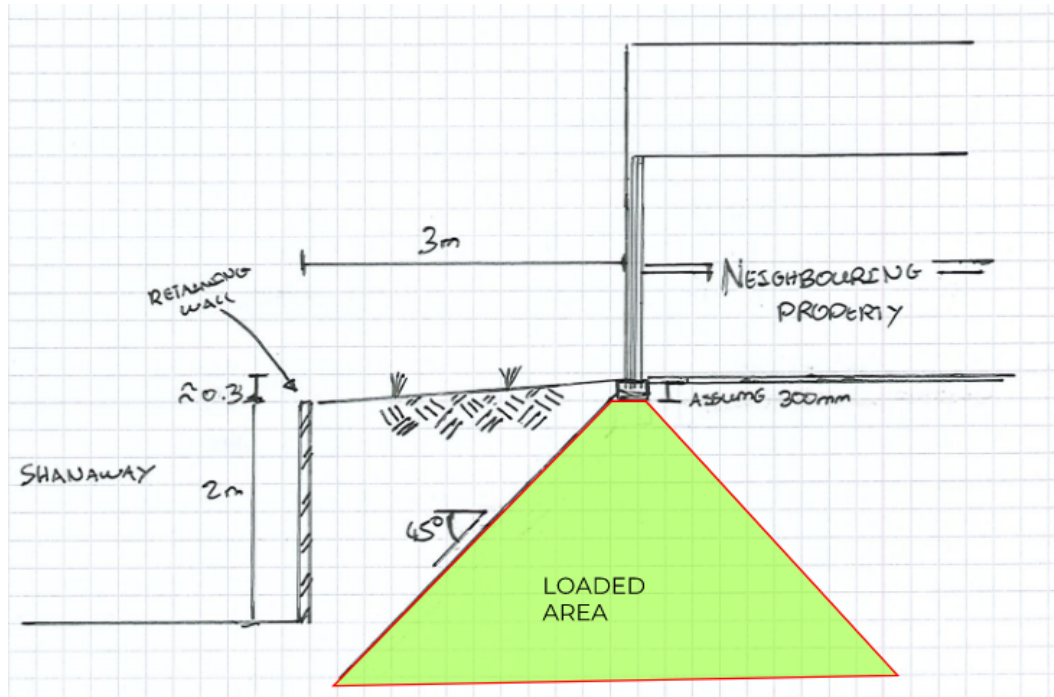


Figure 4: sketch of section A-A

8 Assessment of Existing structure

8.1 Design Parameters

The existing 215mm thick block wall was assessed based on the following parameters

Soil

$\Phi'_{r,k}$ = Characteristic effective shear resistance angle = **34** deg

γ_{mr} = Moist density = **19** kN/m³

$P_{bearing}$ = Presumed bearing capacity = **125** kN/m²

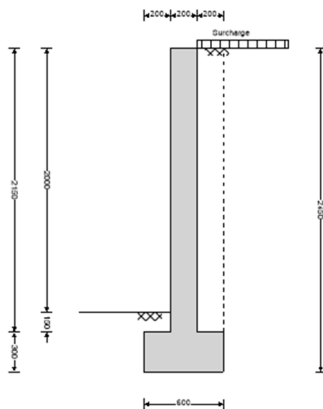
Water table is below the foundation

Foundations are considered drained

Loading

Q = Variable surcharge load = **2.5** kN/m²

Geometry



8.2 Analysis

A full set of calculations can be found in the appendix; however, a summary table is provided below. From the analysis the existing wall was found to be inadequate to provide long term stability as a retaining structure. An overall stability failure has meant that the assessment of the strength of the structure could not be undertaken, however by inspection a 215mm thk blockwork wall will not be able to resist 2m of retained soil.

Analysis summary

Design summary

Overall design utilisation 1000

Overall design status Fail

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	22.3	23.1	0.964	FAIL
Overturning stability	kNm/m	9.9	21	0.474	FAIL
Bearing pressure	kN/m ²	0	0	0.000	FAIL

9 Design of new structure

As the existing structure fails, strengthening is necessary to provide long term stability to the retaining structure.

Two options have been considered. These are:

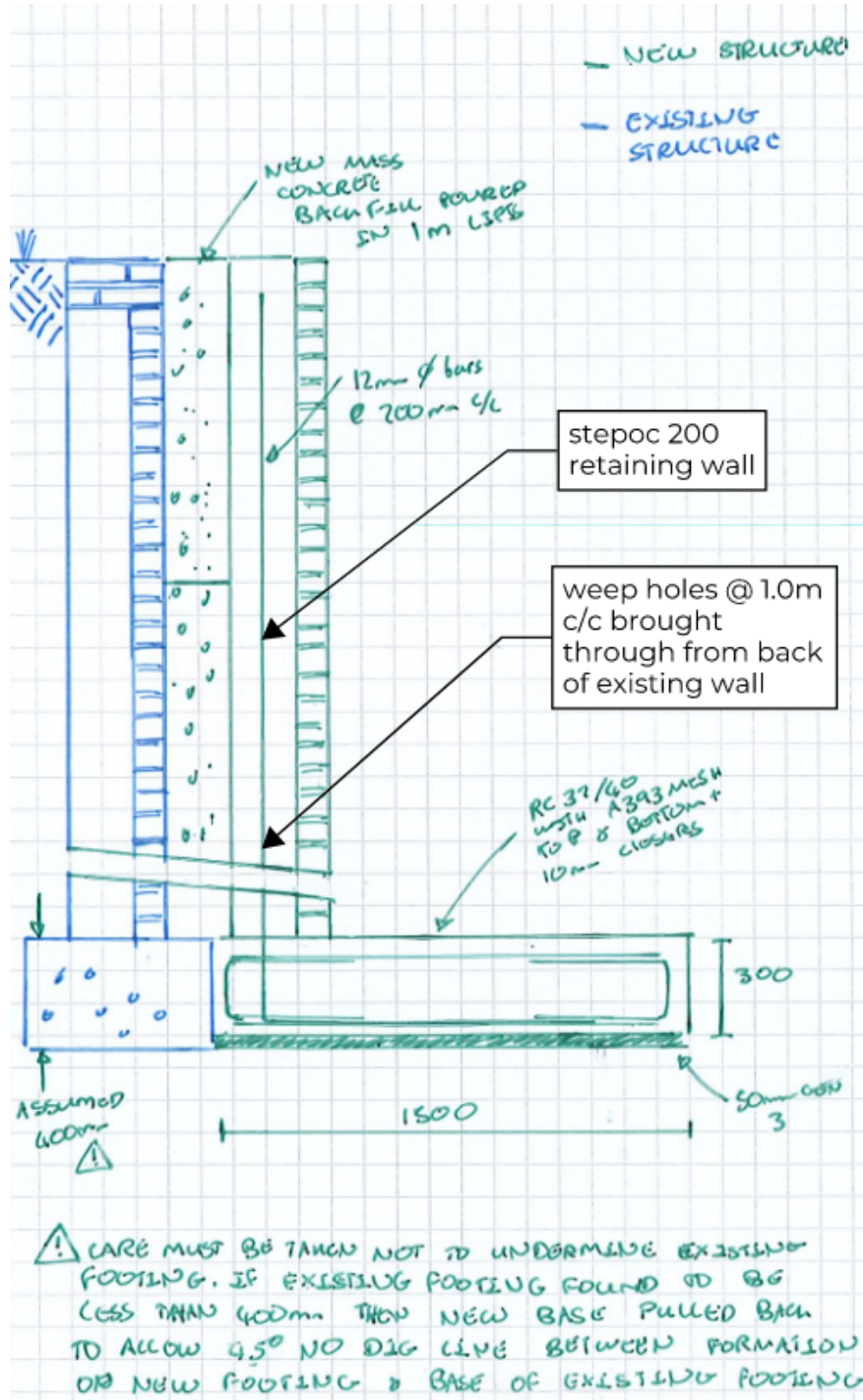
Option 1: Stepoc hollow block wall on a reinforced concrete foundation.

Option 2: Gravity mass concrete retaining wall.

9.1 Option 1: Stepoc hollowblock wall

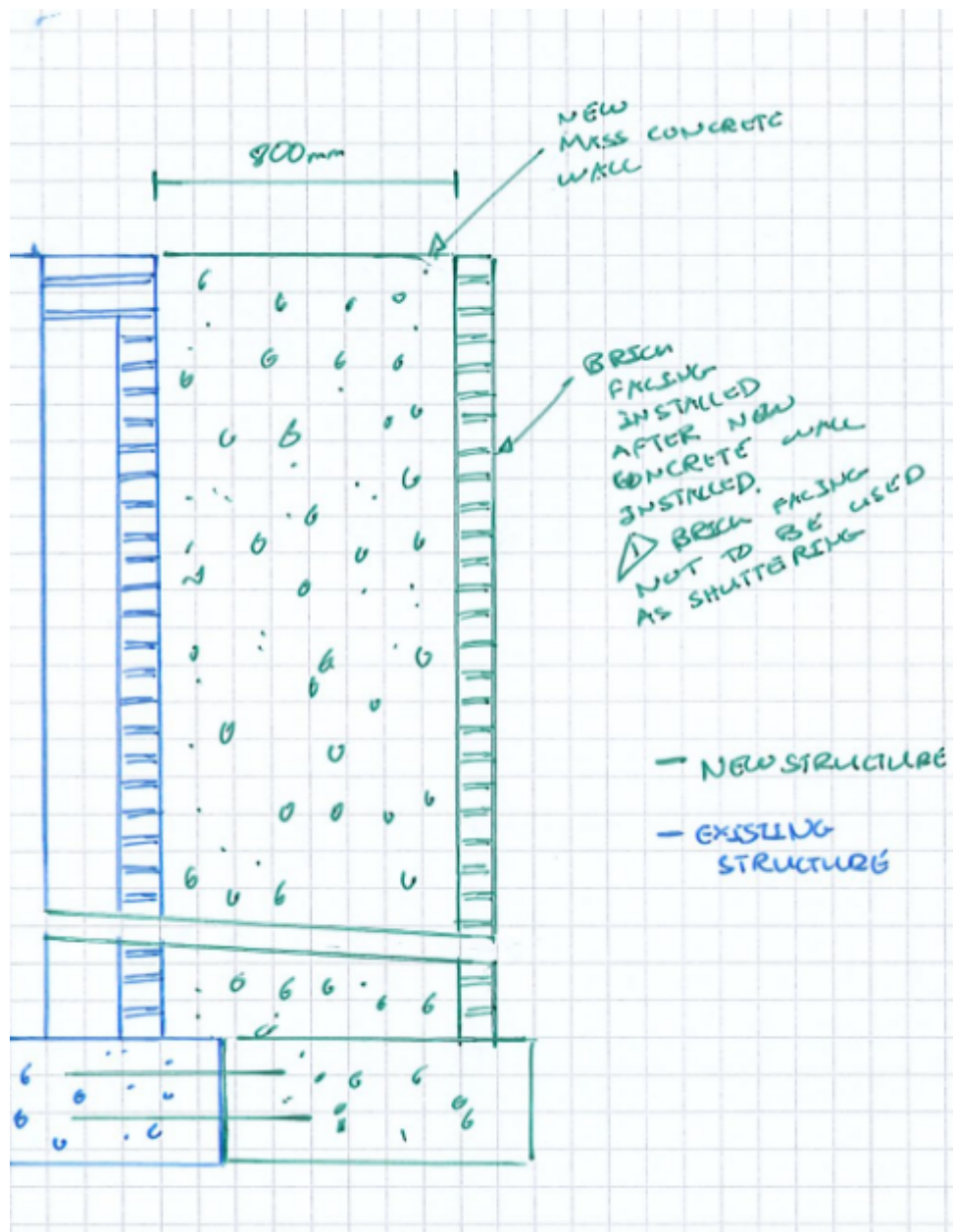
Option 1 comprises the installation of a new stepoc retaining wall on a reinforced concrete base. This option prevents overturning by transferring the lateral forces from the soil into the base and foundation via moment resistance in the wall.

The stepoc wall can be 200mm wide and reinforced with H12 bars going into the base. The base will comprise RC32/40 being 1.5m by 0.3m with A393 Mesh and 10mm closer bars. The base will be sat atop 50mm gen 3 blinding. Care must be taken not to undermine the footing of the existing foundation. At the time of writing this report no information is available depth of the existing footing, however if the footing is less than 400mm thk then the new structure will need to be moved back such that a 45deg no dig line can be drawn from the formation of the new structure to the base of the existing structure. Weep holes should be brought through from the back of the existing structure to the front of the new structure to alleviate any hydrostatic pressure that could be up behind the wall. A sketch of the proposal is shown below. Full calcs are provided in the Appendix.



9.2 Option 2: Mass concrete gravity retaining wall

Option 2 comprises the installation of a mass concrete gravity retaining structure in front of the existing wall. This option prevents overturning using the mass of the new structure to resist the lateral load of the soil. The required width of the wall will need to be a minimum of 800mm from the face of the existing. Like option 1 new weep holes will to be brought through from the back of the existing structure to the front of the new structure to alleviate any hydrostatic pressure that could be up behind the wall. A sketch of the proposal is shown below. Full calcs are provided in the Appendix.



10 Conclusions

Both option 1 and 2 are viable options to strengthen the existing structure. The options should be considered for their impact on the existing layout of the patio and be independently costed by a contractor. A full set of calcs is provided in the appendix.

11 Appendix

11.1 Existing Structure

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.21

Analysis summary

Design summary

Overall design utilisation 1000

Overall design status Fail

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	22.3	23.1	0.964	FAIL
Overturning stability	kNm/m	9.9	21	0.474	FAIL
Bearing pressure	kN/m ²	0	0	0.000	FAIL

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 2150$ mm
Stem thickness	$t_{\text{stem}} = 200$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{\text{stem}} = 25$ kN/m ³
Toe length	$l_{\text{toe}} = 200$ mm
Heel length	$l_{\text{heel}} = 200$ mm
Base thickness	$t_{\text{base}} = 300$ mm
Base density	$\gamma_{\text{base}} = 25$ kN/m ³
Height of retained soil	$h_{\text{ret}} = 2000$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{\text{cover}} = 150$ mm

Retained soil properties

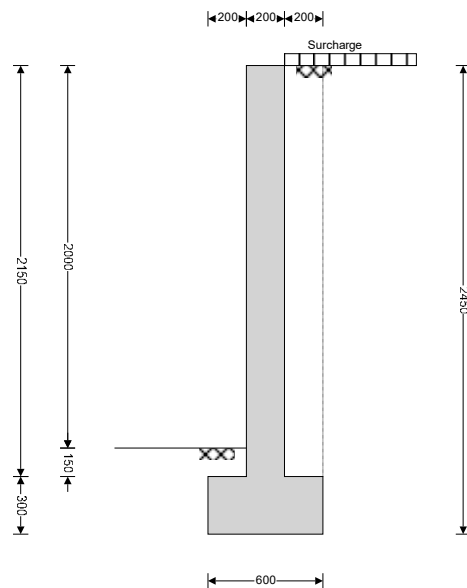
Soil type	Medium dense gravel
Moist density	$\gamma_{\text{mr}} = 19$ kN/m ³
Saturated density	$\gamma_{\text{sr}} = 19$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{r,k} = 34$ deg
Characteristic wall friction angle	$\delta_{r,k} = 17$ deg

Base soil properties

Soil type	Dense gravel
Soil density	$\gamma_b = 17.5$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{b,k} = 40$ deg
Characteristic wall friction angle	$\delta_{b,k} = 18$ deg
Characteristic base friction angle	$\delta_{bb,k} = 40$ deg
Presumed bearing capacity	$P_{\text{bearing}} = 125$ kN/m ²

Loading details

Variable surcharge load	Surcharge _Q = 2.5 kN/m ²
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General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

Moist soil height

Length of surcharge load

- Distance to vertical component

Effective height of wall

- Distance to horizontal component

Area of wall stem

- Distance to vertical component

Area of wall base

- Distance to vertical component

Area of moist soil

- Distance to vertical component

- Distance to horizontal component

Area of base soil

- Distance to vertical component

- Distance to horizontal component

Area of excavated base soil

- Distance to vertical component

- Distance to horizontal component

Using Rankine theory

Active pressure coefficient

Passive pressure coefficient

$$l_{base} = l_{toe} + t_{stem} + l_{heel} = 600 \text{ mm}$$

$$h_{moist} = h_{soil} = 2150 \text{ mm}$$

$$l_{sur} = l_{heel} = 200 \text{ mm}$$

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 500 \text{ mm}$$

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 2450 \text{ mm}$$

$$x_{sur_h} = h_{eff} / 2 = 1225 \text{ mm}$$

$$A_{stem} = h_{stem} \times t_{stem} = 0.43 \text{ m}^2$$

$$x_{stem} = l_{toe} + t_{stem} / 2 = 300 \text{ mm}$$

$$A_{base} = l_{base} \times t_{base} = 0.18 \text{ m}^2$$

$$x_{base} = l_{base} / 2 = 300 \text{ mm}$$

$$A_{moist} = h_{moist} \times l_{heel} = 0.43 \text{ m}^2$$

$$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = 500 \text{ mm}$$

$$x_{moist_h} = h_{eff} / 3 = 817 \text{ mm}$$

$$A_{pass} = d_{cover} \times l_{toe} = 0.03 \text{ m}^2$$

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 100 \text{ mm}$$

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 150 \text{ mm}$$

$$A_{exc} = h_{pass} \times l_{toe} = 0.03 \text{ m}^2$$

$$x_{exc_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = 100 \text{ mm}$$

$$x_{exc_h} = (h_{pass} + h_{base}) / 3 = 150 \text{ mm}$$

$$K_A = (1 - \sin(\phi'_{r.k})) / (1 + \sin(\phi'_{r.k})) = 0.283$$

$$K_P = (1 + \sin(\phi'_{b.k})) / (1 - \sin(\phi'_{b.k})) = 4.599$$

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$
Wall base	$F_{\text{base}} = A_{\text{base}} \times \gamma_{\text{base}} = 4.5 \text{ kN/m}$
Surcharge load	$F_{\text{sur}_v} = \text{Surcharge}_Q \times l_{\text{heel}} = 0.5 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_v} = A_{\text{moist}} \times \gamma_{\text{mr}} = 8.2 \text{ kN/m}$
Base soil	$F_{\text{pass}_v} = A_{\text{pass}} \times \gamma_b = 0.5 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{moist}_v} + F_{\text{pass}_v} = 24.4 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \text{Surcharge}_Q \times h_{\text{eff}} = 1.7 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = K_A \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = 16.1 \text{ kN/m}$
Base soil	$F_{\text{pass}_h} = -K_P \times \gamma_b \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = -8.1 \text{ kN/m}$
Total	$F_{\text{total}_h} = \max(F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} - F_{\text{total}_v} \times \tan(\delta_{\text{bb},k}), 0 \text{ kN/m}) = 0 \text{ kN/m}$

Moments on wall

Wall stem	$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = 3.2 \text{ kNm/m}$
Wall base	$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = 1.4 \text{ kNm/m}$
Surcharge load	$M_{\text{sur}} = F_{\text{sur}_v} \times x_{\text{sur}_v} - F_{\text{sur}_h} \times x_{\text{sur}_h} = -1.9 \text{ kNm/m}$
Moist retained soil	$M_{\text{moist}} = F_{\text{moist}_v} \times x_{\text{moist}_v} - F_{\text{moist}_h} \times x_{\text{moist}_h} = -9.1 \text{ kNm/m}$
Base soil	$M_{\text{pass}} = F_{\text{pass}_v} \times x_{\text{pass}_v} - F_{\text{pass}_h} \times x_{\text{pass}_h} = 1.3 \text{ kNm/m}$
Total	$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{moist}} + M_{\text{pass}} = -5.1 \text{ kNm/m}$

Check bearing pressure

Distance to reaction	$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = -209 \text{ mm}$
Eccentricity of reaction	$e = \bar{x} - l_{\text{base}} / 2 = -509 \text{ mm}$
Loaded length of base	$l_{\text{load}} = 3 \times \bar{x} = -626 \text{ mm}$
Bearing pressure at toe	$q_{\text{toe}} = 0 \text{ kN/m}^2$
Bearing pressure at heel	$q_{\text{heel}} = 0 \text{ kN/m}^2$
Factor of safety	$FoS_{\text{bp}} = 0$

FAIL - Reaction acts outside base area

FAIL - Maximum applied bearing pressure exceeds allowable bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set	A1
Permanent unfavourable action	$\gamma_G = 1.350$
Permanent favourable action	$\gamma_{Gf} = 1.000$
Variable unfavourable action	$\gamma_Q = 1.500$
Variable favourable action	$\gamma_{Qf} = 0.000$

Partial factors for soil parameters – Table A.4 - Combination 1

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_{\gamma} = 1.00$

Retained soil properties

Design moist density	$\gamma_{\text{mr}}' = \gamma_{\text{mr}} / \gamma_{\gamma} = 19 \text{ kN/m}^3$
Design saturated density	$\gamma_{\text{sr}}' = \gamma_{\text{sr}} / \gamma_{\gamma} = 19 \text{ kN/m}^3$

Design effective shear resistance angle
Design wall friction angle

Base soil properties

Design soil density
Design effective shear resistance angle
Design wall friction angle
Design base friction angle
Design effective cohesion

Using Rankine theory

Active pressure coefficient
Passive pressure coefficient

Sliding check

Vertical forces on wall

Wall stem
Wall base
Moist retained soil
Base soil
Total

Horizontal forces on wall

Surcharge load
Moist retained soil
Total

Check stability against sliding

Base soil resistance
Base friction
Resistance to sliding
Factor of safety

Overturning check

Vertical forces on wall

Wall stem
Wall base
Moist retained soil
Base soil
Total

Horizontal forces on wall

Surcharge load
Moist retained soil
Base soil
Total

Overturning moments on wall

Surcharge load
Moist retained soil
Total

Restoring moments on wall

Wall stem

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{34 \text{ deg}}$$

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{17 \text{ deg}}$$

$$\gamma'_b = \gamma_b / \gamma_f = \mathbf{17.5 \text{ kN/m}^3}$$

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{40 \text{ deg}}$$

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{18 \text{ deg}}$$

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{40 \text{ deg}}$$

$$c'_{b,d} = c'_{b,k} / \gamma_c = \mathbf{0 \text{ kN/m}^2}$$

$$K_A = (1 - \sin(\phi'_{r,d})) / (1 + \sin(\phi'_{r,d})) = \mathbf{0.283}$$

$$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = \mathbf{4.599}$$

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{10.8 \text{ kN/m}}$$

$$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{4.5 \text{ kN/m}}$$

$$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{8.2 \text{ kN/m}}$$

$$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma'_b = \mathbf{0.5 \text{ kN/m}}$$

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{23.9 \text{ kN/m}}$$

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{2.6 \text{ kN/m}}$$

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{21.8 \text{ kN/m}}$$

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = \mathbf{24.4 \text{ kN/m}}$$

$$F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \gamma'_b \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{8.1 \text{ kN/m}}$$

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{20.1 \text{ kN/m}}$$

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{28.2 \text{ kN/m}}$$

$$FoS_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.159}$$

PASS - Resistance to sliding is greater than sliding force

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{10.8 \text{ kN/m}}$$

$$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{4.5 \text{ kN/m}}$$

$$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{8.2 \text{ kN/m}}$$

$$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma'_b = \mathbf{0.5 \text{ kN/m}}$$

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{23.9 \text{ kN/m}}$$

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{2.6 \text{ kN/m}}$$

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{21.8 \text{ kN/m}}$$

$$F_{\text{exc}_h} = -\gamma_{Gf} \times K_P \times \gamma'_b \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-8.1 \text{ kN/m}}$$

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{16.2 \text{ kN/m}}$$

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{3.2 \text{ kNm/m}}$$

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{17.8 \text{ kNm/m}}$$

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = \mathbf{21 \text{ kNm/m}}$$

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{3.2 \text{ kNm/m}}$$

Wall base	$M_{\text{base}_R} = F_{\text{base}} \times x_{\text{base}} = 1.4 \text{ kNm/m}$
Moist retained soil	$M_{\text{moist}_R} = F_{\text{moist}_v} \times x_{\text{moist}_v} = 4.1 \text{ kNm/m}$
Base soil	$M_{\text{exc}_R} = F_{\text{exc}_v} \times x_{\text{exc}_v} - F_{\text{exc}_h} \times x_{\text{exc}_h} = 1.3 \text{ kNm/m}$
Total	$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = 9.9 \text{ kNm/m}$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{\text{total}_R} / M_{\text{total}_{OT}} = 0.474$$

FAIL - Overturning moment is greater than maximum restoring moment

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G = 1.000$
Permanent favourable action	$\gamma_{Gf} = 1.000$
Variable unfavourable action	$\gamma_Q = 1.300$
Variable favourable action	$\gamma_{Qf} = 0.000$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} = 1.25$
Effective cohesion	$\gamma_{c'} = 1.25$
Weight density	$\gamma_{\gamma} = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 19 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 19 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 28.4 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 13.7 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_{\gamma} = 17.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 33.9 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 33.9 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Rankine theory

Active pressure coefficient	$K_A = (1 - \sin(\phi'_{r,d})) / (1 + \sin(\phi'_{b,d})) = 0.356$
Passive pressure coefficient	$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{r,d})) = 3.518$

Sliding check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 4.5 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 8.2 \text{ kN/m}$
Base soil	$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 0.5 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = 23.9 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 2.8 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 20.3 \text{ kN/m}$
Total	$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 23.1 \text{ kN/m}$

Check stability against sliding

Base soil resistance

$$F_{exc_h} = \gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{6.2 \text{ kN/m}}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = \mathbf{16.1 \text{ kN/m}}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{22.3 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{0.964}$$

FAIL - Sliding force is greater than resistance to sliding

Overturning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{10.8 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{4.5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{8.2 \text{ kN/m}}$$

Base soil

$$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = \mathbf{0.5 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = \mathbf{23.9 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{2.8 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{20.3 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-6.2 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{16.9 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = \mathbf{3.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = \mathbf{16.6 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{20.1 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{3.2 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{1.4 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{4.1 \text{ kNm/m}}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = \mathbf{1 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{9.6 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{0.481}$$

FAIL - Overturning moment is greater than maximum restoring moment

11.2 Option 1: Stepoc base analysis

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.21

Analysis summary

Design summary

Overall design utilisation 0.993

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	23.3	23.1	1.007	PASS
Overturning stability	kNm/m	26.9	21	1.285	PASS
Bearing pressure	kN/m ²	125	37	3.380	PASS

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 2150$ mm
Stem thickness	$t_{\text{stem}} = 200$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{\text{stem}} = 25$ kN/m ³
Toe length	$l_{\text{toe}} = 1300$ mm
Base thickness	$t_{\text{base}} = 300$ mm
Base density	$\gamma_{\text{base}} = 25$ kN/m ³
Height of retained soil	$h_{\text{ret}} = 2000$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{\text{cover}} = 150$ mm

Retained soil properties

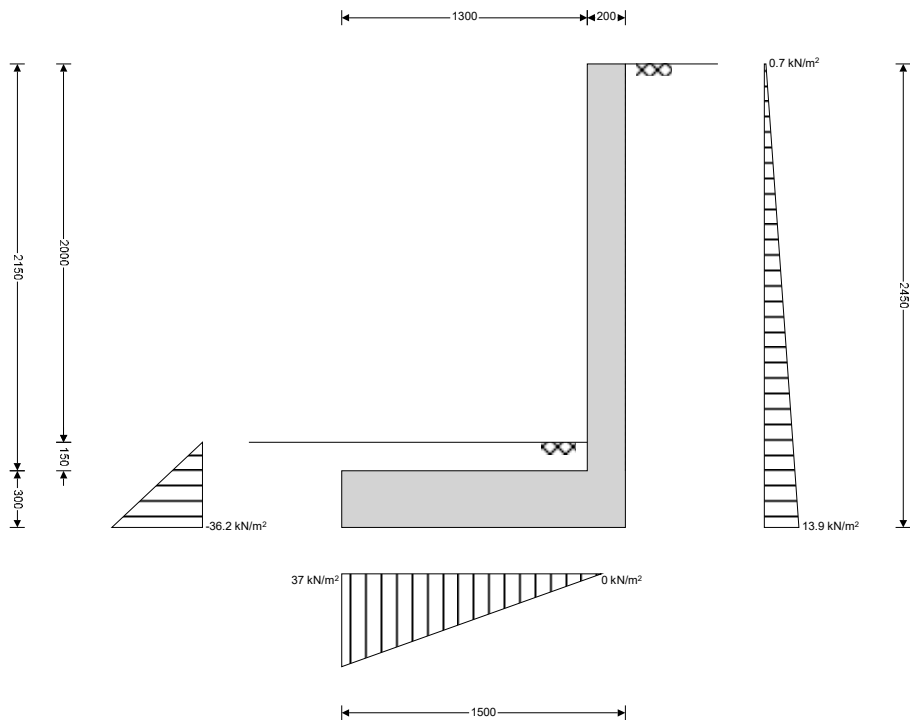
Soil type	Medium dense gravel
Moist density	$\gamma_{\text{mr}} = 19$ kN/m ³
Saturated density	$\gamma_{\text{sr}} = 19$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{r,k} = 34$ deg
Characteristic wall friction angle	$\delta_{r,k} = 17$ deg

Base soil properties

Soil type	Dense gravel
Soil density	$\gamma_b = 17.5$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{b,k} = 40$ deg
Characteristic wall friction angle	$\delta_{b,k} = 18$ deg
Characteristic base friction angle	$\delta_{bb,k} = 40$ deg
Presumed bearing capacity	$P_{\text{bearing}} = 125$ kN/m ²

Loading details

Variable surcharge load	Surcharge _Q = 2.5 kN/m ²
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General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

Moist soil height

Length of surcharge load

- Distance to vertical component

Effective height of wall

- Distance to horizontal component

Area of wall stem

- Distance to vertical component

Area of wall base

- Distance to vertical component

Area of base soil

- Distance to vertical component

- Distance to horizontal component

Area of excavated base soil

- Distance to vertical component

- Distance to horizontal component

Using Rankine theory

Active pressure coefficient

Passive pressure coefficient

Bearing pressure check

Vertical forces on wall

Wall stem

$$l_{\text{base}} = l_{\text{toe}} + t_{\text{stem}} = 1500 \text{ mm}$$

$$h_{\text{moist}} = h_{\text{soil}} = 2150 \text{ mm}$$

$$l_{\text{sur}} = l_{\text{heel}} = 0 \text{ mm}$$

$$x_{\text{sur}_v} = l_{\text{base}} - l_{\text{heel}} / 2 = 1500 \text{ mm}$$

$$h_{\text{eff}} = h_{\text{base}} + d_{\text{cover}} + h_{\text{ret}} = 2450 \text{ mm}$$

$$x_{\text{sur}_h} = h_{\text{eff}} / 2 = 1225 \text{ mm}$$

$$A_{\text{stem}} = h_{\text{stem}} \times t_{\text{stem}} = 0.43 \text{ m}^2$$

$$x_{\text{stem}} = l_{\text{toe}} + t_{\text{stem}} / 2 = 1400 \text{ mm}$$

$$A_{\text{base}} = l_{\text{base}} \times t_{\text{base}} = 0.45 \text{ m}^2$$

$$x_{\text{base}} = l_{\text{base}} / 2 = 750 \text{ mm}$$

$$A_{\text{pass}} = d_{\text{cover}} \times l_{\text{toe}} = 0.195 \text{ m}^2$$

$$x_{\text{pass}_v} = l_{\text{base}} - (d_{\text{cover}} \times l_{\text{toe}} \times (l_{\text{base}} - l_{\text{toe}} / 2)) / A_{\text{pass}} = 650 \text{ mm}$$

$$x_{\text{pass}_h} = (d_{\text{cover}} + h_{\text{base}}) / 3 = 150 \text{ mm}$$

$$A_{\text{exc}} = h_{\text{pass}} \times l_{\text{toe}} = 0.195 \text{ m}^2$$

$$x_{\text{exc}_v} = l_{\text{base}} - (h_{\text{pass}} \times l_{\text{toe}} \times (l_{\text{base}} - l_{\text{toe}} / 2)) / A_{\text{exc}} = 650 \text{ mm}$$

$$x_{\text{exc}_h} = (h_{\text{pass}} + h_{\text{base}}) / 3 = 150 \text{ mm}$$

$$K_A = (1 - \sin(\phi'_{r.k})) / (1 + \sin(\phi'_{r.k})) = 0.283$$

$$K_P = (1 + \sin(\phi'_{b.k})) / (1 - \sin(\phi'_{b.k})) = 4.599$$

$$F_{\text{stem}} = A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$$

Wall base
Base soil
Total

$$F_{\text{base}} = A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{11.2 \text{ kN/m}}$$

$$F_{\text{pass}_v} = A_{\text{pass}} \times \gamma_b = \mathbf{3.4 \text{ kN/m}}$$

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{pass}_v} = \mathbf{25.4 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load
Moist retained soil
Base soil
Total

$$F_{\text{sur}_h} = K_A \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{1.7 \text{ kN/m}}$$

$$F_{\text{moist}_h} = K_A \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = \mathbf{16.1 \text{ kN/m}}$$

$$F_{\text{pass}_h} = -K_P \times \gamma_b \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{-8.1 \text{ kN/m}}$$

$$F_{\text{total}_h} = \max(F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} - F_{\text{total}_v} \times \tan(\delta_{\text{bb},k}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem
Wall base
Surcharge load
Moist retained soil
Base soil
Total

$$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = \mathbf{15.1 \text{ kNm/m}}$$

$$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = \mathbf{8.4 \text{ kNm/m}}$$

$$M_{\text{sur}} = -F_{\text{sur}_h} \times x_{\text{sur}_h} = \mathbf{-2.1 \text{ kNm/m}}$$

$$M_{\text{moist}} = -F_{\text{moist}_h} \times x_{\text{moist}_h} = \mathbf{-13.2 \text{ kNm/m}}$$

$$M_{\text{pass}} = F_{\text{pass}_v} \times x_{\text{pass}_v} - F_{\text{pass}_h} \times x_{\text{pass}_h} = \mathbf{3.4 \text{ kNm/m}}$$

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{moist}} + M_{\text{pass}} = \mathbf{11.6 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction
Eccentricity of reaction
Loaded length of base
Bearing pressure at toe
Bearing pressure at heel
Factor of safety

$$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = \mathbf{458 \text{ mm}}$$

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{-292 \text{ mm}}$$

$$l_{\text{load}} = 3 \times \bar{x} = \mathbf{1374 \text{ mm}}$$

$$q_{\text{toe}} = 2 \times F_{\text{total}_v} / l_{\text{load}} = \mathbf{37 \text{ kN/m}^2}$$

$$q_{\text{heel}} = \mathbf{0 \text{ kN/m}^2}$$

$$FoS_{\text{bp}} = P_{\text{bearing}} / \max(q_{\text{toe}}, q_{\text{heel}}) = \mathbf{3.38}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set	A1
Permanent unfavourable action	$\gamma_G = \mathbf{1.350}$
Permanent favourable action	$\gamma_{Gf} = \mathbf{1.000}$
Variable unfavourable action	$\gamma_Q = \mathbf{1.500}$
Variable favourable action	$\gamma_{Qf} = \mathbf{0.000}$

Partial factors for soil parameters – Table A.4 - Combination 1

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'} = \mathbf{1.00}$
Effective cohesion	$\gamma_{c'} = \mathbf{1.00}$
Weight density	$\gamma_{\gamma} = \mathbf{1.00}$

Retained soil properties

Design moist density	$\gamma_{\text{mr}}' = \gamma_{\text{mr}} / \gamma_{\gamma} = \mathbf{19 \text{ kN/m}^3}$
Design saturated density	$\gamma_{\text{sr}}' = \gamma_{\text{sr}} / \gamma_{\gamma} = \mathbf{19 \text{ kN/m}^3}$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{34 \text{ deg}}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{17 \text{ deg}}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_{\gamma} = \mathbf{17.5 \text{ kN/m}^3}$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{40 \text{ deg}}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{18 \text{ deg}}$
Design base friction angle	$\delta_{\text{bb},d} = \text{atan}(\tan(\delta_{\text{bb},k}) / \gamma_{\phi'}) = \mathbf{40 \text{ deg}}$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_c = 0 \text{ kN/m}^2$$

Using Rankine theory

Active pressure coefficient

$$K_A = (1 - \sin(\phi'_{r,d})) / (1 + \sin(\phi'_{r,d})) = 0.283$$

Passive pressure coefficient

$$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = 4.599$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma G_f \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma G_f \times A_{\text{base}} \times \gamma_{\text{base}} = 11.2 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_v} = \gamma G_f \times A_{\text{exc}} \times \gamma_b' = 3.4 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{exc}_v} = 25.4 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 2.6 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 21.8 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 24.4 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma G_f \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 8.1 \text{ kN/m}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{\text{bb},d}) = 21.3 \text{ kN/m}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 29.5 \text{ kN/m}$$

Factor of safety

$$\text{FoS}_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.21$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma G_f \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma G_f \times A_{\text{base}} \times \gamma_{\text{base}} = 11.2 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_v} = \gamma G_f \times A_{\text{exc}} \times \gamma_b' = 3.4 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{exc}_v} = 25.4 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 2.6 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 21.8 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_h} = -\gamma G_f \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = -8.1 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = 16.2 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_{\text{OT}}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = 3.2 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_{\text{OT}}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = 17.8 \text{ kNm/m}$$

Total

$$M_{\text{total}_{\text{OT}}} = M_{\text{sur}_{\text{OT}}} + M_{\text{moist}_{\text{OT}}} = 21 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = 15.1 \text{ kNm/m}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = 8.4 \text{ kNm/m}$$

Base soil

$$M_{\text{exc}_R} = F_{\text{exc}_v} \times X_{\text{exc}_v} - F_{\text{exc}_h} \times X_{\text{exc}_h} = 3.4 \text{ kNm/m}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{exc}_R} = 26.9 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$\text{FoS}_{\text{ot}} = M_{\text{total}_R} / M_{\text{total}_{\text{OT}}} = 1.285$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G = 1.000$
Permanent favourable action	$\gamma_{Gf} = 1.000$
Variable unfavourable action	$\gamma_Q = 1.300$
Variable favourable action	$\gamma_{Qf} = 0.000$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} = 1.25$
Effective cohesion	$\gamma_{c'} = 1.25$
Weight density	$\gamma_f = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_f = 19 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_f = 19 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 28.4 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 13.7 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_f = 17.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 33.9 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 33.9 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Rankine theory

Active pressure coefficient	$K_A = (1 - \sin(\phi'_{r,d})) / (1 + \sin(\phi'_{r,d})) = 0.356$
Passive pressure coefficient	$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = 3.518$

Sliding check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 11.2 \text{ kN/m}$
Base soil	$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 3.4 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{exc}_v} = 25.4 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 2.8 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 20.3 \text{ kN/m}$
Total	$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 23.1 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 6.2 \text{ kN/m}$
Base friction	$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 17.1 \text{ kN/m}$
Resistance to sliding	$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 23.3 \text{ kN/m}$
Factor of safety	$FoS_{sl} = F_{\text{rest}} / F_{\text{total}_h} = 1.007$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.8 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 11.2 \text{ kN/m}$

Base soil

$$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = \mathbf{3.4 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{exc_v} = \mathbf{25.4 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{2.8 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{20.3 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-6.2 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{16.9 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = \mathbf{3.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = \mathbf{16.6 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{20.1 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{15.1 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{8.4 \text{ kNm/m}}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = \mathbf{3.2 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{exc_R} = \mathbf{26.6 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{1.328}$$

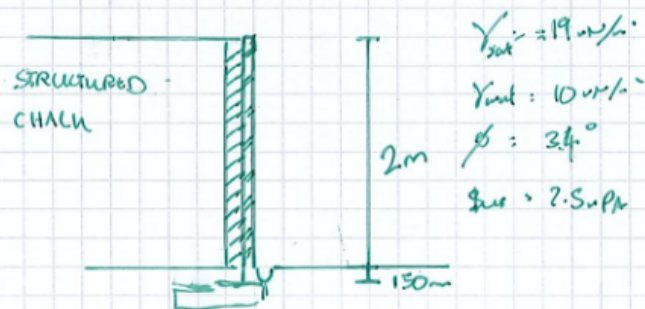
PASS - Maximum restoring moment is greater than overturning moment

11.3 Option 1: Stepoc wall analysis

PROJECT	SHANAWAY	JOB N°	14861	SHEET N°	1	REV	
ELEMENT	RETAINING WALL : COADING	DATE	23.12.25	BY	36	CHECKED	

INTRODUCTION

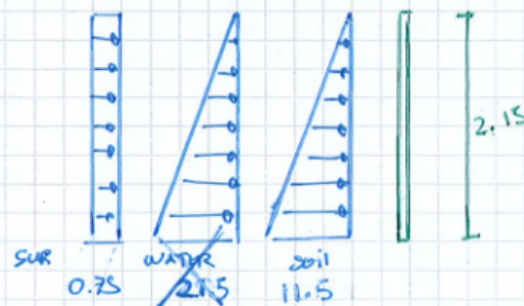
THE PURPOSE OF THIS CALCULATION IS TO DESIGN STRENGTHENING FOR THE RETAINING WALL @ SHANAWAY



DESIGN

$$K_a = \frac{(1 - \sin \phi)}{(1 + \sin \phi)} = \frac{(1 - \sin 34)}{(1 + \sin 34)} = 0.28$$

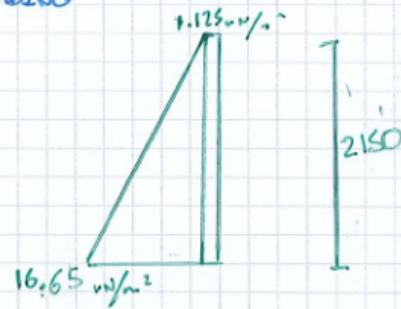
$$K_p = \frac{1 + \sin \phi}{1 - \sin \phi} = \frac{(1 + \sin 34)}{(1 - \sin 34)} = 3.5$$



ASSUME LUGGED HOLES ARE POST INSTALLED

PROJECT	SHANAWAY	JOB N°	14861	SHEET N°	2	REV	
ELEMENT	RETAINING WALL : LOADING	DATE	23.12.25	BY	SG	CHECKED	

DESIGN LOADING

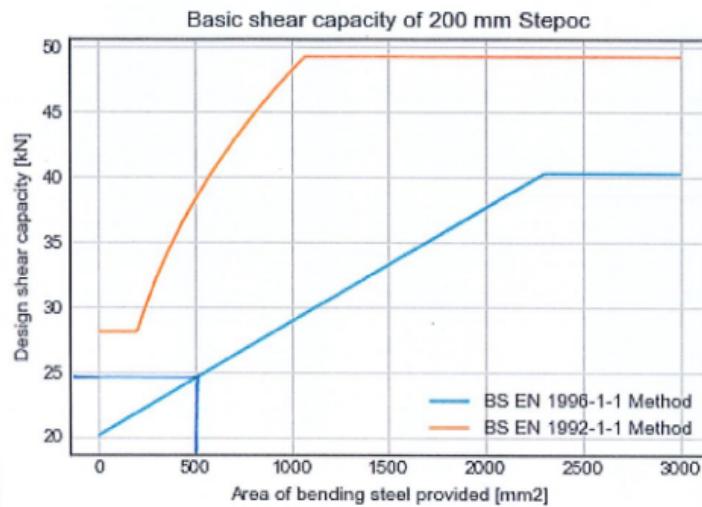


$$V_{ed} : 1.125 \times 2.15 + 16.65 \times \frac{2.15}{2} = 20.3 \text{ kN/m}$$

$$M_{ed} : 1.125 \times \frac{2.15^2}{2} + 16.65 \times \frac{2.15}{2 \times 3} = 15.6 \text{ kNm}$$

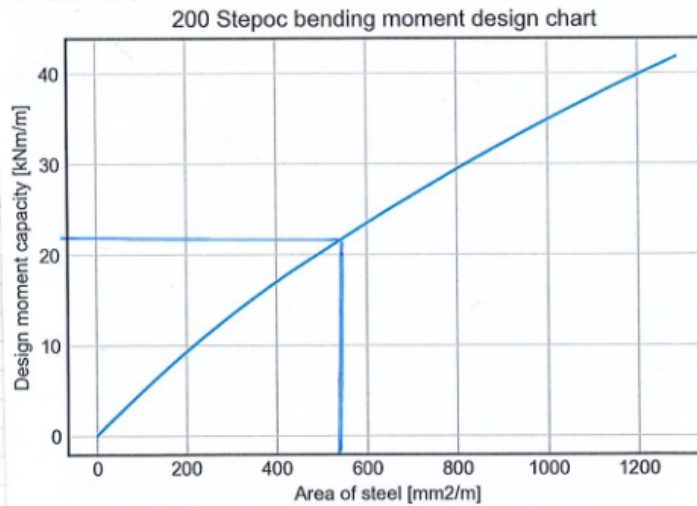
PROJECT	SHANAWAY	JOB N°	14861	SHEET N°	3	REV	
ELEMENT	RETAINING WALL : OPTION 1 : STOPS	DATE	23.12.25	BY	SG	CHECKED	

DESIGN STOPOC WALL



USE
H12 @ 200
c/c
 $A_s = 565 \text{ mm}^2/\text{m}$

$$V_{Rd} = 25 \text{ kN/m} > 20.3 \text{ kN/m}$$



$$M_{Rd} = 22 \text{ kNm/m} > 15.6 \text{ kNm/m}$$

11.4 Option 2: Mass concrete Gravity retaining structure



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CONSULTING STRUCTURAL & CIVIL ENGINEERS

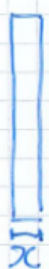
Romsey: 01794 524447 Bath: 01225 251498
mail@awaengineers.com
www.awaengineers.com



PROJECT	SHANAWAN	JOB N°	1426	SHEET N°	4	REV	
ELEMENT	RETAINING WALL: OPTION 2	DATE	23.12.25	BY	JS	CHECKED	

MASS CONCRETE WALL OPTION

15.4 kNm OVERTURNING



$$\frac{M}{N} < \frac{x}{6}$$

$$\frac{15.4}{2 \times x \times 2.4} < \frac{x}{2}$$

$$30.8 = 48x^2$$

$x = 0.8m$

CHECK



$M_o : 15.4 \text{ kNm}$

$M_R : 38.4 \times 0.4 = 15.36 \approx 15.4 \text{ kNm}$

11.5 Sketch: Option 1: Stepoc Wall

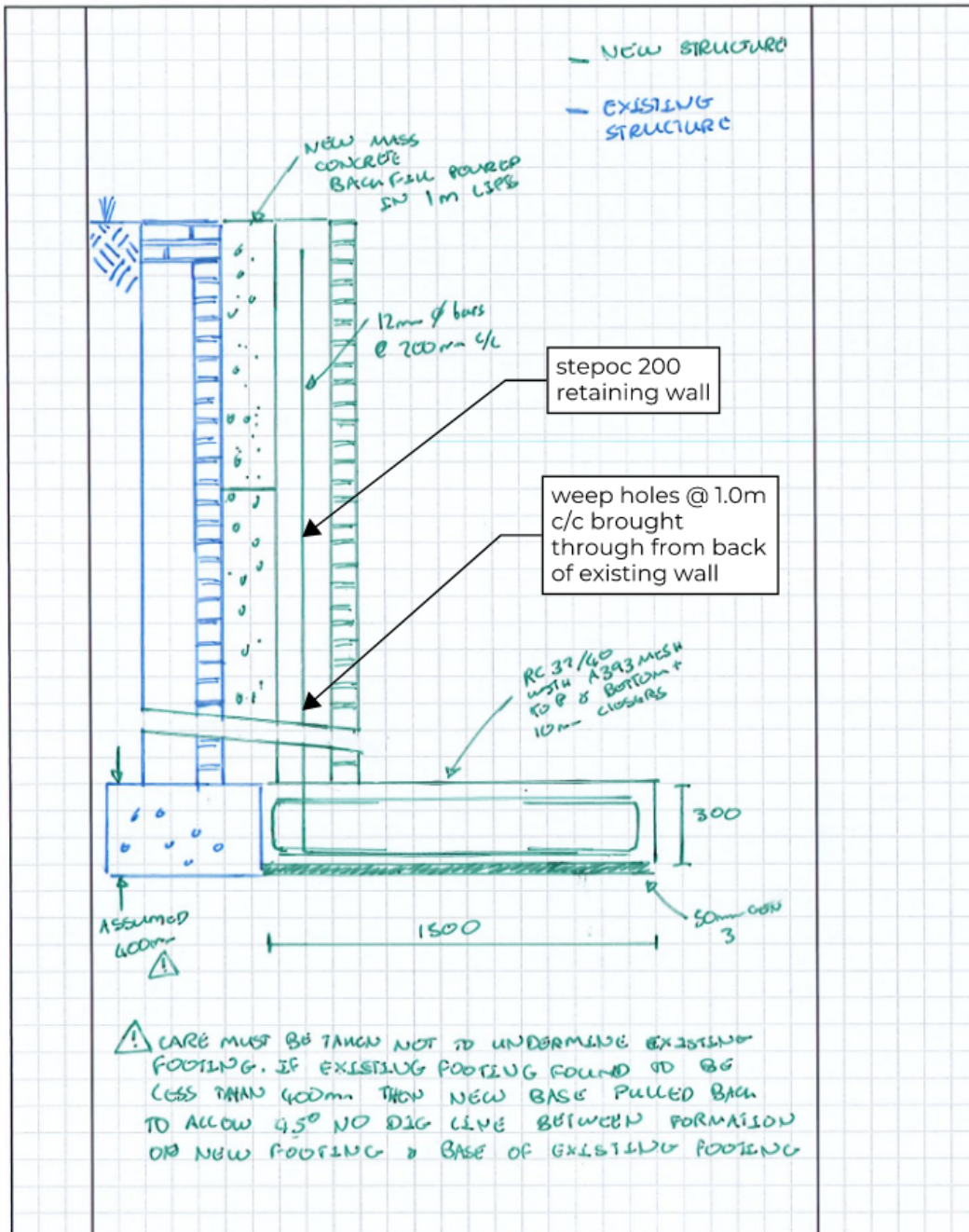


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PROJECT	SHANAWAY	JOB N°	14861	SHEET N°	5	REV	
ELEMENT	OPTION 1: STEP OC WALL	DATE	23.12.23	BY	SG	CHECKED	



11.6 Sketch: Option 2: Mass Concrete Gravity Retaining Wall



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PROJECT	SHANAWAY	JOB N°	14861	SHEET N°	6	REV	
ELEMENT	OPTION 2: MASS CONCRETE WALL	DATE	23.12.23	BY	JG	CHECKED	

