STRUCTURAL CALCULATIONS

EXTENSIONS AND ALTERATIONS

For

MR Matt Godfrey

C/O

76 FLEET ROAD

LONDON

NW3 2QT

June 2016

PREAMBLE

1. The calculations that follow form part only of the overall application submitted for Building Control Approval and are based upon drawings prepared by others. Dimensions used in calculations have been scaled/obtained from such drawings.

2. The purpose of the calculations is to justify the use of identified structural members as shown on plans, or to determine minimum sizes necessary to comply with relevant Standards where sizes have either not been shown on plans or have proved to be undersized. Should sizes calculated conflict with those shown on plans the most structurally beneficial shall be adopted and it is the responsibility of the drawing originator to amend plans as appropriate.

3. The calculations are in respect only of those structural elements to which they specifically refer. No responsibility or liability is therefore accepted in respect of any other element or part of the building.

4. The contractor is to take all necessary precautions to ensure the safety of the building and its stability during all stages of the proposed works.

5. Any alterations to the drawings or any on site discrepancies or changes affected on site during construction should be notified to the Structural Engineer in writing, with specific instructions to accommodate the changes made – as such changes could materially affect the sizes of the structural members that have been designed, approved and adopted on plans.

6. In any event, all work shall be made available for inspection by, and shall be to the entire satisfaction of, the Local Authority Building Control Inspector or other Approved Inspector.

7. No work appertaining to the plans should be carried out until the plans and calculations have been examined by the appropriate Local/Statutory Authority and formal written approval obtained. Any works carried before such approval is obtained, either for the original Application or revised information, is done solely at the Contractor's/Owners own risk. No works relating to these calculations should be carried out if 'Conditional Approval Subject to Calculations' is granted by the Local Authority.

8. No site visits are to be made by the Engineer during the course of construction unless specifically requested in writing.

GENERAL NOTES

1. For setting out dimensions and general construction details, see Architect's Drawings. Any Engineer's sketch or drawings must not be scaled.

2. Contractor to check all dimensions and levels prior to commencing any construction or fabrication.

3. Any sketch, drawing or specification is to be read in conjunction with all other sketches, drawings or specifications relating to the project.

4. Where site or adjoining building details are at variance with issued details the Engineer is to be informed immediately in writing.

5. The contractor is to ensure the stability of each element and the whole building until the construction is complete.

6. All designs, connections, workmanship and materials are to comply with current Building Regulations, relevant British Standards, Codes of Practice, Manufacturers recommendations and Engineer details.

7. No structural members are to be cut, notched or jointed unless specified.

8. Proprietary structural elements, fixings or admixtures may only be used with Engineer's approval and to manufacturers' recommendations.

9. Unless noted otherwise, all connections (including laps and anchorage of any reinforcement in concrete) shall mobilize the full structural capacity of the member.

10. All boiled connections of steelwork shall have a minimum of 2 bolts.

11. All structural connections of timber to be formed using double-sided timber connectors and bolts with large washers.

12. No holes of any size to be formed in structural members unless specified by the Engineer or approval by him in writing.

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LOADING (kN/m^2)

The following loading is generally considered in the design of structural elements.

PITCHED ROOF:	**Tiles**		0.55
	Rafters, Battens and Felt	0.15	
	IMPOSED		0.60
			1.30
FLAT ROOF:	**Chipping's and Bitumen**	0.20	
	Three Layers Felt		0.10
	Boarding, Joists	0.29	
	Insulation		0.05
	Plasterboard & Skim		0.18
	IMPOSED		0.75
			1.55
LOFT / CEILING:	**Joists / Boarding**		0.12
	Insulation		0.03
	Plasterboard and Skim	0.18	
	IMPOSED		0.25
			0.58
FLOOR:	**Boarding**		0.13
	Joists		0.17
	Plasterboard and Skim	0.20	
	IMPOSED		1.50
			2.00
STUD WALL:	**Studs and Noggins**		0.09
	Insulation		0.03
	Plasterboard and Skim	0.36	
			0.48
100mm BRICK WALL:	**Bricks**		2.15
	Plaster and Skim x 2		0.70
			2.85
215mm BRICK WALL:	**Bricks**		4.30
	Render, Plaster and Skim		0.70
			5.00
CAVITY WALL:	**102 Brick**		2.15
	125 Block + Insulation		0.58
	Plaster and Skim		0.35
			3.08
GLASS BRICK WALL:	**102 Brick**		**2.45**
	50 Brick		**1.2**

BASEMENT RETAINING WALL & SLAB DESIGN

BASEMENT SLAB

Loading:

Self-weight = 0.15x25kN/m^3 = 3.75kN/m^2

Screed/Insulation = 0.075mx23kN/m^3 = 1.73kN/m^2

Variable load due to imposed loading on the slab surface = 1.5kN/m^2

Variable load due to uplift pressure from the water (assuming 3m of waterhead) = 10kN/m^3 x 3m = 30kN/m^2

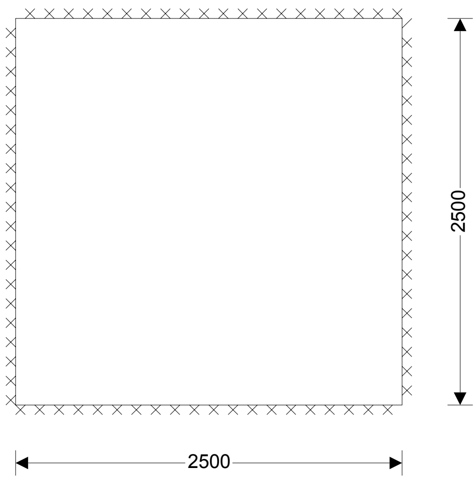
Span moment due to gravity loads = (1.35 x 5.48 + 1.5x1.5) x 2.5^2/8 = 7.53kNm/m

Span moment due to uplift pressure = (1.35x5.48 – 1.5x30) x 2.5^2/8 (conservatively ignore imposed load) = -29.37kNm/m

Maximum Shear Force = 37.6kN x 2.5/2 = 47.0kN

RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex



Slab definition

Slab reference name;	**Basement Infill Slab**
Type of slab;	**Two way spanning with restrained edges**
Overall slab depth;	h = **150** mm
Shorter effective span of panel;	l_x = **2500** mm
Longer effective span of panel;	l_y = **2500** mm
Support conditions;	**Four edges continuous (interior panel)**
Top outer layer of reinforcement;	**Short span direction**
Bottom outer layer of reinforcement;	**Short span direction**

Loading

Characteristic permanent action;	G_k = **5.5** kN/m^2
Characteristic variable action;	Q_k = **28.5** kN/m^2
Partial factor for permanent action;	γ_G = **1.35**
Partial factor for variable action;	γ_Q = **1.50**
Quasi-permanent value of variable action;	ψ_2 = **0.30**
Design ultimate load;	$q = \gamma_G \times G_k + \gamma_Q \times Q_k$ = **50.1** kN/m^2
Quasi-permanent load;	$q_{SLS} = 1.0 \times G_k + \psi_2 \times Q_k$ = **14.0** kN/m^2

Concrete properties

Concrete strength class;	C25/30
Characteristic cylinder strength;	f_{ck} = **25** N/mm^2
Partial factor (Table 2.1N);	γ_C = **1.50**
Compressive strength factor (cl. 3.1.6);	α_{cc} = **0.85**
Design compressive strength (cl. 3.1.6);	f_{cd} = **14.2** N/mm^2
Mean axial tensile strength (Table 3.1);	$f_{ctm} = 0.30\ N/mm^2 \times (f_{ck} / 1\ N/mm^2)^{2/3}$ = **2.6** N/mm^2
Maximum aggregate size;	d_g = **20** mm

Reinforcement properties

Characteristic yield strength;	f_{yk} = **500** N/mm^2
Partial factor (Table 2.1N);	γ_S = **1.15**
Design yield strength (fig. 3.8);	$f_{yd} = f_{yk} / \gamma_S$ = **434.8** N/mm^2

Concrete cover to reinforcement

Nominal cover to outer top reinforcement;	c_{nom_t} = **30** mm
Nominal cover to outer bottom reinforcement;	c_{nom_b} = **50** mm
Fire resistance period to top of slab;	R_{top} = **30** min
Fire resistance period to bottom of slab;	R_{btm} = **30** min
Axia distance to top reinft (Table 5.8);	a_{fi_t} = **10** mm
Axia distance to bottom reinft (Table 5.8);	a_{fi_b} = **10** mm
Min. top cover requirement with regard to bond;	c_{min,b_t} = **10** mm
Min. btm cover requirement with regard to bond;	c_{min,b_b} = **10** mm
Reinforcement fabrication;	**Not subject to QA system**
Cover allowance for deviation;	Δc_{dev} = **10** mm
Min. required nominal cover to top reinft;	$c_{nom\_t\_min}$ = **20.0** mm
Min. required nominal cover to bottom reinft;	$c_{nom\_b\_min}$ = **20.0** mm

PASS - There is sufficient cover to the top reinforcement

PASS - There is sufficient cover to the bottom reinforcement

Reinforcement design at midspan in short span direction (cl.6.1)

Bending moment coefficient;	β_{sx_p} = **0.0240**
Design bending moment;	$M_{x\_p} = \beta_{sx\_p} \times q \times l_x^2$ = **7.5** kNm/m
Reinforcement provided;	A393 mesh
Area provided;	A_{sx_p} = 393 mm^2/m
Effective depth to tension reinforcement;	$d_{x\_p} = h - c_{nom\_b} - \phi_{x\_p} / 2$ = **95.0** mm
K factor;	$K = M_{x\_p} / (b \times d_{x\_p}^2 \times f_{ck})$ = **0.033**
Redistribution ratio;	δ = 1.0
K' factor;	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm;	$z = \min(0.95 \times d_{x\_p}, d_{x\_p}/2 \times (1 + (1 - 3.53\times K)^{0.5}))$ = **90.2** mm
Area of reinforcement required for bending;	$A_{sx\_p\_m} = M_{x\_p} / (f_{yd} \times z)$ = **192** mm^2/m
Minimum area of reinforcement required;	$A_{sx\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_p}, 0.0013\times b\times d_{x\_p})$ = **127** mm^2/m
Area of reinforcement required;	$A_{sx\_p\_req} = \max(A_{sx\_p\_m}, A_{sx\_p\_min})$ = **192** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress;	$\sigma_{sx\_p} = (f_{yk} / \gamma_S) \times \min((A_{sx\_p\_m}/A_{sx\_p}), 1.0) \times q_{SLS} / q$ = **59.3** N/mm^2
Maximum allowable spacing (Table 7.3N);	$s_{max\_x\_p}$ = **300** mm
Actual bar spacing;	s_{x_p} = **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan in long span direction (cl.6.1)

Bending moment coefficient; β_{sy_p} = **0.0240**

Design bending moment; $M_{y\_p} = \beta_{sy\_p} \times q \times l_x^2$ = **7.5** kNm/m

Reinforcement provided; A393 mesh

Area provided; A_{sy_p} = 393 mm^2/m

Effective depth to tension reinforcement; $d_{y\_p} = h - c_{nom\_b} - \phi_{x\_p} - \phi_{y\_p} / 2$ = **85.0** mm

K factor; $K = M_{y\_p} / (b \times d_{y\_p}^2 \times f_{ck})$ = **0.042**

Redistribution ratio; $\delta = 1.0$

K' factor; $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm; $z = \min(0.95 \times d_{y\_p}, d_{y\_p}/2 \times (1 + (1 - 3.53\times K)^{0.5}))$ = **80.7** mm

Area of reinforcement required for bending; $A_{sy\_p\_m} = M_{y\_p} / (f_{yd} \times z)$ = **214** mm^2/m

Minimum area of reinforcement required; $A_{sy\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_p}, 0.0013\times b\times d_{y\_p})$ = **113** mm^2/m

Area of reinforcement required; $A_{sy\_p\_req} = \max(A_{sy\_p\_m}, A_{sy\_p\_min})$ = **214** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress; $\sigma_{sy\_p} = (f_{yk} / \gamma_S) \times \min((A_{sy\_p\_m}/A_{sy\_p}), 1.0) \times q_{SLS} / q$ = **66.3** N/mm^2

Maximum allowable spacing (Table 7.3N); $s_{max\_y\_p}$ = **300** mm

Actual bar spacing; s_{y_p} = **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at continuous support in short span direction (cl.6.1)

Bending moment coefficient; β_{sx_n} = **0.0310**

Design bending moment; $M_{x\_n} = \beta_{sx\_n} \times q \times l_x^2$ = **9.7** kNm/m

Reinforcement provided; A393 mesh + 10 mm dia. bars at 200 mm centres

Area provided; A_{sx_n} = 786 mm^2/m

Effective depth to tension reinforcement; $d_{x\_n} = h - c_{nom\_t} - \phi_{x\_n} / 2$ = **115.0** mm

K factor; $K = M_{x\_n} / (b \times d_{x\_n}^2 \times f_{ck})$ = **0.029**

Redistribution ratio; $\delta = 1.0$

K' factor; $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm; $z = \min(0.95 \times d_{x\_n}, d_{x\_n}/2 \times (1 + (1 - 3.53\times K)^{0.5}))$ = **109.2** mm

Area of reinforcement required for bending; $A_{sx\_n\_m} = M_{x\_n} / (f_{yd} \times z)$ = **205** mm^2/m

Minimum area of reinforcement required; $A_{sx\_n\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_n}, 0.0013\times b\times d_{x\_n})$ = **153** mm^2/m

Area of reinforcement required; $A_{sx\_n\_req} = \max(A_{sx\_n\_m}, A_{sx\_n\_min})$ = **205** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress; $\sigma_{sx\_n} = (f_{yk} / \gamma_S) \times \min((A_{sx\_n\_m}/A_{sx\_n}), 1.0) \times q_{SLS} / q$ = **31.7** N/mm^2

Maximum allowable spacing (Table 7.3N); $s_{max\_x\_n}$ = **300** mm

Actual bar spacing; s_{x_n} = **100** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at continuous support in long span direction (cl.6.1)

Bending moment coefficient; β_{sy_n} = **0.0320**

Design bending moment; $M_{y\_n} = \beta_{sy\_n} \times q \times l_x^2$ = **10.0** kNm/m

Reinforcement provided; A393 mesh + 10 mm dia. bars at 200 mm centres

Area provided; A_{sy_n} = 786 mm²/m

Effective depth to tension reinforcement; $d_{y\_n} = h - c_{nom\_t} - \phi_{x\_n} - \phi_{y\_n} / 2$ = **105.0** mm

K factor; $K = M_{y\_n} / (b \times d_{y\_n}^2 \times f_{ck})$ = **0.036**

Redistribution ratio; $\delta = 1.0$

K' factor; $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm; $z = \min(0.95 \times d_{y\_n}, d_{y\_n}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **99.7** mm

Area of reinforcement required for bending; $A_{sy\_n\_m} = M_{y\_n} / (f_{yd} \times z)$ = **231** mm²/m

Minimum area of reinforcement required; $A_{sy\_n\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_n}, 0.0013 \times b \times d_{y\_n})$ = **140** mm²/m

Area of reinforcement required; $A_{sy\_n\_req} = \max(A_{sy\_n\_m}, A_{sy\_n\_min})$ = **231** mm²/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress; $\sigma_{sy\_n} = (f_{yk} / \gamma_S) \times \min((A_{sy\_n\_m}/A_{sy\_n}), 1.0) \times q_{SLS} / q$ = **35.8** N/mm²

Maximum allowable spacing (Table 7.3N); $s_{max\_y\_n}$ = **300** mm

Actual bar spacing; s_{y_n} = **100** mm

PASS - The reinforcement spacing is acceptable

Shear capacity check at short span continuous support

Shear force; $V_{x\_n} = q \times l_x / 2$ = **62.7** kN/m

Effective depth factor (cl. 6.2.2); $k = \min(2.0, 1 + (200 \text{ mm} / d_{x\_n})^{0.5})$ = **2.000**

Reinforcement ratio; $\rho_l = \min(0.02, A_{sx\_n} / (b \times d_{x\_n}))$ = **0.0068**

Minimum shear resistance (Exp. 6.3N); $V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{x\_n}$

V_{Rd,c_min} = **56.9** kN/m

Shear resistance (Exp. 6.2a); $V_{Rd,c\_x\_n} = \max(V_{Rd,c\_min}, (0.18 \text{ N/mm}^2 / \gamma_C) \times k \times (100 \times \rho_l \times (f_{ck} / 1 \text{ N/mm}^2))^{0.333} \times b \times d_{x\_n})$

V_{Rd,c_x_n} = **71.0** kN/m

PASS - Shear capacity is adequate

Shear capacity check at long span continuous support

Shear force; $V_{y\_n} = q \times l_x / 2$ = **62.7** kN/m

Effective depth factor (cl. 6.2.2); $k = \min(2.0, 1 + (200 \text{ mm} / d_{y\_n})^{0.5})$ = **2.000**

Reinforcement ratio; $\rho_l = \min(0.02, A_{sy\_n} / (b \times d_{y\_n}))$ = **0.0075**

Minimum shear resistance (Exp. 6.3N); $V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{y\_n}$

V_{Rd,c_min} = **52.0** kN/m

Shear resistance (Exp. 6.2a); $V_{Rd,c\_y\_n} = \max(V_{Rd,c\_min}, (0.18 \text{ N/mm}^2 / \gamma_C) \times k \times (100 \times \rho_l \times (f_{ck} / 1 \text{ N/mm}^2))^{0.333} \times b \times d_{y\_n})$

V_{Rd,c_y_n} = **66.8** kN/m

PASS - Shear capacity is adequate

Basic span-to-depth deflection ratio check (cl. 7.4.2)

Reference reinforcement ratio; $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000$ = **0.0050**

Required tension reinforcement ratio; $\rho = \max(0.0035, A_{sx\_p\_req} / (b \times d_{x\_p}))$ = **0.0035**

Required compression reinforcement ratio; $\rho' = A_{scx\_p\_req} / (b \times d_{x\_p})$ = **0.0000**

Stuctural system factor (Table 7.4N); K_δ = **1.5**

Basic limit span-to-depth ratio; $ratio_{lim\_x\_bas} = K_\delta \times [11 + 1.5 \times (f_{ck}/1 \text{ N/mm}^2)^{0.5} \times \rho_0/\rho + 3.2 \times (f_{ck}/1 \text{ N/mm}^2)^{0.5} \times (\rho_0/\rho - 1)^{1.5}]$

(Exp. 7.16); $ratio_{lim\_x\_bas}$ = **39.31**

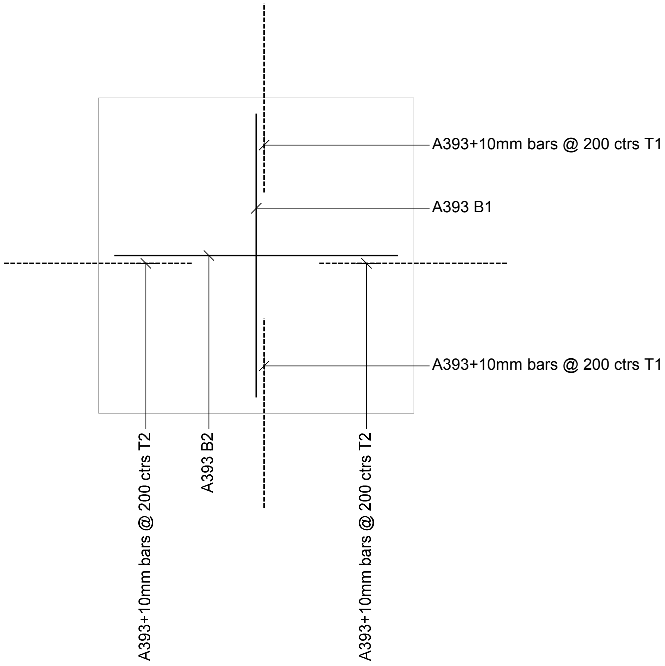
Mod span-to-depth ratio limit; $ratio_{lim\_x} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2/f_{yk}) \times (A_{sx\_p}/A_{sx\_p\_m})) \times ratio_{lim\_x\_bas})$ = **58.96**

Actual span-to-eff. depth ratio; $ratio_{act\_x} = l_x / d_{x\_p}$ = **26.32**

PASS - Actual span-to-effective depth ratio is acceptable

Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.



BASEMENT RETAINING WALLS:

CASE 1: FRONT RETAINING WALL ANALYSIS AND DESIGN

ASSUMPTIONS & PARAMETERS:

The retaining wall design is based on the parameters obtained from geotechnical report carried out by 'Chelmer Consultancy Services' reference GENV/5839. The following design parameters are used:

Retained Height (assuming existing foundations 200mm below ground level) = 3.8m

Concrete Strength: C32/40

Wall is designed as propped at the base in the permanent condition – prop being offered by the basement slab

Water table is assumed at 1.0m below ground level based on the worst case scenario

Soil Type: London Clay Formation

Bearing Capacity: 125kN/m^2

Loading:

Permanent Loads

Allow for slab permanent load on the wall's toe = 10.5kN/m

Variable Loads

Total Variable Load UDL = 15.20kN/m

Allow for slab variable load on the wall's toe = 2.8kN/m

RETAINING WALL ANALYSIS

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

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **3400** mm
Stem thickness;	t_{stem} = **400** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1500** mm
Heel length;	l_{heel} = **300** mm
Base thickness;	t_{base} = **400** mm
Key position;	p_{key} = **1500** mm
Key depth;	d_{key} = **500** mm
Key thickness;	t_{key} = **400** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **3400** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **0** mm
Height of water;	h_{water} = **2400** mm
Water density;	γ_w = **9.8** kN/m^3

Retained soil properties

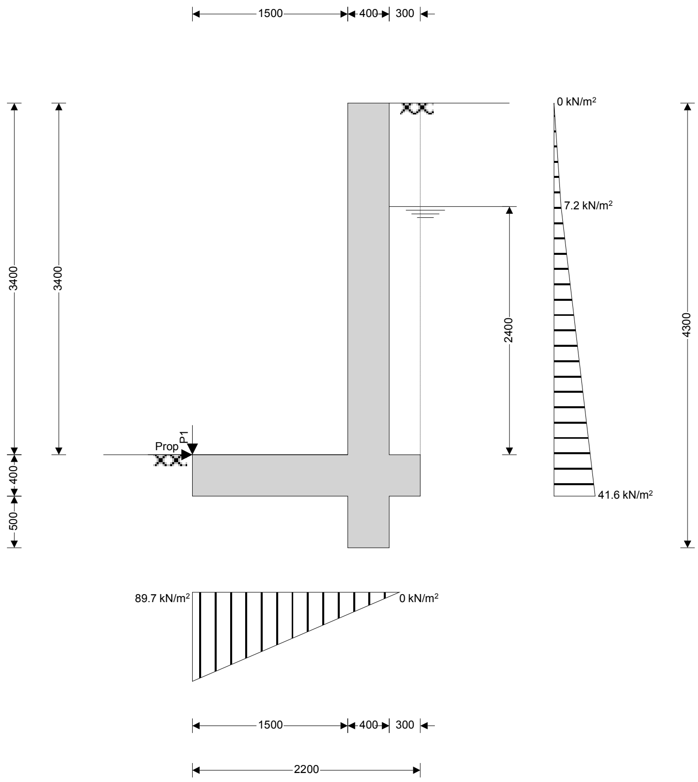
Soil type;	Organic clay
Moist density;	γ_{mr} = **15** kN/m^3
Saturated density;	γ_{sr} = **15** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{r.k}$ = **18** deg
Characteristic wall friction angle;	$\delta_{r.k}$ = **9** deg

Base soil properties

Soil type;	Organic clay
Soil density;	γ_b = **15** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{b.k}$ = **18** deg
Characteristic wall friction angle;	$\delta_{b.k}$ = **9** deg
Characteristic base friction angle;	$\delta_{bb.k}$ = **12** deg
Presumed bearing capacity;	$P_{bearing}$ = **125** kN/m^2

Loading details

Vertical line load at 0 mm;	P_{G1} = **10.5** kN/m
;	P_{Q1} = **2.8** kN/m



General arrangement

Calculate retaining wall geometry

Base length;	$l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **2200** mm
Base height;	$h_{base} = t_{base} + d_{key}$ = **900** mm
Saturated soil height;	$h_{sat} = h_{water} + d_{cover}$ = **2400** mm
Moist soil height;	$h_{moist} = h_{ret} - h_{water}$ = **1000** mm
Retained surface length;	$l_{sur} = l_{heel}$ = **300** mm
Effective height of wall;	$h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **4300** mm
Area of wall stem;	$A_{stem} = h_{stem} \times t_{stem}$ = **1.36** m^2
- Distance to vertical component;	$x_{stem} = l_{toe} + t_{stem} / 2$ = **1700** mm
Area of wall base;	$A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key}$ = **1.08** m^2
- Distance to vertical component;	$x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base}$ = **1211** mm
Area of saturated soil;	$A_{sat} = h_{sat} \times l_{heel}$ = **0.72** m^2
- Distance to vertical component;	$x_{sat\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat}$ = **2050** mm
- Distance to horizontal component;	$x_{sat\_h} = (h_{sat} + h_{base}) / 3 - d_{key}$ = **600** mm
- Distance to horizontal component above key;	$x_{sat\_h\_a} = (h_{sat} + t_{base}) / 3$ = **933** mm
Area of water;	$A_{water} = h_{sat} \times l_{heel}$ = **0.72** m^2
- Distance to vertical component;	$x_{water\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat}$ = **2050** mm
- Distance to horizontal component;	$x_{water\_h} = (h_{sat} + h_{base}) / 3 - d_{key}$ = **600** mm
- Distance to horizontal component above key;	$x_{water\_h\_a} = (h_{sat} + t_{base}) / 3$ = **933** mm
Area of moist soil;	$A_{moist} = h_{moist} \times l_{heel}$ = **0.3** m^2
- Distance to vertical component;	$x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist}$ = **2050** mm

- Distance to horizontal component; $x_{moist\_h} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + h_{base}) \times ((h_{sat} + h_{base})/2 - d_{key})) / (h_{sat} + h_{base} + h_{moist} / 2) =$ **1411** mm

- Distance to horizontal component above key; $x_{moist\_h\_a} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + t_{base})^2/2) / (h_{sat} + t_{base} + h_{moist} / 2) =$ **1663** mm

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2) =$ **0.483**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2) =$ **2.359**

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = A_{stem} \times \gamma_{stem} =$ **34** kN/m

Wall base; $F_{base} = A_{base} \times \gamma_{base} =$ **27** kN/m

Line loads; $F_{P\_v} = P_{G1} + P_{Q1} =$ **13.3** kN/m

Saturated retained soil; $F_{sat\_v} = A_{sat} \times (\gamma_{sr}' - \gamma_w') =$ **3.7** kN/m

Water; $F_{water\_v} = A_{water} \times \gamma_w' =$ **7.1** kN/m

Moist retained soil; $F_{moist\_v} = A_{moist} \times \gamma_{mr}' =$ **4.5** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{water\_v} + F_{P\_v} =$ **89.6** kN/m

Horizontal forces on wall

Saturated retained soil; $F_{sat\_h} = K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + t_{base})^2 / 2 =$ **9.7** kN/m

Water; $F_{water\_h} = \gamma_w' \times (h_{water} + d_{cover} + t_{base})^2 / 2 =$ **38.5** kN/m

Moist retained soil; $F_{moist\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + t_{base})) =$ **23.6** kN/m

Base soil; $F_{pass\_h} = -K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-14.2** kN/m

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} =$ **57.6** kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem} =$ **57.8** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base} =$ **32.7** kNm/m

Saturated retained soil; $M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h} =$ **1.8** kNm/m

Water; $M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h} =$ **-8.6** kNm/m

Moist retained soil; $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} =$ **-24.1** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_P =$ **59.6** kNm/m

Check bearing pressure

Propping force; $F_{prop\_base} = F_{total\_h} =$ **57.6** kN/m

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v} =$ **666** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 =$ **-434** mm

Loaded length of base; $l_{load} = 3 \times \bar{x} =$ **1997** mm

Bearing pressure at toe; $q_{toe} = 2 \times F_{total\_v} / l_{load} =$ **89.7** kN/m^2

Bearing pressure at heel; $q_{heel} =$ **0** kN/m^2

Factor of safety; $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.393**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

CASE 2: PARTY WALL RETAINING WALL ANALYSIS AND DESIGN

ASSUMPTIONS & PARAMETERS:

The retaining wall design is based on the parameters obtained from geotechnical report carried out by 'Chelmer Consultancy Services' reference GENV/5839. The following design parameters are used:

Retained Height (assuming existing foundations 200mm below ground level) = 3.8m

Concrete Strength: C32/40

Wall is designed as propped at the base in the permanent condition – prop being offered by the basement slab

Water table is assumed at 1.0m below ground level based on the worst case scenario

Soil Type: London Clay Formation

Bearing Capacity: 125kN/m^2

Loading:

Permanent Loads

Ground floor wall - 343mm (13.5") wall (3.50m height) = 23kN/m^3 x 3.50m x 0.343m = 27.62kN/m

Walls for first floor and above – 229mm (9") (9.00m height) = 23kN/m^3 x 9.00m x 0.229m = 47.40kN/m

Floor loads = 0.75kN/m^2 x 4.50m/2 x 4 (no. of floors) = 6.75kN/m

Roof load = 0.80kN/m^2 x 4.50m/2 = 1.8kN/m

Total Permanent Load UDL = 83.60kN/m

Allow for slab permanent load on the wall's toe = 10.5kN/m

Variable Loads

Floor loads = 1.50kN/m^2 x 4.50m/2 x 4 (no. of floors) = 13.50kN/m

Roof load = 0.75kN/m^2 x 4.50m/2 = 1.69kN/m

Total Variable Load UDL = 15.20kN/m

Allow for slab variable load on the wall's toe = 2.8kN/m

RETAINING WALL ANALYSIS

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

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **3400** mm
Stem thickness;	t_{stem} = **400** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1500** mm
Base thickness;	t_{base} = **400** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **3400** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **0** mm
Height of water;	h_{water} = **2800** mm
Water density;	γ_w = **9.8** kN/m^3

Retained soil properties

Soil type;	Organic clay

Moist density; γ_{mr} = **15** kN/m^3

Saturated density; γ_{sr} = **15** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **9** deg

Base soil properties

Soil type; Organic clay

Soil density; γ_b = **15** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **9** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

Presumed bearing capacity; $P_{bearing}$ = **125** kN/m^2

Loading details

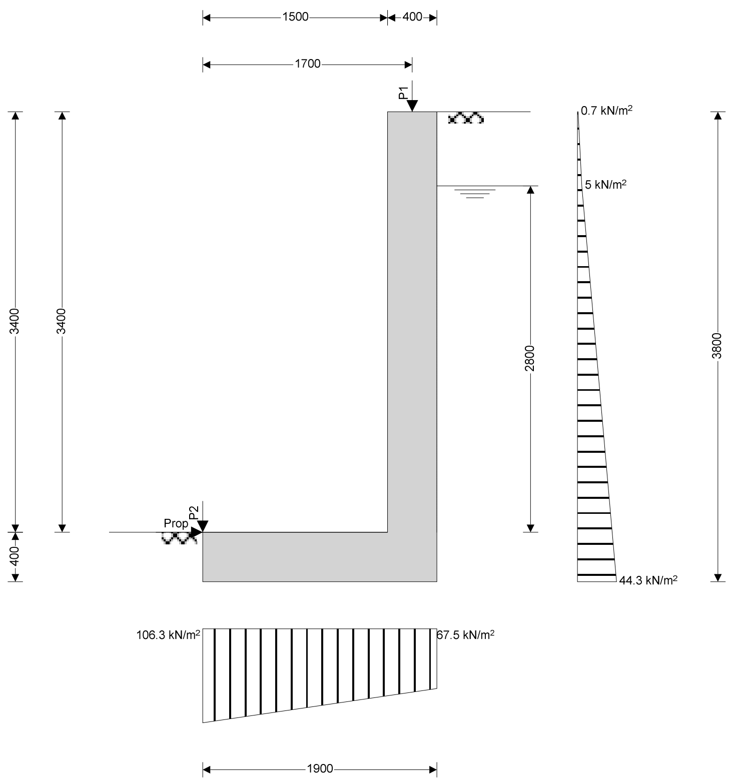
Variable surcharge load; $Surcharge_Q$ = **1.5** kN/m^2

Vertical line load at 1700 mm; P_{G1} = **83.6** kN/m

; P_{Q1} = **15.2** kN/m

Vertical line load at 0 mm; P_{G2} = **10.5** kN/m

; P_{Q2} = **2.8** kN/m



General arrangement

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem}$ = **1900** mm

Saturated soil height; $h_{sat} = h_{water} + d_{cover}$ = **2800** mm

Moist soil height; $h_{moist} = h_{ret} - h_{water}$ = **600** mm

Length of surcharge load; $l_{sur} = l_{heel}$ = **0** mm

- Distance to vertical component; $x_{sur\_v} = l_{base} - l_{heel} / 2 =$ **1900** mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret} =$ **3800** mm

- Distance to horizontal component; $x_{sur\_h} = h_{eff} / 2 =$ **1900** mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem} =$ **1.36** m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2 =$ **1700** mm

Area of wall base; $A_{base} = l_{base} \times t_{base} =$ **0.76** m^2

- Distance to vertical component; $x_{base} = l_{base} / 2 =$ **950** mm

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2) =$ **0.483**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2) =$ **2.359**

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = A_{stem} \times \gamma_{stem} =$ **34** kN/m

Wall base; $F_{base} = A_{base} \times \gamma_{base} =$ **19** kN/m

Line loads; $F_{P\_v} = P_{G1} + P_{Q1} + P_{G2} + P_{Q2} =$ **112.1** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v} =$ **165.1** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times Surcharge_Q \times h_{eff} =$ **2.7** kN/m

Saturated retained soil; $F_{sat\_h} = K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 =$ **12.7** kN/m

Water; $F_{water\_h} = \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **50.2** kN/m

Moist retained soil; $F_{moist\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **15** kN/m

Base soil; $F_{pass\_h} = -K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-2.8** kN/m

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} + F_{sur\_h} =$ **77.9** kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem} =$ **57.8** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base} =$ **18.1** kNm/m

Surcharge load; $M_{sur} = -F_{sur\_h} \times x_{sur\_h} =$ **-5.2** kNm/m

Line loads; $M_P = (P_{G1} + P_{Q1}) \times p_1 + (P_{G2} + P_{Q2}) \times p_2 =$ **168** kNm/m

Saturated retained soil; $M_{sat} = -F_{sat\_h} \times x_{sat\_h} =$ **-13.5** kNm/m

Water; $M_{water} = -F_{water\_h} \times x_{water\_h} =$ **-53.6** kNm/m

Moist retained soil; $M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **-26.4** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_{sur} + M_P =$ **145.2** kNm/m

Check bearing pressure

Propping force; $F_{prop\_base} = F_{total\_h} =$ **77.9** kN/m

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v} =$ **879** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 =$ **-71** mm

Loaded length of base; $l_{load} = l_{base} =$ **1900** mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base}) =$ **106.3** kN/m^2

Bearing pressure at heel; $q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base}) =$ **67.5** kN/m^2

Factor of safety; $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.176**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

CASE 3: REAR PARTY WALL RETAINING WALL ANALYSIS AND DESIGN

ASSUMPTIONS & PARAMETERS:

The retaining wall design is based on the parameters obtained from geotechnical report carried out by 'Chelmer Consultancy Services' reference GENV/5839. The following design parameters are used:

Retained Height (assuming existing foundations 200mm below ground level) = 3.3m

Concrete Strength: C32/40

Wall is designed as propped at the base in the permanent condition – prop being offered by the basement slab

Water table is assumed at 1.0m below ground level based on the worst case scenario

Soil Type: London Clay Formation

Bearing Capacity: 125kN/m^2

Loading:

Permanent Loads

Ground floor wall - 343mm (13.5") wall (3.00m height) = 23kN/m^3 x 3.00m x 0.343m = 23.67kN/m

Walls for first floor and above – 229mm (9") (5.50m height) = 23kN/m^3 x 5.50m x 0.229m = 28.97kN/m

Floor loads = 0.75kN/m^2 x 4.50m/2 x 3 (no. of floors) = 5.06kN/m

Total Permanent Load UDL = 57.70kN/m

Allow for slab permanent load on the wall's toe = 10.5kN/m

Variable Loads

Floor loads = 1.50kN/m^2 x 4.50m/2 x 3 (no. of floors) = 10.13kN/m

Total Variable Load UDL = 10.13kN/m

Allow for slab variable load on the wall's toe = 2.8kN/m

RETAINING WALL ANALYSIS

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

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **2900** mm
Stem thickness;	t_{stem} = **400** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1200** mm
Base thickness;	t_{base} = **400** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **2900** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **0** mm
Height of water;	h_{water} = **2300** mm

Water density; γ_w = **9.8** kN/m^3

Retained soil properties

Soil type; Organic clay

Moist density; γ_{mr} = **15** kN/m^3

Saturated density; γ_{sr} = **15** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **9** deg

Base soil properties

Soil type; Organic clay

Soil density; γ_b = **15** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **9** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

Presumed bearing capacity; $P_{bearing}$ = **125** kN/m^2

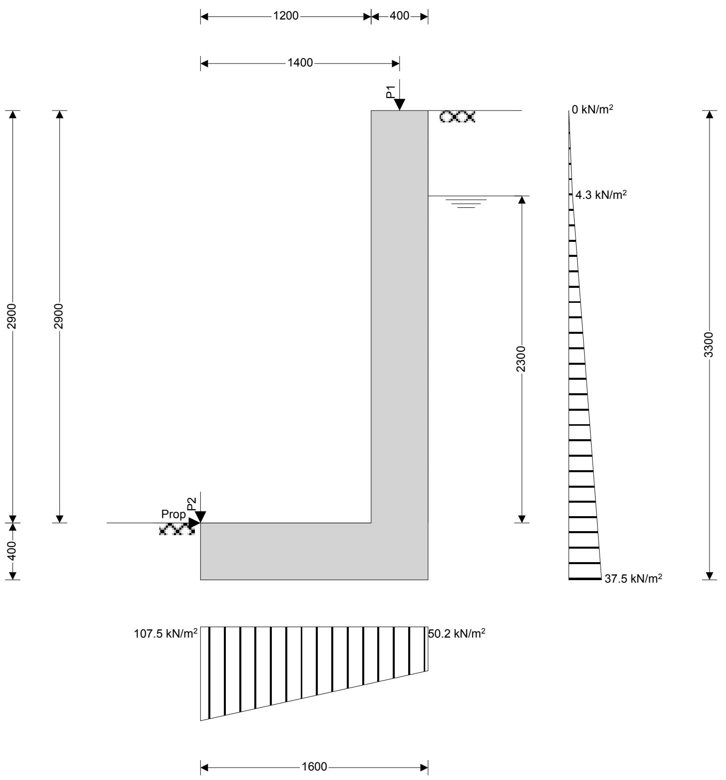
Loading details

Vertical line load at 1400 mm; P_{G1} = **57.7** kN/m

; P_{Q1} = **10.1** kN/m

Vertical line load at 0 mm; P_{G2} = **10.5** kN/m

; P_{Q2} = **2.8** kN/m



General arrangement

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem}$ = **1600** mm

Saturated soil height; $h_{sat} = h_{water} + d_{cover} =$ **2300** mm

Moist soil height; $h_{moist} = h_{ret} - h_{water} =$ **600** mm

Retained surface length; $l_{sur} = l_{heel} =$ **0** mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret} =$ **3300** mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem} =$ **1.16** m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2 =$ **1400** mm

Area of wall base; $A_{base} = l_{base} \times t_{base} =$ **0.64** m^2

- Distance to vertical component; $x_{base} = l_{base} / 2 =$ **800** mm

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2) =$ **0.483**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2) =$ **2.359**

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = A_{stem} \times \gamma_{stem} =$ **29** kN/m

Wall base; $F_{base} = A_{base} \times \gamma_{base} =$ **16** kN/m

Line loads; $F_{P\_v} = P_{G1} + P_{Q1} + P_{G2} + P_{Q2} =$ **81.1** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v} =$ **126.1** kN/m

Horizontal forces on wall

Saturated retained soil; $F_{sat\_h} = K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 =$ **9** kN/m

Water; $F_{water\_h} = \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **35.8** kN/m

Moist retained soil; $F_{moist\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **12.9** kN/m

Base soil; $F_{pass\_h} = -K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-2.8** kN/m

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} =$ **54.9** kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem} =$ **40.6** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base} =$ **12.8** kNm/m

Line loads; $M_P = (P_{G1} + P_{Q1}) \times p_1 + (P_{G2} + P_{Q2}) \times p_2 =$ **95** kNm/m

Saturated retained soil; $M_{sat} = -F_{sat\_h} \times x_{sat\_h} =$ **-8.1** kNm/m

Water; $M_{water} = -F_{water\_h} \times x_{water\_h} =$ **-32.2** kNm/m

Moist retained soil; $M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **-19.4** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_P =$ **88.7** kNm/m

Check bearing pressure

Propping force; $F_{prop\_base} = F_{total\_h} =$ **54.9** kN/m

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v} =$ **703** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 =$ **-97** mm

Loaded length of base; $l_{load} = l_{base} =$ **1600** mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base}) =$ **107.5** kN/m^2

Bearing pressure at heel; $q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base}) =$ **50.2** kN/m^2

Factor of safety; $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.163**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

CASE 4: REAR GARDEN RETAINING SIDE (FENCE) WALL ANALYSIS AND DESIGN

ASSUMPTIONS & PARAMETERS:

The retaining wall design is based on the parameters obtained from geotechnical report carried out by 'Chelmer Consultancy Services' reference GENV/5839. The following design parameters are used:

Retained Height (assuming existing foundations 200mm below ground level) = 3.3m

Concrete Strength: C32/40

Wall is designed as propped at the base in the permanent condition – prop being offered by the basement slab

Water table is assumed at 1.0m below ground level based on the worst case scenario

Soil Type: London Clay Formation

Bearing Capacity: 125kN/m^2

Loading:

Permanent Loads

Ground floor wall - 229mm (9") (5.50m height) = 23kN/m^3 x 5.50m x 0.229m = 29.00kN/m

Total Permanent Load UDL = 29.00kN/m

Allow for slab permanent load on the wall's toe = 10.5kN/m

Variable Loads

Allow for slab variable load on the wall's toe = 2.8kN/m

RETAINING WALL ANALYSIS

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

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **2900** mm
Stem thickness;	t_{stem} = **400** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1500** mm
Base thickness;	t_{base} = **400** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **2900** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **0** mm
Height of water;	h_{water} = **2300** mm
Water density;	γ_w = **9.8** kN/m^3

Retained soil properties

Soil type;	Organic clay
Moist density;	γ_{mr} = **15** kN/m^3
Saturated density;	γ_{sr} = **15** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{r.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **9** deg

Base soil properties

Soil type; Organic clay

Soil density; γ_b = **15** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **9** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

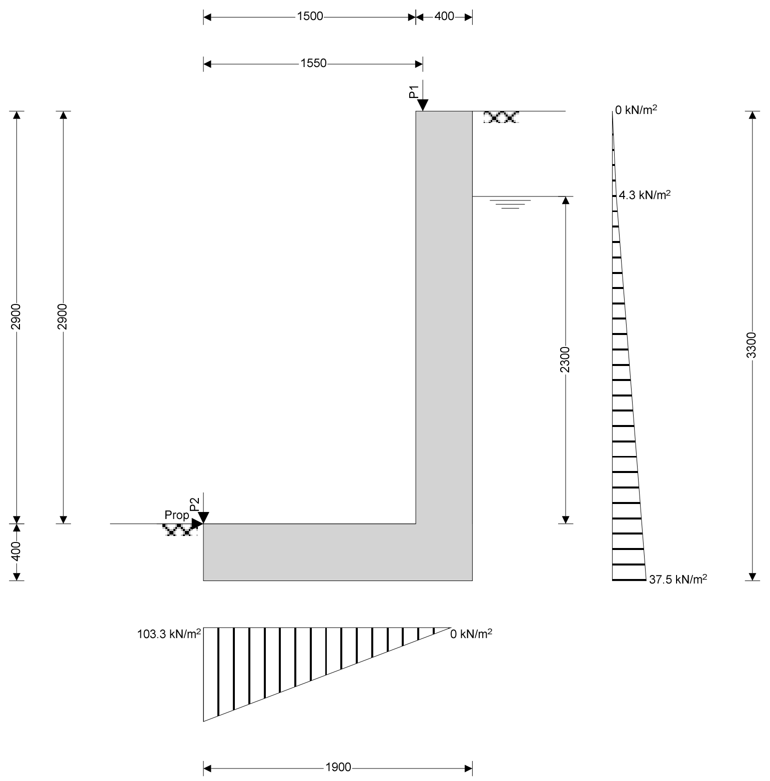
Presumed bearing capacity; $P_{bearing}$ = **125** kN/m^2

Loading details

Vertical line load at 1550 mm; P_{G1} = **29** kN/m

Vertical line load at 0 mm; P_{G2} = **10.5** kN/m

; P_{Q2} = **2.8** kN/m



General arrangement

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem}$ = **1900** mm

Saturated soil height; $h_{sat} = h_{water} + d_{cover}$ = **2300** mm

Moist soil height; $h_{moist} = h_{ret} - h_{water}$ = **600** mm

Retained surface length; $l_{sur} = l_{heel}$ = **0** mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **3300** mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem}$ = **1.16** m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2$ = **1700** mm

Area of wall base; $A_{base} = l_{base} \times t_{base}$ = **0.76** m^2

- Distance to vertical component; $x_{base} = l_{base} / 2$ = **950** mm

Using Coulomb theory

Active pressure coefficient;	$K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2) = \mathbf{0.483}$
Passive pressure coefficient;	$K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2) = \mathbf{2.359}$

Bearing pressure check

Vertical forces on wall

Wall stem;	$F_{stem} = A_{stem} \times \gamma_{stem}$ = **29** kN/m
Wall base;	$F_{base} = A_{base} \times \gamma_{base}$ = **19** kN/m
Line loads;	$F_{P\_v} = P_{G1} + P_{G2} + P_{Q2}$ = **42.3** kN/m
Total;	$F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **90.3** kN/m

Horizontal forces on wall

Saturated retained soil;	$F_{sat\_h} = K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2$ = **9** kN/m
Water;	$F_{water\_h} = \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **35.8** kN/m
Moist retained soil;	$F_{moist\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base}))$ = **12.9** kN/m
Base soil;	$F_{pass\_h} = -K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-2.8** kN/m
Total;	$F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h}$ = **54.9** kN/m

Moments on wall

Wall stem;	$M_{stem} = F_{stem} \times x_{stem}$ = **49.3** kNm/m
Wall base;	$M_{base} = F_{base} \times x_{base}$ = **18.1** kNm/m
Line loads;	$M_P = P_{G1} \times p_1 + (P_{G2} + P_{Q2}) \times p_2$ = **45** kNm/m
Saturated retained soil;	$M_{sat} = -F_{sat\_h} \times x_{sat\_h}$ = **-8.1** kNm/m
Water;	$M_{water} = -F_{water\_h} \times x_{water\_h}$ = **-32.2** kNm/m
Moist retained soil;	$M_{moist} = -F_{moist\_h} \times x_{moist\_h}$ = **-19.4** kNm/m
Total;	$M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_P$ = **52.6** kNm/m

Check bearing pressure

Propping force;	$F_{prop\_base} = F_{total\_h}$ = **54.9** kN/m
Distance to reaction;	$\bar{x} = M_{total} / F_{total\_v}$ = **583** mm
Eccentricity of reaction;	$e = \bar{x} - l_{base} / 2$ = **-367** mm
Loaded length of base;	$l_{load} = 3 \times \bar{x}$ = **1748** mm
Bearing pressure at toe;	$q_{toe} = 2 \times F_{total\_v} / l_{load}$ = **103.3** kN/m^2
Bearing pressure at heel;	q_{heel} = **0** kN/m^2
Factor of safety;	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **1.21**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

LIBRARY ITEM: BEARING FOS OUTPUT

CASE 5: REAR GARDEN RETAINING BACK WALL ANALYSIS AND DESIGN

ASSUMPTIONS & PARAMETERS:

The retaining wall design is based on the parameters obtained from geotechnical report carried out by ‘Chelmer Consultancy Services’ reference GENV/5839. The following design parameters are used:

Retained Height (assuming existing foundations 200mm below ground level) = 3.4m

Concrete Strength: C32/40

Wall is designed as propped at the base in the permanent condition – prop being offered by the basement slab

Water table is assumed at 1.0m below ground level based on the worst case scenario

Soil Type: London Clay Formation

Bearing Capacity: 125kN/m^2

Loading:

Permanent Loads

Allow for slab permanent load on the wall's toe = 10.5kN/m

Variable Loads

Allow for slab variable load on the wall's toe = 2.80kN/m

Surcharge load = 1.50kN/m^2

RETAINING WALL ANALYSIS

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

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **3000** mm
Stem thickness;	t_{stem} = **400** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1500** mm
Heel length;	l_{heel} = **200** mm
Base thickness;	t_{base} = **400** mm
Key position;	p_{key} = **1500** mm
Key depth;	d_{key} = **500** mm
Key thickness;	t_{key} = **400** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **3000** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **0** mm
Height of water;	h_{water} = **2400** mm
Water density;	γ_w = **9.8** kN/m^3

Retained soil properties

Soil type;	Organic clay
Moist density;	γ_{mr} = **15** kN/m^3
Saturated density;	γ_{sr} = **15** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{r.k}$ = **18** deg
Characteristic wall friction angle;	$\delta_{r.k}$ = **9** deg

Base soil properties

Soil type;	Organic clay
Soil density;	γ_b = **15** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{b.k}$ = **18** deg
Characteristic wall friction angle;	$\delta_{b.k}$ = **9** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

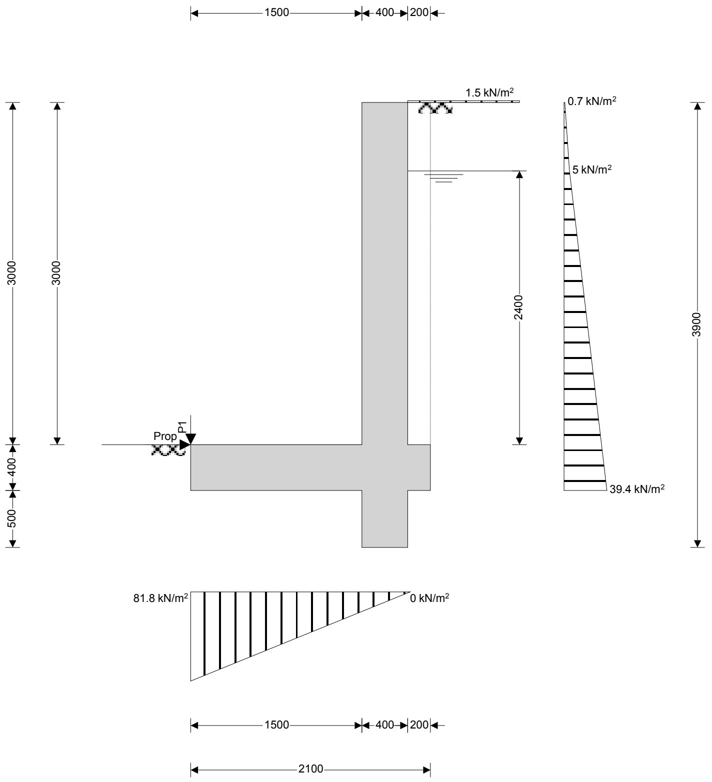
Presumed bearing capacity; $P_{bearing}$ = **125** kN/m^2

Loading details

Variable surcharge load; $Surcharge_Q$ = **1.5** kN/m^2

Vertical line load at 0 mm; P_{G1} = **10.5** kN/m

; P_{Q1} = **2.8** kN/m



General arrangement

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **2100** mm

Base height; $h_{base} = t_{base} + d_{key}$ = **900** mm

Saturated soil height; $h_{sat} = h_{water} + d_{cover}$ = **2400** mm

Moist soil height; $h_{moist} = h_{ret} - h_{water}$ = **600** mm

Length of surcharge load; $l_{sur} = l_{heel}$ = **200** mm

- Distance to vertical component; $x_{sur\_v} = l_{base} - l_{heel} / 2$ = **2000** mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **3900** mm

- Distance to horizontal component; $x_{sur\_h} = h_{eff} / 2 - d_{key}$ = **1450** mm
- Distance to horizontal component above key; $x_{sur\_h\_a} = (h_{eff} - d_{key}) / 2$ = **1700** mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem}$ = **1.2** m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2$ = **1700** mm

Area of wall base; $A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key}$ = **1.04** m^2

- Distance to vertical component; $x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base}$ = **1175** mm

Area of saturated soil; $A_{sat} = h_{sat} \times l_{heel}$ = **0.48** m^2

- Distance to vertical component; $x_{sat\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat}$ = **2000** mm

- Distance to horizontal component; $x_{sat\_h} = (h_{sat} + h_{base}) / 3 - d_{key}$ = **600** mm
- Distance to horizontal component above key; $x_{sat\_h\_a} = (h_{sat} + t_{base}) / 3$ = **933** mm

Area of water; $A_{water} = h_{sat} \times l_{heel}$ = **0.48** m²

- Distance to vertical component; $x_{water\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat}$ = **2000** mm
- Distance to horizontal component; $x_{water\_h} = (h_{sat} + h_{base}) / 3 - d_{key}$ = **600** mm
- Distance to horizontal component above key; $x_{water\_h\_a} = (h_{sat} + t_{base}) / 3$ = **933** mm

Area of moist soil; $A_{moist} = h_{moist} \times l_{heel}$ = **0.12** m²

- Distance to vertical component; $x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist}$ = **2000** mm
- Distance to horizontal component; $x_{moist\_h} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + h_{base}) \times ((h_{sat} + h_{base})/2 - d_{key})) / (h_{sat} + h_{base} + h_{moist} / 2)$ = **1304** mm
- Distance to horizontal component above key; $x_{moist\_h\_a} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + t_{base})^2/2) / (h_{sat} + t_{base} + h_{moist} / 2)$ = **1555** mm

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2)$ = **0.483**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2)$ = **2.359**

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = A_{stem} \times \gamma_{stem}$ = **30** kN/m

Wall base; $F_{base} = A_{base} \times \gamma_{base}$ = **26** kN/m

Surcharge load; $F_{sur\_v} = Surcharge_Q \times l_{heel}$ = **0.3** kN/m

Line loads; $F_{P\_v} = P_{G1} + P_{Q1}$ = **13.3** kN/m

Saturated retained soil; $F_{sat\_v} = A_{sat} \times (\gamma_{sr}' - \gamma_w')$ = **2.5** kN/m

Water; $F_{water\_v} = A_{water} \times \gamma_w'$ = **4.7** kN/m

Moist retained soil; $F_{moist\_v} = A_{moist} \times \gamma_{mr}'$ = **1.8** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{water\_v} + F_{sur\_v} + F_{P\_v}$ = **78.6** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times Surcharge_Q \times (h_{eff} - d_{key})$ = **2.4** kN/m

Saturated retained soil; $F_{sat\_h} = K_A \times \cos(\delta_{r.d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + t_{base})^2 / 2$ = **9.7** kN/m

Water; $F_{water\_h} = \gamma_w' \times (h_{water} + d_{cover} + t_{base})^2 / 2$ = **38.5** kN/m

Moist retained soil; $F_{moist\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + t_{base}))$ = **13.3** kN/m

Base soil; $F_{pass\_h} = -K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-14.2** kN/m

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} + F_{sur\_h}$ = **49.8** kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem}$ = **51** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base}$ = **30.6** kNm/m

Surcharge load; $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h}$ = **-2.9** kNm/m

Saturated retained soil; $M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h}$ = **-0.8** kNm/m

Water; $M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h}$ = **-13.7** kNm/m

Moist retained soil; $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h}$ = **-13.8** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_{sur} + M_P$ = **50.4** kNm/m

Check bearing pressure

Propping force; $F_{prop\_base} = F_{total\_h} = \mathbf{49.8}$ kN/m

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v} = \mathbf{641}$ mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 = \mathbf{-409}$ mm

Loaded length of base; $l_{load} = 3 \times \bar{x} = \mathbf{1922}$ mm

Bearing pressure at toe; $q_{toe} = 2 \times F_{total\_v} / l_{load} = \mathbf{81.8}$ kN/m^2

Bearing pressure at heel; $q_{heel} = \mathbf{0}$ kN/m^2

Factor of safety; $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{1.529}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure