BIA Appendix 5: Structural Engineer's Statement and Calculations

54 Sumatra Road London NW6 1PR

Description of the Structural Works:

The structural alteration consists of extending and enlarging the existing cellar to form a new habitable space under the foot print of the main house.   The basement construction will be in the form of reinforced concrete cantilevering retaining with reinforced base raft slab**.**

The requirement of Building Regulations will be met via providing full structural calculations and provided at detailed design in accordance to the following design standards and codes as well as relevant reports and document produced to support the planning application:

Relevant Design Standards and guidance notes

- BS 8103-1: 1995 Structural Design of Low Rise Buildings
- BS 648: 1964 Schedule of Weights of Building Materials
- BS 6399: Part 1: 1996 Loading for Buildings: Code of Practice for Dead and Imposed Loads
- BS 6399: Part 3: 1988 Loading for Buildings: Code of Practice for Imposed Roof Loads
- BS 8110;Part 1: 1997 Structural use of Concrete

The design takes into consideration vertical loads from existing building and any adjacent building or highway, lateral loads from wind, soil water and adjacent properties as well as surcharge loads applied as lateral loads to the retaining walls, loadings in the temporary condition, uplift forces from hydrostatic effects and soil heave.

The design must provide stability and robustness to both during temporary and permanent conditions. The design takes into account the method of construction in order to ensure that the proposed alterations can be achieved. The enclosed calculations are pertinent to the planning application process.

LOAD SUMMARY:

Dead Loads:

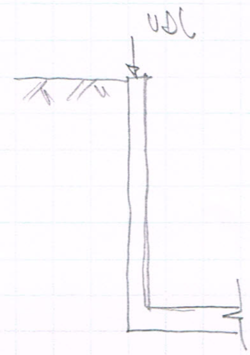
FLOORS: - Timber Floor: ceiling, joists, insulation, boards, finishes:	0.6 kN/m^2
- Concrete Floor:	24 kN/m^3
+ Finishes:	0.2 kN/m^2
ROOF: Timber Roof: ceiling, rafters, insulation, battens, tiles:	1.0 kN/m^2
WALLS: - Brick Wall:	19 kN/m^3
+ Finishes:	0.2 kN/m^2
- Blockwork Wall:	16 kN/m^3
+ Finishes:	0.2 kN/m^2
- Stud Wall:	0.45 or 0.6 kN/m^2
-Lav&Paster stud wall:	1.0kN/m^2

Imposed Loads:

FLOORS: - Residential:	1.5 kN/m^2
- Storage	0.75 kN/m^2
ROOF:	0.6 kN/m^2
Terrace Roof:	1.0kN/m^2

Bini Struct-e Ltd. Consulting Structural Engineers	Project: 54 Sumatra road, London, NW6 1PR		Job Ref: 11654	
	Drawing Ref	Calculations by: MR	Checked by: VC	Sheet of
	Part of Structure		Date: 10.2018	

RETAINING WALL DESIGN FRONT WALL



UDL due to walk-on glass

@ DL = $1 \times \frac{2,2}{2} = 1,1$ kN/m

LL = $1,5 \times \frac{2,2}{2} = 1,7$ kN/m

SURCHARGE 10 kN/m

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 2.6.04

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **2700** mm
Prop height	h_{prop} = **2000** mm
Stem thickness	t_{stem} = **300** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **3000** mm
Base thickness	t_{base} = **400** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **2500** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **200** mm
Depth of excavation	d_{exc} = **200** mm

Retained soil properties

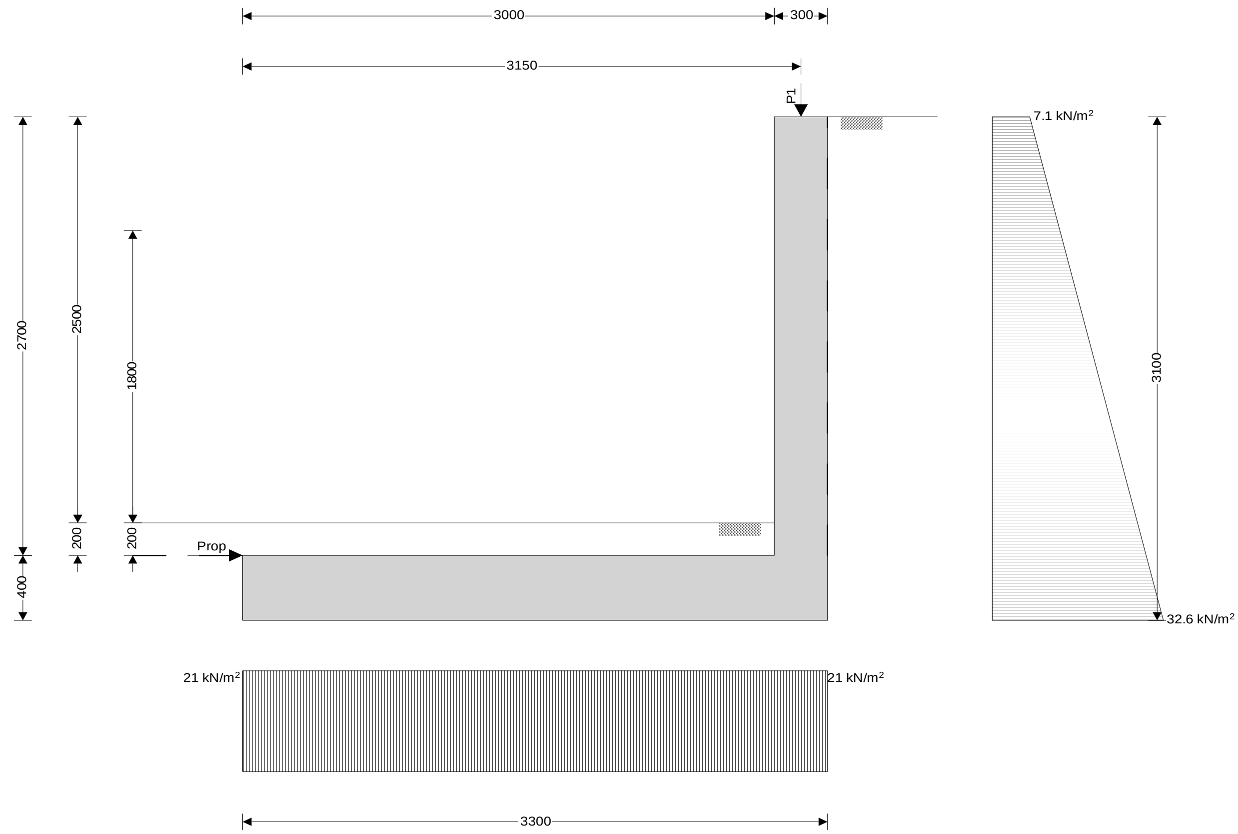
Soil type	Organic clay
Moist density	γ_{mr} = **15** kN/m^3
Saturated density	γ_{sr} = **15** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{r.k}$ = **18** deg
Characteristic wall friction angle	$\delta_{r.k}$ = **9** deg

Base soil properties

Soil type	Stiff or hard glacial silty clay
Moist density	γ_{mb} = **21** kN/m^3
Characteristic cohesion	$c'_{b.k}$ = **0** kN/m^2
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **22** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **11** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **14.7** deg

Loading details

Variable surcharge load	$Surcharge_Q$ = **10** kN/m^2
Vertical line load at 3150 mm	P_{G1} = **1.1** kN/m
	P_{Q1} = **1.7** kN/m



Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} = \mathbf{3300}$ mm
Moist soil height	$h_{moist} = h_{soil} = \mathbf{2700}$ mm
Length of surcharge load	$l_{sur} = l_{heel} = \mathbf{0}$ mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{3300}$ mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{3100}$ mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 = \mathbf{1550}$ mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.81}$ m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{3150}$ mm
Area of wall base	$A_{base} = l_{base} \times t_{base} = \mathbf{1.32}$ m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 = \mathbf{1650}$ mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe} = \mathbf{0.6}$ m^2
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{1500}$ mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 = \mathbf{200}$ mm

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

Permanent unfavourable action	$\gamma_G = \mathbf{1.35}$
Permanent favourable action	$\gamma_{Gf} = \mathbf{1.00}$
Variable unfavourable action	$\gamma_Q = \mathbf{1.50}$
Variable favourable action	$\gamma_{Qf} = \mathbf{0.00}$

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

Angle of shearing resistance $\gamma_{\phi'}$ = **1.00**

Effective cohesion $\gamma_{c'}$ = **1.00**

Weight density γ_{γ} = **1.00**

Retained soil properties

Design effective shear resistance angle $\phi'_{r.d} = atan(tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **18** deg

Design wall friction angle $\delta_{r.d} = atan(tan(\delta_{r.k}) / \gamma_{\phi'})$ = **9** deg

Base soil properties

Design effective shear resistance angle $\phi'_{b.d} = atan(tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **22** deg

Design wall friction angle $\delta_{b.d} = atan(tan(\delta_{b.k}) / \gamma_{\phi'})$ = **11** deg

Design base friction angle $\delta_{bb.d} = atan(tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **14.7** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

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

Passive pressure coefficient $K_P = sin(90 - \phi'_{b.d})^2 / (sin(90 + \delta_{b.d}) \times [1 - \sqrt{[sin(\phi'_{b.d} + \delta_{b.d}) \times sin(\phi'_{b.d}) / (sin(90 + \delta_{b.d}))]}]^2)$ = **2.958**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **20.3** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **33** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **1.1** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v}$ = **54.4** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **22.2** kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2$ = **46.4** kN/m

Base soil $F_{exc\_h} = -\gamma_{Gf} \times K_P \times cos(\delta_{b.d}) \times \gamma_{mb} \times (h_{pass} + h_{base})^2 / 2$ = **-4.9** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{exc\_h} + F_{sur\_h}$ = **63.7** kN/m

Overturning moments on wall

Surcharge load $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **34.4** kNm/m

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **48** kNm/m

Total $M_{total\_OT} = M_{moist\_OT} + M_{sur\_OT}$ = **82.4** kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem}$ = **63.8** kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base}$ = **54.5** kNm/m

Line loads $M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1$ = **3.5** kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R}$ = **121.7** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.478**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem — $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{27.3}$ kN/m

Wall base — $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{44.6}$ kN/m

Line loads — $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = \mathbf{4}$ kN/m

Base soil — $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb} = \mathbf{17}$ kN/m

Total — $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v} + F_{P\_v} = \mathbf{92.9}$ kN/m

Horizontal forces on wall

Surcharge load — $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{22.2}$ kN/m

Moist retained soil — $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2 = \mathbf{46.4}$ kN/m

Base soil — $F_{pass\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-11}$ kN/m

Total — $F_{total\_h} = F_{moist\_h} + F_{pass\_h} + F_{sur\_h} = \mathbf{57.6}$ kN/m

Moments on wall

Wall stem — $M_{stem} = F_{stem} \times x_{stem} = \mathbf{86.1}$ kNm/m

Wall base — $M_{base} = F_{base} \times x_{base} = \mathbf{73.5}$ kNm/m

Surcharge load — $M_{sur} = -F_{sur\_h} \times x_{sur\_h} = \mathbf{-34.4}$ kNm/m

Line loads — $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = \mathbf{12.7}$ kNm/m

Moist retained soil — $M_{moist} = -F_{moist\_h} \times x_{moist\_h} = \mathbf{-48}$ kNm/m

Base soil — $M_{pass} = F_{pass\_v} \times x_{pass\_v} = \mathbf{25.5}$ kNm/m

Total — $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_{sur} + M_P = \mathbf{115.5}$ kNm/m

Check bearing pressure

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

Distance to reaction — $\bar{x} = l_{base} / 2 = \mathbf{1650}$ mm

Eccentricity of reaction — $e = \bar{x} - l_{base} / 2 = \mathbf{0}$ mm

Loaded length of base — $l_{load} = l_{base} = \mathbf{3300}$ mm

Bearing pressure at toe — $q_{toe} = F_{total\_v} / l_{base} = \mathbf{28.2}$ kN/m^2

Bearing pressure at heel — $q_{heel} = F_{total\_v} / l_{base} = \mathbf{28.2}$ kN/m^2

Effective overburden pressure — $q = (t_{base} + d_{cover}) \times \gamma_{mb} = \mathbf{12.6}$ kN/m^2

Design effective overburden pressure — $q' = q / \gamma_\gamma = \mathbf{12.6}$ kN/m^2

Bearing resistance factors — $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 deg + \phi'_{b.d} / 2))^2 = \mathbf{7.821}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{16.883}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{5.512}$

Foundation shape factors — $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors — $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_base} = \mathbf{0}$ kN/m

$V = F_{total\_v} = \mathbf{92.9}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{1}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \mathbf{1}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{1}$

Net ultimate bearing capacity $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{mb} \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma$ = **289.5** kN/m^2

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel})$ = **10.281**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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

Permanent unfavourable action γ_G = **1.00**

Permanent favourable action γ_{Gf} = **1.00**

Variable unfavourable action γ_Q = **1.30**

Variable favourable action γ_{Qf} = **0.00**

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

Angle of shearing resistance $\gamma_{\phi'}$ = **1.25**

Effective cohesion $\gamma_{c'}$ = **1.25**

Weight density γ_γ = **1.00**

Retained soil properties

Design effective shear resistance angle $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **14.6** deg

Design wall friction angle $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **7.2** deg

Base soil properties

Design effective shear resistance angle $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **17.9** deg

Design wall friction angle $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **8.8** deg

Design base friction angle $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **11.9** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.553**

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **2.340**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **20.3** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **33** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **1.1** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v}$ = **54.4** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **22.1** kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2$ = **39.5** kN/m

Base soil $F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (h_{pass} + h_{base})^2 / 2$ = **-3.9** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{exc\_h} + F_{sur\_h}$ = **57.8** kN/m

Overturning moments on wall

Surcharge load $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **34.3** kNm/m

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **40.9** kNm/m

Total $M_{total\_OT} = M_{moist\_OT} + M_{sur\_OT} = \mathbf{75.1}$ kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem} = \mathbf{63.8}$ kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base} = \mathbf{54.5}$ kNm/m

Line loads $M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 = \mathbf{3.5}$ kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} = \mathbf{121.7}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT} = \mathbf{1.62}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{20.3}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{33}$ kN/m

Line loads $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = \mathbf{3.3}$ kN/m

Base soil $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb} = \mathbf{12.6}$ kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v} + F_{P\_v} = \mathbf{69.2}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{22.1}$ kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2 = \mathbf{39.5}$ kN/m

Base soil $F_{pass\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-8.7}$ kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{pass\_h} + F_{sur\_h} = \mathbf{52.9}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{63.8}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{54.5}$ kNm/m

Surcharge load $M_{sur} = -F_{sur\_h} \times x_{sur\_h} = \mathbf{-34.3}$ kNm/m

Line loads $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = \mathbf{10.4}$ kNm/m

Moist retained soil $M_{moist} = -F_{moist\_h} \times x_{moist\_h} = \mathbf{-40.9}$ kNm/m

Base soil $M_{pass} = F_{pass\_v} \times x_{pass\_v} = \mathbf{18.9}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_{sur} + M_P = \mathbf{72.5}$ kNm/m

Check bearing pressure

Propping force $F_{prop\_base} = F_{total\_h} = \mathbf{52.9}$ kN/m

Distance to reaction $\bar{x} = l_{base} / 2 = \mathbf{1650}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{0}$ mm

Loaded length of base $l_{load} = l_{base} = \mathbf{3300}$ mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{base} = \mathbf{21}$ kN/m^2

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{base} = \mathbf{21}$ kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_{mb} = \mathbf{12.6}$ kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{12.6}$ kN/m^2

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = \mathbf{5.213}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{13.034}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{2.723}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_base} = \mathbf{0}$ kN/m

$V = F_{total\_v} = \mathbf{69.2}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{1}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \mathbf{1}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{1}$

Net ultimate bearing capacity $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{mb} \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{160}$ kN/m^2

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{7.637}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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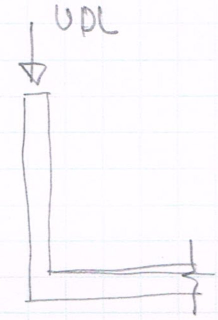
RETAINING WALL DESIGN - PARTY WALL WITH No52



UDL due to party wall

REACTION FROM GB5

@ DL = [(0.215×19+0.2)×6.2 + 0.6 × 6/2 + 3.7/2 × 0.6 + 3.7/2 × 1] × 4.7/2

= 73.6 kN.

@ LL = (1.5 × 6/2 + 1.5 × 3.7/2 + 0.6 × 3.7/2) × 4.7/2 = 19.7 kN.

REACTION FROM GB2

@ DL = [(0.1×19+0.2)×3 + 7.5/2 × 0.6 × 3 + 0.6 × 3 + 7.5/2 × 1] × 4.7/2

= 43.7 kN

LL = (7.5/2 × 1.5 × 3 + 7.5/2 × 0.6) × 4.7/2 = 19.2 kN

CONSIDER No. 52 LOADINGS → ALL ABOVE REACTIONS ×2.

UDL @ DL = (0.215×19+0.2)×10 + (73.6×2 + 43.7×2)/10

= 66.31 kN/m.

LL = (19.7×2 + 19.2×2) / 10 = 7.8 kN/m.

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 2.6.04

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **900** mm
Prop height	h_{prop} = **900** mm
Stem thickness	t_{stem} = **300** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **2000** mm
Base thickness	t_{base} = **400** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **700** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **200** mm
Depth of excavation	d_{exc} = **200** mm

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	Stiff or hard glacial silty clay
Moist density	γ_{mb} = **21** kN/m^3
Characteristic cohesion	$c'_{b.k}$ = **0** kN/m^2
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **22** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **11** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **14.7** deg

Loading details

Vertical line load at 2150 mm	P_{G1} = **67** kN/m
	P_{Q1} = **8** kN/m

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem}$ = **2300** mm
Moist soil height	$h_{moist} = h_{soil}$ = **900** mm
Retained surface length	$l_{sur} = l_{heel}$ = **0** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **1300** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.27** m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **2150** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.92** m^2
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **1150** mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe}$ = **0.4** m^2
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass}$ = **1000** mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3$ = **200** mm

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

Permanent unfavourable action	γ_G = **1.35**
Permanent favourable action	γ_{Gf} = **1.00**
Variable unfavourable action	γ_Q = **1.50**
Variable favourable action	γ_{Qf} = **0.00**

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

Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Effective cohesion	$\gamma_{c'}$ = **1.00**
Weight density	γ_{γ} = **1.00**

Retained soil properties

Design effective shear resistance angle	$\phi'_{r.d} = \mathrm{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **18** deg

Design wall friction angle $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **9** deg

Base soil properties

Design effective shear resistance angle $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **22** deg

Design wall friction angle $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **11** deg

Design base friction angle $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **14.7** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'} =$ **0** kN/m^2

Using Coulomb theory

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

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2) =$ **2.958**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} =$ **6.8** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **23** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} =$ **67** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} =$ **96.8** kN/m

Horizontal forces on wall

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2 =$ **8.2** kN/m

Base soil $F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (h_{pass} + h_{base})^2 / 2 =$ **-4.9** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{exc\_h} =$ **3.3** kN/m

Overturning moments on wall

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} =$ **3.5** kNm/m

Total $M_{total\_OT} = M_{moist\_OT} =$ **3.5** kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem} =$ **14.5** kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base} =$ **26.4** kNm/m

Line loads $M_{P\_R} = (\text{abs}(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 =$ **144.1** kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} =$ **185** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT} =$ **52.297**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **9.1** kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **31.1** kN/m

Line loads $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} =$ **102.5** kN/m

Base soil $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb} =$ **11.3** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v} + F_{P\_v} =$ **154** kN/m

Horizontal forces on wall

Moist retained soil — $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2 =$ **8.2** kN/m

Base soil — $F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h})) =$ **-8.2** kN/m

Total — $F_{total\_h} = F_{moist\_h} + F_{pass\_h} =$ **0** kN/m

Moments on wall

Wall stem — $M_{stem} = F_{stem} \times x_{stem} =$ **19.6** kNm/m

Wall base — $M_{base} = F_{base} \times x_{base} =$ **35.7** kNm/m

Line loads — $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 =$ **220.3** kNm/m

Moist retained soil — $M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **-3.5** kNm/m

Base soil — $M_{pass} = F_{pass\_v} \times x_{pass\_v} =$ **11.3** kNm/m

Total — $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_P =$ **283.4** kNm/m

Check bearing pressure

Propping force — $F_{prop\_base} = F_{total\_h} =$ **0** kN/m

Distance to reaction — $\bar{x} = l_{base} / 2 =$ **1150** mm

Eccentricity of reaction — $e = \bar{x} - l_{base} / 2 =$ **0** mm

Loaded length of base — $l_{load} = l_{base} =$ **2300** mm

Bearing pressure at toe — $q_{toe} = F_{total\_v} / l_{base} =$ **66.9** kN/m^2

Bearing pressure at heel — $q_{heel} = F_{total\_v} / l_{base} =$ **66.9** kN/m^2

Effective overburden pressure — $q = (t_{base} + d_{cover}) \times \gamma_{mb} =$ **12.6** kN/m^2

Design effective overburden pressure — $q' = q / \gamma_\gamma =$ **12.6** kN/m^2

Bearing resistance factors — $N_q = \text{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 =$ **7.821**

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) =$ **16.883**

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) =$ **5.512**

Foundation shape factors — $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors — $H = F_{moist\_h} + F_{pass\_h} - F_{prop\_base} =$ **0** kN/m

$V = F_{total\_v} =$ **154** kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m =$ **1**

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} =$ **1**

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) =$ **1**

Net ultimate bearing capacity — $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{mb} \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **231.7** kN/m^2

Factor of safety — $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **3.461**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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

Permanent unfavourable action — $\gamma_G =$ **1.00**

Permanent favourable action — $\gamma_{Gf} =$ **1.00**

Variable unfavourable action — $\gamma_Q =$ **1.30**

Variable favourable action — $\gamma_{Qf} =$ **0.00**

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

Angle of shearing resistance	$\gamma_{\phi'}$ = **1.25**
Effective cohesion	$\gamma_{c'}$ = **1.25**
Weight density	γ_{γ} = **1.00**

Retained soil properties

Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **14.6** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **7.2** deg

Base soil properties

Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **17.9** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **8.8** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **11.9** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.553**
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **2.340**

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **6.8** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **23** kN/m
Line loads	$F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **67** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v}$ = **96.8** kN/m

Horizontal forces on wall

Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2$ = **7** kN/m
Base soil	$F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (h_{pass} + h_{base})^2 / 2$ = **-3.9** kN/m
Total	$F_{total\_h} = F_{moist\_h} + F_{exc\_h}$ = **3.1** kN/m

Overturning moments on wall

Moist retained soil	$M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **3** kNm/m
Total	$M_{total\_OT} = M_{moist\_OT}$ = **3** kNm/m

Restoring moments on wall

Wall stem	$M_{stem\_R} = F_{stem} \times x_{stem}$ = **14.5** kNm/m
Wall base	$M_{base\_R} = F_{base} \times x_{base}$ = **26.4** kNm/m
Line loads	$M_{P\_R} = (\text{abs}(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1$ = **144.1** kNm/m
Total	$M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R}$ = **185** kNm/m

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **61.413**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **6.8** kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **23** kN/m

Line loads $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}$ = **77.4** kN/m

Base soil $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb}$ = **8.4** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v} + F_{P\_v}$ = **115.6** kN/m

Horizontal forces on wall

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2$ = **7** kN/m

Base soil $F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h}))$ = **-7** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{pass\_h}$ = **0** kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem}$ = **14.5** kNm/m

Wall base $M_{base} = F_{base} \times x_{base}$ = **26.4** kNm/m

Line loads $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1$ = **166.4** kNm/m

Moist retained soil $M_{moist} = -F_{moist\_h} \times x_{moist\_h}$ = **-3** kNm/m

Base soil $M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **8.4** kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_P$ = **212.8** kNm/m

Check bearing pressure

Propping force $F_{prop\_base} = F_{total\_h}$ = **0** kN/m

Distance to reaction $\bar{x} = l_{base} / 2$ = **1150** mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2$ = **0** mm

Loaded length of base $l_{load} = l_{base}$ = **2300** mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{base}$ = **50.2** kN/m^2

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{base}$ = **50.2** kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_{mb}$ = **12.6** kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma$ = **12.6** kN/m^2

Bearing resistance factors $N_q = \text{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2$ = **5.213**

$N_c = (N_q - 1) \times \cot(\phi'_{b.d})$ = **13.034**

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d})$ = **2.723**

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{moist\_h} + F_{pass\_h} - F_{prop\_base}$ = **0** kN/m

$V = F_{total\_v}$ = **115.6** kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m$ = **1**

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)}$ = **1**

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d}))$ = **1**

Net ultimate bearing capacity $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{mb} \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma$ = **131.4** kN/m^2

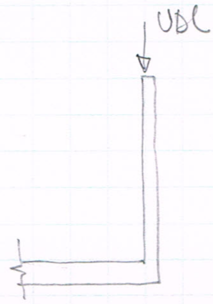
Factor of safety $FoS_{bp} = n_f / max(q_{toe}, q_{heel})$ = **2.616**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Bini Struct-e Ltd. Consulting Structural Engineers	Project: 54 Sumatra road, London, NW6 1PR		Job Ref: 11654	
	Drawing Ref	Calculations by: MR	Checked by: VC	Sheet of
	Part of Structure		Date: 10.2018	

RETAINING WALL DESIGN – PARTY WALL WITH NO.56.

UDL due to reaction from
GB5 / GB2 & PARTY WALL WITH CHIMNEY BREASTS.



UDL @ DL = (0.215 x 19 + 0.2) x 9 +
[(0.215 x 19 + 0.2) x 12 x 3.2] / 10 x 2
+ (73.6 x 2 + 43.7 x 2) / 10 = 95 kN/m.

LL = (19.7 x 2 + 19.2 x 2) / 10 = 7.8 kN/m.

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 2.6.04

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **2300** mm
Prop height	h_{prop} = **900** mm
Stem thickness	t_{stem} = **300** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **2000** mm
Base thickness	t_{base} = **400** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **2100** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **200** mm
Depth of excavation	d_{exc} = **200** mm

Retained soil properties

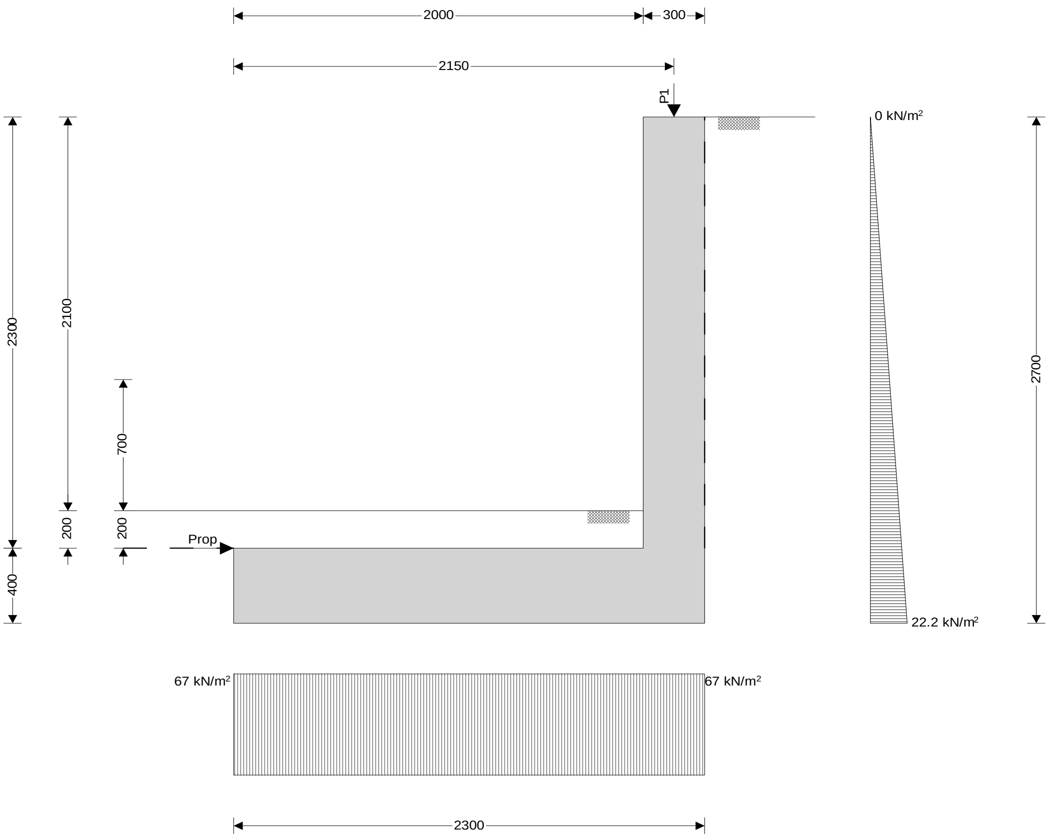
Soil type	Organic clay
Moist density	γ_{mr} = **15** kN/m^3
Saturated density	γ_{sr} = **15** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{r.k}$ = **18** deg
Characteristic wall friction angle	$\delta_{r.k}$ = **9** deg

Base soil properties

Soil type	Stiff or hard glacial silty clay
Moist density	γ_{mb} = **21** kN/m^3
Characteristic cohesion	$c'_{b.k}$ = **0** kN/m^2
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **22** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **11** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **14.7** deg

Loading details

Vertical line load at 2150 mm	P_{G1} = **95** kN/m
	P_{Q1} = **8** kN/m



Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} = \mathbf{2300}$ mm
Moist soil height	$h_{moist} = h_{soil} = \mathbf{2300}$ mm
Retained surface length	$l_{sur} = l_{heel} = \mathbf{0}$ mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{2700}$ mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.69}$ m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{2150}$ mm
Area of wall base	$A_{base} = l_{base} \times t_{base} = \mathbf{0.92}$ m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 = \mathbf{1150}$ mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe} = \mathbf{0.4}$ m^2
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{1000}$ mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 = \mathbf{200}$ mm

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

Permanent unfavourable action	$\gamma_G = \mathbf{1.35}$
Permanent favourable action	$\gamma_{Gf} = \mathbf{1.00}$
Variable unfavourable action	$\gamma_Q = \mathbf{1.50}$
Variable favourable action	$\gamma_{Qf} = \mathbf{0.00}$

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

Angle of shearing resistance	$\gamma_{\phi'} = \mathbf{1.00}$

Effective cohesion $\gamma_{c'}$ = **1.00**

Weight density γ_{γ} = **1.00**

Retained soil properties

Design effective shear resistance angle $\phi'_{r.d} = atan(tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **18** deg

Design wall friction angle $\delta_{r.d} = atan(tan(\delta_{r.k}) / \gamma_{\phi'})$ = **9** deg

Base soil properties

Design effective shear resistance angle $\phi'_{b.d} = atan(tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **22** deg

Design wall friction angle $\delta_{b.d} = atan(tan(\delta_{b.k}) / \gamma_{\phi'})$ = **11** deg

Design base friction angle $\delta_{bb.d} = atan(tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **14.7** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

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

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{}[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2)$ = **2.958**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **17.3** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **23** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **95** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v}$ = **135.3** kN/m

Horizontal forces on wall

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2$ = **35.2** kN/m

Base soil $F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (h_{pass} + h_{base})^2 / 2$ = **-4.9** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{exc\_h}$ = **30.3** kN/m

Overturning moments on wall

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **31.7** kNm/m

Total $M_{total\_OT} = M_{moist\_OT}$ = **31.7** kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem}$ = **37.1** kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base}$ = **26.4** kNm/m

Line loads $M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1$ = **204.3** kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R}$ = **267.8** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **8.449**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **23.3** kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **31.1** kN/m

Line loads $F_{P_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = $ **140.3** kN/m

Base soil $F_{pass_v} = \gamma_G \times A_{pass} \times \gamma_{mb} = $ **11.3** kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{pass_v} + F_{P_v} = $ **205.9** kN/m

Horizontal forces on wall

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2 = $ **35.2** kN/m

Base soil $F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2 = $ **-11** kN/m

Total $F_{total_h} = F_{moist_h} + F_{pass_h} = $ **24.2** kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = $ **50.1** kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = $ **35.7** kNm/m

Line loads $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = $ **301.5** kNm/m

Moist retained soil $M_{moist} = -F_{moist_h} \times x_{moist_h} = $ **-31.7** kNm/m

Base soil $M_{pass} = F_{pass_v} \times x_{pass_v} = $ **11.3** kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_P = $ **367** kNm/m

Check bearing pressure

Propping force $F_{prop_base} = F_{total_h} = $ **24.2** kN/m

Distance to reaction $\bar{x} = l_{base} / 2 = $ **1150** mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = $ **0** mm

Loaded length of base $l_{load} = l_{base} = $ **2300** mm

Bearing pressure at toe $q_{toe} = F_{total_v} / l_{base} = $ **89.5** kN/m^2

Bearing pressure at heel $q_{heel} = F_{total_v} / l_{base} = $ **89.5** kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_{mb} = $ **12.6** kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = $ **12.6** kN/m^2

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = $ **7.821**

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = $ **16.883**

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = $ **5.512**

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{moist_h} + F_{pass_h} - F_{prop_base} = $ **0** kN/m

$V = F_{total_v} = $ **205.9** kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = $ **1**

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = $ **1**

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = $ **1**

Net ultimate bearing capacity $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{mb} \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = $ **231.7** kN/m^2

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = $ **2.587**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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

Permanent unfavourable action $\gamma_G = $ **1.00**

Permanent favourable action $\gamma_{Gf} = $ **1.00**

Variable unfavourable action γ_Q = **1.30**

Variable favourable action γ_{Qf} = **0.00**

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

Angle of shearing resistance $\gamma_{\phi'}$ = **1.25**

Effective cohesion $\gamma_{c'}$ = **1.25**

Weight density γ_γ = **1.00**

Retained soil properties

Design effective shear resistance angle $\phi'_{r.d} = atan(tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **14.6** deg

Design wall friction angle $\delta_{r.d} = atan(tan(\delta_{r.k}) / \gamma_{\phi'})$ = **7.2** deg

Base soil properties

Design effective shear resistance angle $\phi'_{b.d} = atan(tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **17.9** deg

Design wall friction angle $\delta_{b.d} = atan(tan(\delta_{b.k}) / \gamma_{\phi'})$ = **8.8** deg

Design base friction angle $\delta_{bb.d} = atan(tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **11.9** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{}[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2)$ = **0.553**

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{}[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2)$ = **2.340**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **17.3** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **23** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **95** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v}$ = **135.3** kN/m

Horizontal forces on wall

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2$ = **30** kN/m

Base soil $F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (h_{pass} + h_{base})^2 / 2$ = **-3.9** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{exc\_h}$ = **26.1** kN/m

Overturning moments on wall

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **27** kNm/m

Total $M_{total\_OT} = M_{moist\_OT}$ = **27** kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem}$ = **37.1** kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base}$ = **26.4** kNm/m

Line loads $M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1$ = **204.3** kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R}$ = **267.8** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **9.922**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{17.3}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{23}$ kN/m

Line loads $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = \mathbf{105.4}$ kN/m

Base soil $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_{mb} = \mathbf{8.4}$ kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v} + F_{P\_v} = \mathbf{154.1}$ kN/m

Horizontal forces on wall

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr} \times h_{eff}^2 / 2 = \mathbf{30}$ kN/m

Base soil $F_{pass\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_{mb} \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-8.7}$ kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{pass\_h} = \mathbf{21.2}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{37.1}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{26.4}$ kNm/m

Line loads $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = \mathbf{226.6}$ kNm/m

Moist retained soil $M_{moist} = -F_{moist\_h} \times x_{moist\_h} = \mathbf{-27}$ kNm/m

Base soil $M_{pass} = F_{pass\_v} \times x_{pass\_v} = \mathbf{8.4}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_P = \mathbf{271.6}$ kNm/m

Check bearing pressure

Propping force $F_{prop\_base} = F_{total\_h} = \mathbf{21.2}$ kN/m

Distance to reaction $\bar{x} = l_{base} / 2 = \mathbf{1150}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{0}$ mm

Loaded length of base $l_{load} = l_{base} = \mathbf{2300}$ mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{base} = \mathbf{67}$ kN/m²

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{base} = \mathbf{67}$ kN/m²

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_{mb} = \mathbf{12.6}$ kN/m²

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{12.6}$ kN/m²

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2 = \mathbf{5.213}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{13.034}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{2.723}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{moist\_h} + F_{pass\_h} - F_{prop\_base} = \mathbf{0}$ kN/m

$V = F_{total\_v} = \mathbf{154.1}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{1}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \mathbf{1}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{1}$

Net ultimate bearing capacity $n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{mb} \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **131.4** kN/m²

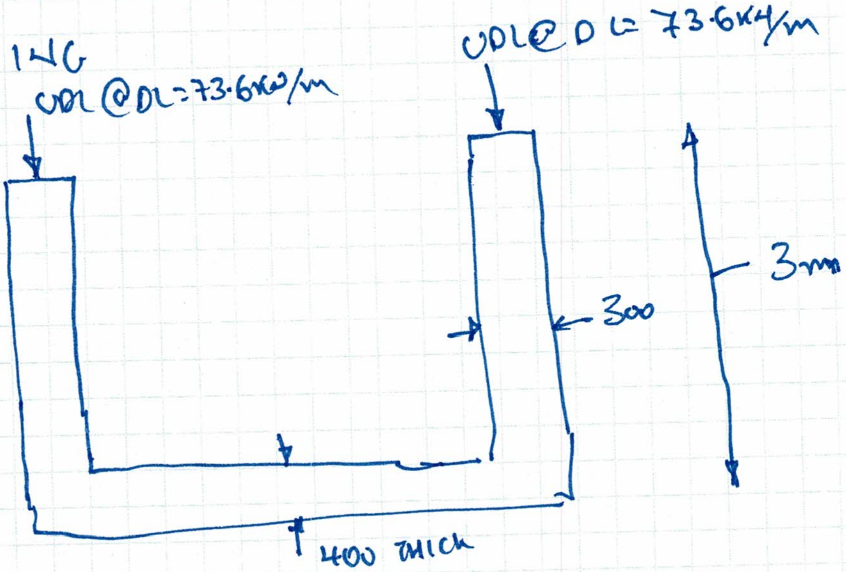
Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{1.963}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Bini Struct-e Ltd. Consulting Structural Engineers	Project: 54 Sumatra road, London, NW6 1PR		Job Ref: 11654	
	Drawing Ref	Calculations by: BD	Checked by: DB	Sheet of
	Part of Structure: UPLIFT FORCE		Date: 09.2018	

MOVEMENT DUE TO REMOVAL OF SOIL : i.e. UPLIFT & HEAVE

TOTAL LOAD DUE TO EXISTING BUILDING



∴ DUE TO WALLS & FLOORS ABOVE = 73.6 × (8×2 + 5.2×2) = 1928 kN

DUE TO WALLS AT BASEMENT = 0.3 × 3 × 24 × (8×2 + 5.2×2) = 570 kN

DUE TO RAFT SLAB & SCREED = 0.475 × 24 × 8 × 5.2 = 474 kN

TOTAL LOAD = 1928 + 570 + 474 = 2972 kN

SOIL REMOVAL ∴ TOTAL UPLIFT FORCE

= 18 × 8 × 3.7 × 2.8 + 1.2 × 8 × 1.5 × 18 = 1751 kN

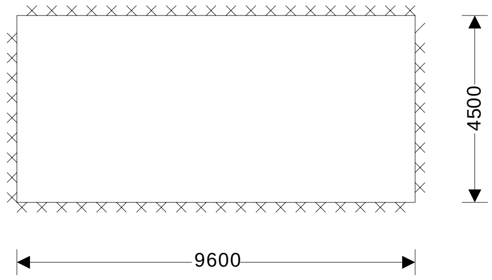
∴ F.O.S = 2972/1751 = 1.7 ∴ NO UPLIFT.

SLAB & HEAVE DESIGN REFER TO FOLLOWING PAGES

RC SLAB DESIGN

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

Tedds calculation version 1.0.10



Slab definition

Type of slab	**Two way spanning with restrained edges**
Overall slab depth	h = **400** mm
Shorter effective span of panel	l_x = **4500** mm
Longer effective span of panel	l_y = **9600** 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 = **54.0** kN/m^2
Characteristic variable action	Q_k = **0.0** 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	$q = \gamma_G \times G_k + \gamma_Q \times Q_k$ = **72.9** kN/m^2
Quasi-permanent load	$q_{SLS} = 1.0 \times G_k + \psi_2 \times Q_k$ = **54.0** kN/m^2

Concrete properties

Concrete strength class	C35/45
Characteristic cylinder strength	f_{ck} = **35** 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} = **19.8** N/mm^2
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30\ \text{N/mm}^2 \times (f_{ck} / 1\ \text{N/mm}^2)^{2/3}$ = **3.2** 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} = **30** mm
Fire resistance period to top of slab	R_{top} = **60** min
Fire resistance period to bottom of slab	R_{btm} = **60** min
Axia distance to top reinft (Table 5.8)	a_{fi_t} = **15** mm
Axia distance to bottom reinft (Table 5.8)	a_{fi_b} = **15** mm
Min. top cover requirement with regard to bond	c_{min,b_t} = **16** 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	$c_{nom\_t\_min}$ = **26.0** 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} = **0.0480**
Design bending moment	$M_{x\_p} = \beta_{sx\_p} \times q \times l_x^2$ = **70.9** kNm/m
Reinforcement provided	A393 mesh + 10 mm dia. bars at 200 mm centres
Area provided	A_{sx_p} = 786 mm^2/m
Effective depth to tension reinforcement	$d_{x\_p} = h - c_{nom\_b} - \phi_{x\_p} / 2$ = **365.0** mm
K factor	$K = M_{x\_p} / (b \times d_{x\_p}^2 \times f_{ck})$ = **0.015**
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	$z = \min(0.95 \times d_{x\_p}, d_{x\_p}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **346.8** mm
Area of reinforcement required for bending	$A_{sx\_p\_m} = M_{x\_p} / (f_{yd} \times z)$ = **470** mm^2/m
Minimum area of reinforcement required	$A_{sx\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_p}, 0.0013 \times b \times d_{x\_p})$ = **609** mm^2/m
Area of reinforcement required	$A_{sx\_p\_req} = \max(A_{sx\_p\_m}, A_{sx\_p\_min})$ = **609** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress	$\sigma_{sx\_p} = (f_{yk} / \gamma_S) \times \min((A_{sx\_p\_m}/A_{sx\_p}), 1.0) \times q_{SLS} / q$ = **192.7** N/mm^2
Maximum allowable spacing (Table 7.3N)	$s_{max\_x\_p}$ = **259** mm
Actual bar spacing	s_{x_p} = **100** 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	$M_{y\_p} = \beta_{sy\_p} \times q \times l_x^2$ = **35.4** kNm/m
Reinforcement provided	A393 mesh + 10 mm dia. bars at 200 mm centres
Area provided	A_{sy_p} = 786 mm^2/m
Effective depth to tension reinforcement	$d_{y\_p} = h - c_{nom\_b} - \phi_{x\_p} - \phi_{y\_p} / 2$ = **355.0** mm
K factor	$K = M_{y\_p} / (b \times d_{y\_p}^2 \times f_{ck})$ = **0.008**
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	$z = \min(0.95 \times d_{y\_p}, d_{y\_p}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **337.3** mm
Area of reinforcement required for bending	$A_{sy\_p\_m} = M_{y\_p} / (f_{yd} \times z)$ = **242** mm^2/m
Minimum area of reinforcement required	$A_{sy\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_p}, 0.0013 \times b \times d_{y\_p})$ = **593** mm^2/m

Area of reinforcement required — $A_{sy\_p\_req} = \max(A_{sy\_p\_m}, A_{sy\_p\_min}) =$ **593** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress — $\sigma_{sy\_p} = (f_{yk} / \gamma_S) \times \min((A_{sy\_p\_m}/A_{sy\_p}), 1.0) \times q_{SLS} / q =$ **99.0** N/mm^2

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

Actual bar spacing — $s_{y\_p} =$ **100** mm

PASS - The reinforcement spacing is acceptable

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

Bending moment coefficient — $\beta_{sx\_n} =$ **0.0630**

Design bending moment — $M_{x\_n} = \beta_{sx\_n} \times q \times l_x^2 =$ **93.0** kNm/m

Reinforcement provided — A393 mesh + 16 mm dia. bars at 200 mm centres

Area provided — $A_{sx\_n} = 1398\ mm^2/m$

Effective depth to tension reinforcement — $d_{x\_n} = h - c_{nom\_t} - \phi_{x\_n} / 2 =$ **362.0** mm

K factor — $K = M_{x\_n} / (b \times d_{x\_n}^2 \times f_{ck}) =$ **0.020**

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 — $z = \min(0.95 \times d_{x\_n}, d_{x\_n}/2 \times (1 + (1 - 3.53\times K)^{0.5})) =$ **343.9** mm

Area of reinforcement required for bending — $A_{sx\_n\_m} = M_{x\_n} / (f_{yd} \times z) =$ **622** mm^2/m

Minimum area of reinforcement required — $A_{sx\_n\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_n}, 0.0013\times b\times d_{x\_n}) =$ **604** mm^2/m

Area of reinforcement required — $A_{sx\_n\_req} = \max(A_{sx\_n\_m}, A_{sx\_n\_min}) =$ **622** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress — $\sigma_{sx\_n} = (f_{yk} / \gamma_S) \times \min((A_{sx\_n\_m}/A_{sx\_n}), 1.0) \times q_{SLS} / q =$ **143.3** 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 — $\beta_{sy\_n} =$ **0.0320**

Design bending moment — $M_{y\_n} = \beta_{sy\_n} \times q \times l_x^2 =$ **47.2** kNm/m

Reinforcement provided — A393 mesh + 16 mm dia. bars at 200 mm centres

Area provided — $A_{sy\_n} = 1398\ mm^2/m$

Effective depth to tension reinforcement — $d_{y\_n} = h - c_{nom\_t} - \phi_{x\_n} - \phi_{y\_n} / 2 =$ **346.0** mm

K factor — $K = M_{y\_n} / (b \times d_{y\_n}^2 \times f_{ck}) =$ **0.011**

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 — $z = \min(0.95 \times d_{y\_n}, d_{y\_n}/2 \times (1 + (1 - 3.53\times K)^{0.5})) =$ **328.7** mm

Area of reinforcement required for bending — $A_{sy\_n\_m} = M_{y\_n} / (f_{yd} \times z) =$ **331** mm^2/m

Minimum area of reinforcement required — $A_{sy\_n\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_n}, 0.0013\times b\times d_{y\_n}) =$ **578** mm^2/m

Area of reinforcement required — $A_{sy\_n\_req} = \max(A_{sy\_n\_m}, A_{sy\_n\_min}) =$ **578** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress — $\sigma_{sy\_n} = (f_{yk} / \gamma_S) \times \min((A_{sy\_n\_m}/A_{sy\_n}), 1.0) \times q_{SLS} / q =$ **76.1** N/mm^2

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 $V_{x\_n} = q \times l_x / 2 =$ **164.0** kN/m

Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200 \text{ mm} / d_{x\_n})^{0.5}) =$ **1.743**

Reinforcement ratio $\rho_l = \min(0.02, A_{sx\_n} / (b \times d_{x\_n})) =$ **0.0039**

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} = **172.5** 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} = **180.2** kN/m

PASS - Shear capacity is adequate

Shear capacity check at long span continuous support

Shear force $V_{y\_n} = q \times l_x / 2 =$ **164.0** kN/m

Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200 \text{ mm} / d_{y\_n})^{0.5}) =$ **1.760**

Reinforcement ratio $\rho_l = \min(0.02, A_{sy\_n} / (b \times d_{y\_n})) =$ **0.0040**

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} = **167.3** 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} = **176.6** kN/m

PASS - Shear capacity is adequate

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

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 =$ **0.0059**

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) $ratio_{lim\_x\_bas}$ = **55.29**

Mod span-to-depth ratio limit $ratio_{lim\_x} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2/f_{yk}) \times (A_{sx\_p}/A_{sx\_p\_m})) \times ratio_{lim\_x\_bas}) =$ **60.00**

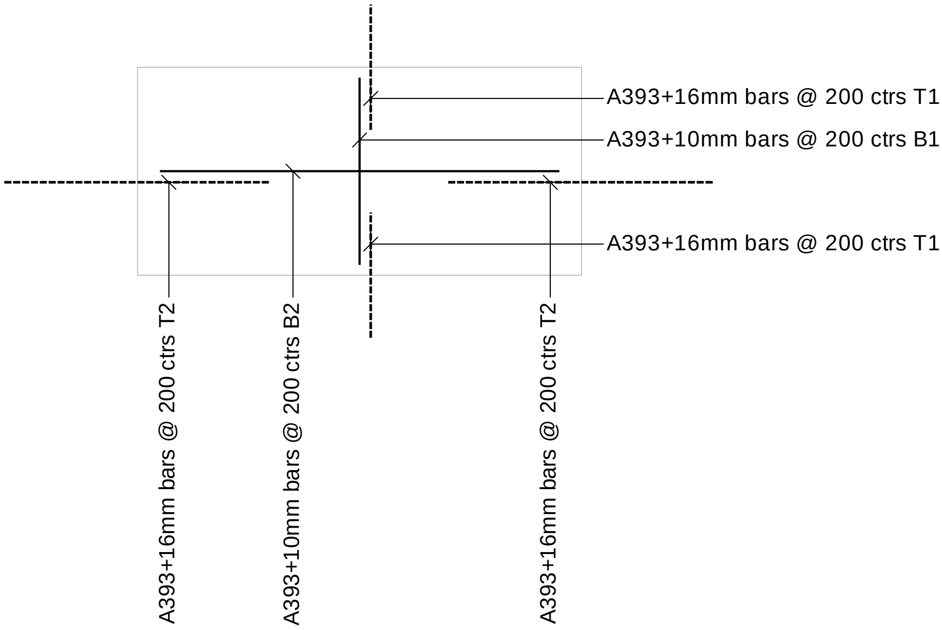
Actual span-to-eff. depth ratio $ratio_{act\_x} = l_x / d_{x\_p} =$ **12.33**

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.

Tedds Bini Struct-e	Project: 54 Sumatra road, London, NW6 1PR				Job no.: 11654	
	Calcs for: Basement Slab - HEAVE				Start page no./Revision: 5	
	Calcs by: DB	Calcs date: 21/10/2018	Checked by	Checked date	Approved by	Approved date



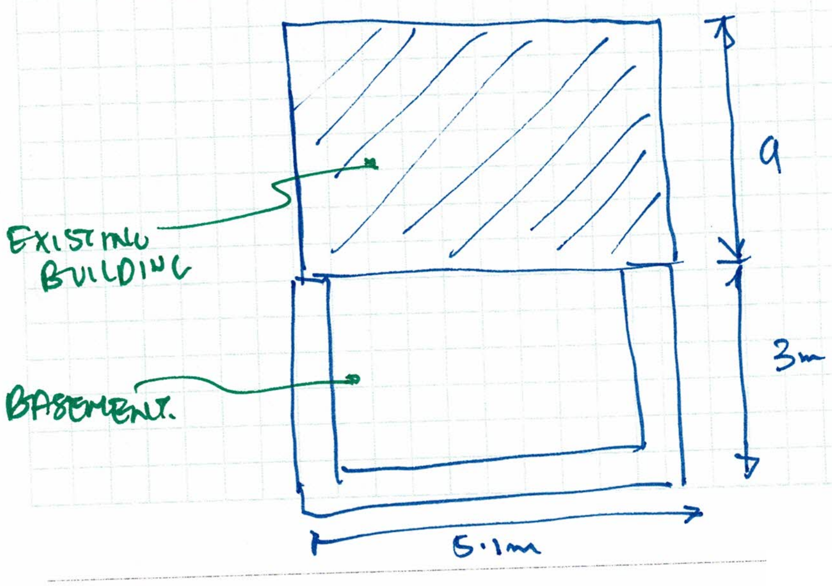
Bini Struct-e Ltd. Consulting Structural Engineers	Project 54 Sumatra road, London, NW6 1PR		Job Ref 11654	
	Drawing Ref	Calculations by BD	Checked by DB	Sheet of
	Part of Structure HORIZONTAL MOVEMENT DUE TO EXCAVATION & INSTALLATION OF WALL.		Date 09.2018	

HORIZONTAL & VERTICAL MOVEMENT ASSESSMENT TO CIRIA C580 FOR EMBEDDED RETAINING WALLS.

TABLE 2.4 CIRIA C580

CATEGORY OF DAMAGE	NORMAL DEGREE	LIMITING TENSILE STRAIN %
0	NEGLIGIBLE	0.00% - 0.05%
1	VERY SLIGHT	0.05% - 0.075%
2	SLIGHT	0.075% - 0.15%
3	MODERATE	0.15% - 0.3%
4 to 5	SEVERE TO VERY SEVERE	> 0.3%
5	~	~

THE HORIZONTAL MOVEMENT WILL BE DETERMINED BASED ON ACCUMULATION OF POTENTIAL MOVEMENT DUE TO WALL EXCAVATION & INSTALLATION.



Bini Struct-e Ltd. Consulting Structural Engineers	Project: 54 Sumatra road, London, NW6 1PR		Job Ref: 11654	
	Drawing Ref	Calculations by: BD	Checked by: DB	Sheet of
	Part of Structure: HORIZONTAL MOVEMENT CONT..		Date: 09.2018	

POTENTIAL MOVEMENT DUE TO WALL INSTALLATION

- HORIZONTAL SURFACE MOVEMENT ≈ 0.05%

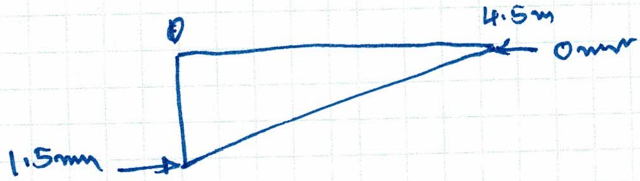
$\delta H = 0.05\% \times 3000 \approx 1.5mm$

- VERTICAL SURFACE MOVEMENT = 0.05%

$\delta V = 0.05\% \times 3000 = 1.5mm$

DISTANCE BEHIND WALL TO NEGLIGIBLE MOVENT

$l_h = 3000 \times 1.5 = 4500mm$



POTENTIAL MOVEMENT DUE TO WALL EXCAVATION

HORIZONTAL SURFACE MOVEMENT ≈ 0.15%

$\delta H = 0.15 \times 3000 = 4.5mm$

~~DISTANCE~~ VERTICAL SURFACE MOVENT ≈ 0.1%

$\delta V = 0.1 \times 3000 \approx 3mm$

DISTANCE BEHIND WALL TO NEGLIGIBLE MOVEMENT

$l_h = 3000 \times 3.75 = 11250$

∴ TOTAL HORIZONTAL MOVEMENT OVER 11250mm ≈ 6mm.

$\therefore \delta i = 6/11250 = 0.053\%$

- ∴ THE ANTICIPATED DAMAGE TO BUILDING/S IS CATEGORISED AS NEGLIGBLE TO VERY SLIGH CATEGORY