PRICE & MYERS

REPORT

56 Croftdown Road
25293

Response to Campbell Reith Audit Query Tracker

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Job Number: **25293**

Date	Version	Notes / Amendments / Issue Purpose
December 2017	2	In response to Campbell Reith Audit comments Oct '17

Query Number:

3 **Structural calculations - Retaining wall and Underpins**
See Appendix A – Head of water at 2/3 basement depth added

Construction methodology and temporary works sequencing and propping
See Appendix B – Updated construction sequence with an additional section through the light well added

Monitoring of structures
See Appendix C – Monitoring positions and trigger limits set

5 **Flood risk assessment**
See Appendix D – York Rise Zone: flood risk assessment

Appendices
Appendix A: P&M retaining underpinned wall calculations Ver2
Appendix B: P&M drawings CS02 RevA and CS03
Appendix C: P&M movement monitoring plan
Appendix D: York Rise Zone: Flood risk assessment

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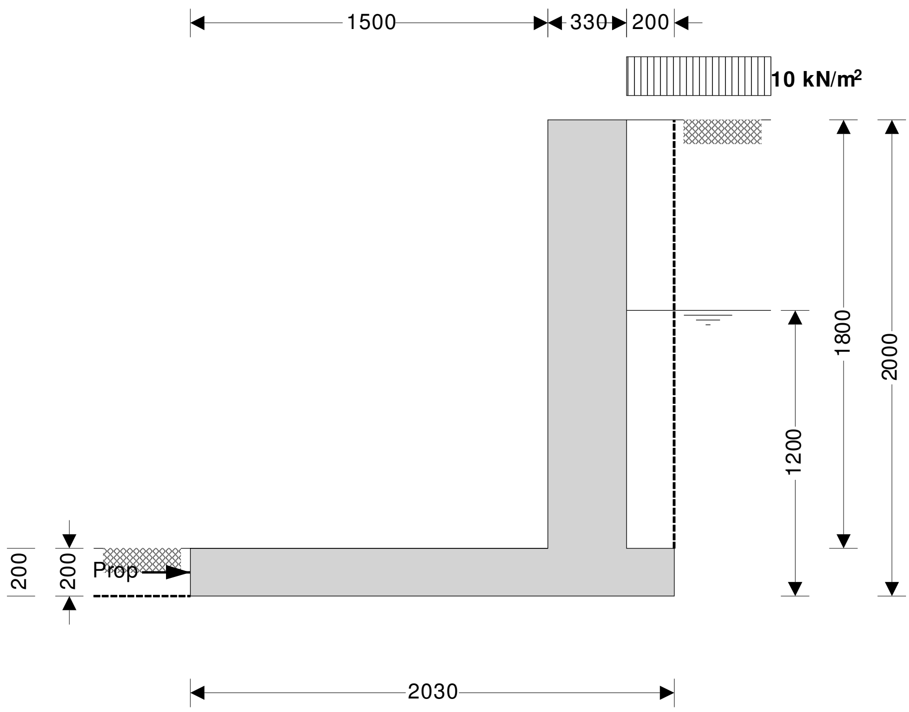
Appendix A

Structural Calculations for Retaining Underpin Walls

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **1800** mm
Thickness of wall stem	t_{wall} = **330** mm
Length of toe	l_{toe} = **1500** mm
Length of heel	l_{heel} = **200** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **2030** mm
Thickness of base	t_{base} = **200** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1030** mm
Thickness of downstand	t_{ds} = **200** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **2000** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **200** mm
Height of ground water behind wall	h_{water} = **1200** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **1000** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **2000** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **21.0** kN/m^3

Saturated density of retained material γ_s = **23.0** kN/m³

Design shear strength ϕ' = **21.1** deg

Angle of wall friction δ = **16.1** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m³

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m²

Using Rankine theory

Active pressure coefficient for retained material $K_a = (\cos(\beta) - \sqrt{[(\cos(\beta))^2 - (\cos(\phi'))^2]}) / (\cos(\beta) + \sqrt{[(\cos(\beta))^2 - (\cos(\phi'))^2]})$

K_a = **0.471**

Passive pressure coefficient for base material $K_p = (1 + \sqrt{[1 - (\cos(\phi'_b))^2]}) / (1 - \sqrt{[1 - (\cos(\phi'_b))^2]})$ = **2.389**

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.640**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m²

Applied vertical dead load on wall W_{dead} = **0.0** kN/m

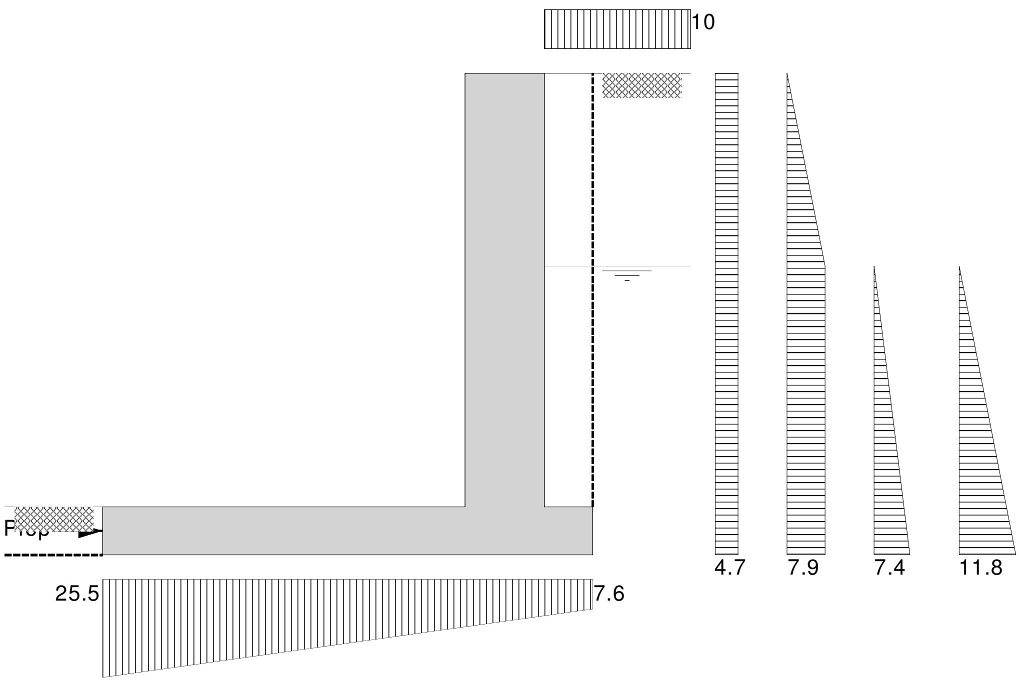
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **0** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **14** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **9.6** kN/m
Surcharge	w_{sur} = Surcharge $\times l_{heel}$ = **2** kN/m
Moist backfill to top of wall	$w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **3.4** kN/m
Saturated backfill	$w_s = l_{heel} \times h_{sat} \times \gamma_s$ = **4.6** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + w_s$ = **33.6** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times$ Surcharge $\times h_{eff}$ = **9.4** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **3.2** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **9.5** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **4.5** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **7.1** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **33.6** kN/m

Calculate propping force

Propping force	$F_{prop} = \max(F_{total} - (W_{total} - w_{sur}) \times \tan(\delta_b), 0$ kN/m)
	F_{prop} = **23.0** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **9.4** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **4.6** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **5.7** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **1.8** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **2.8** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **24.4** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **23.3** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **9.7** kNm/m
Moist backfill	$M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3))$ = **6.5** kNm/m
Saturated backfill	$M_{s\_r} = w_s \times (l_{base} - l_{heel} / 2)$ = **8.9** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m\_r} + M_{s\_r}$ = **48.4** kNm/m

Check bearing pressure

Surcharge	$M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **3.9** kNm/m
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur\_r}$ = **27.9** kNm/m
Total vertical reaction	$R = W_{total}$ = **33.6** kN/m
Distance to reaction	$x_{bar} = M_{total} / R$ = **832** mm
Eccentricity of reaction	$e = \mathrm{abs}((l_{base} / 2) - x_{bar})$ = **183** mm
	Reaction acts within middle third of base
Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **25.5** kN/m²
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **7.6** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Project				Job no.	
TEKLA Tedds	56 Croftdown Road				
Price & Myers 30 Newman Street London W1T 1LT	Calcs for Light well pocket brick retaining wall			Start page no./Revision 4	
	Calcs by TP	Calcs date 14/12/2017	Checked by	Checked date	Approved by	Approved date

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **19.6** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **13.4** kN/m

Surcharge $w_{sur\_f} = \gamma_{f\_l} \times Surcharge \times l_{heel}$ = **3.2** kN/m

Moist backfill to top of wall $w_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **4.7** kN/m

Saturated backfill $w_{s\_f} = \gamma_{f\_d} \times l_{heel} \times h_{sat} \times \gamma_s$ = **6.4** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{m\_w\_f} + w_{s\_f}$ = **47.4** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **20.5** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **6** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **18.1** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **8.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **9.9** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **63** kN/m

Calculate propping force

Propping force $F_{prop\_f} = \max(F_{total\_f} - (W_{total\_f} - w_{sur\_f}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **48.1** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **20.5** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **8.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **10.8** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **3.4** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **4** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **47.5** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **32.7** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **13.6** kNm/m

Surcharge $M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2)$ = **6.2** kNm/m

Moist backfill $M_{m\_r\_f} = (w_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + w_{m\_s\_f} \times (l_{base} - l_{heel} / 3))$ = **9.1** kNm/m

Saturated backfill $M_{s\_r\_f} = w_{s\_f} \times (l_{base} - l_{heel} / 2)$ = **12.4** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} + M_{s\_r\_f}$ = **74** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **26.5** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **47.4** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **559** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **456** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **56.6** kN/m²

Bearing pressure at heel — $p_{heel\_f} = 0$ kN/m^2 = **0** kN/m^2

Rate of change of base reaction — rate = $p_{toe\_f} / (3 \times x_{bar\_f})$ = **33.75** kN/m^2/m

Bearing pressure at stem / toe — $p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2)$ = **5.9** kN/m^2

Bearing pressure at mid stem — $p_{stem\_mid\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **0.4** kN/m^2

Bearing pressure at stem / heel — $p_{stem\_heel\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **0** kN/m^2

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete — f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement — f_y = **500** N/mm^2

Base details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in toe — c_{toe} = **50** mm

Calculate shear for toe design

Shear from bearing pressure — $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2$ = **46.9** kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **9.9** kN/m

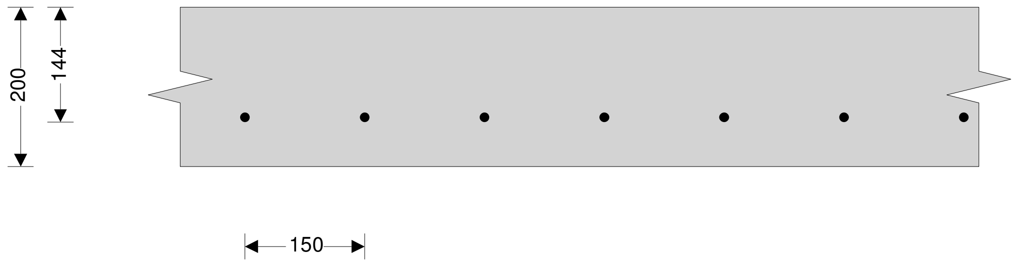
Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base}$ = **37** kN/m

Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6$ = **52.4** kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **9.2** kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base}$ = **43.3** kNm/m



Check toe in bending

Width of toe — b = **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **144.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.052**

Compression reinforcement is not required

Lever arm — $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

z_{toe} = **135** mm

Area of tension reinforcement required — $As_{toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **736** mm^2/m

Minimum area of tension reinforcement — $As_{toe\_min} = k \times b \times t_{base}$ = **260** mm^2/m

Area of tension reinforcement required — $As_{toe\_req} = \text{Max}(As_{toe\_des}, As_{toe\_min})$ = **736** mm^2/m

Reinforcement provided — **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided — As_{toe_prov} = **754** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.257** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.769** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall heel (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in heel c_{heel} = **30** mm

Calculate shear for heel design

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base}$ = **1.3** kN/m

Shear from weight of moist backfill $V_{heel\_wt\_m} = w_{m\_w\_f}$ = **4.7** kN/m

Shear from weight of saturated backfill $V_{heel\_wt\_s} = w_{s\_f}$ = **6.4** kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f}$ = **3.2** kN/m

Total shear for heel design $V_{heel} = V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_wt\_s} + V_{heel\_sur}$ = **15.7** kN/m

Calculate moment for heel design

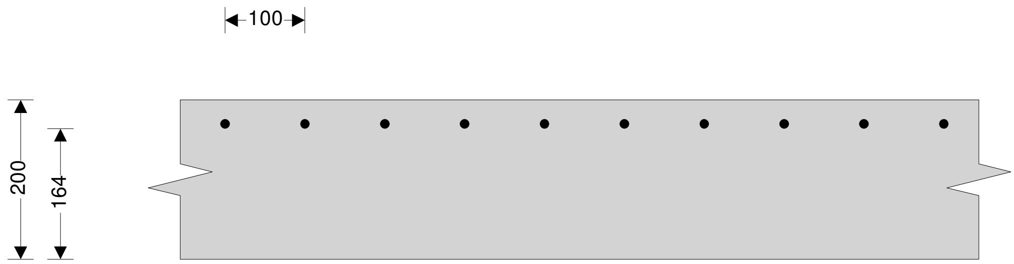
Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2)$ = **0.4** kNm/m

Moment from weight of moist backfill $M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2$ = **1.2** kNm/m

Moment from weight of saturated backfill $M_{heel\_wt\_s} = w_{s\_f} \times (l_{heel} + t_{wall}) / 2$ = **1.7** kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2$ = **0.8** kNm/m

Total moment for heel design $M_{heel} = M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_wt\_s} + M_{heel\_sur}$ = **4.2** kNm/m



Check heel in bending

Width of heel b = **1000** mm/m

Depth of reinforcement $d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2)$ = **164.0** mm

Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu})$ = **0.004**

Compression reinforcement is not required

Lever arm $z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$

z_{heel} = **156** mm

Area of tension reinforcement required $A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel})$ = **63** mm^2/m

Minimum area of tension reinforcement $A_{s\_heel\_min} = k \times b \times t_{base}$ = **260** mm^2/m

Area of tension reinforcement required $A_{s\_heel\_req} = \mathrm{Max}(A_{s\_heel\_des}, A_{s\_heel\_min})$ = **260** mm^2/m

Reinforcement provided **12 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s\_heel\_prov}$ = **1131** mm^2/m

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel})$ = **0.096** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000} \text{ N/mm}^2$

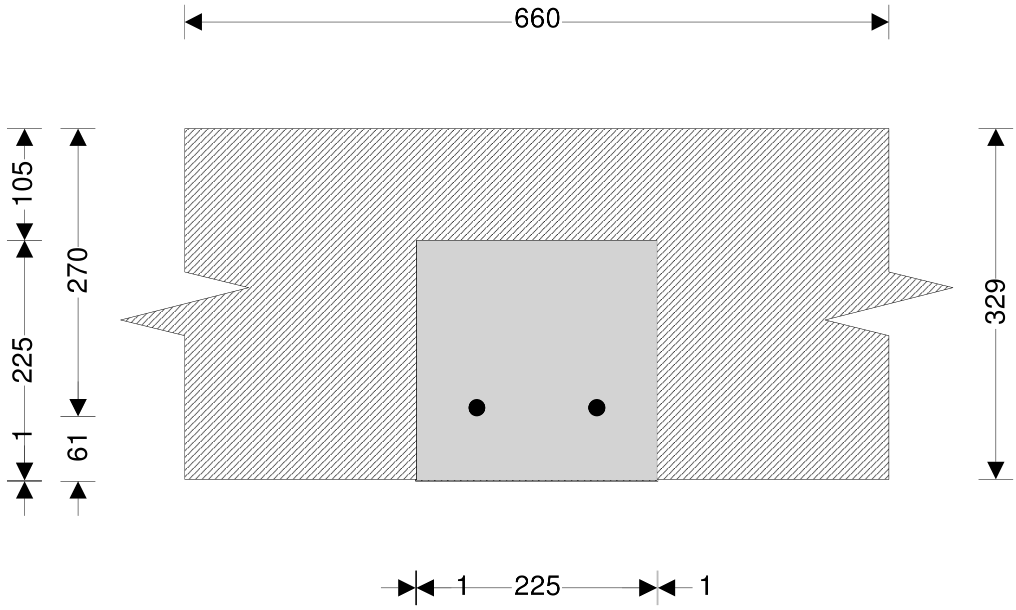
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_heel} = \mathbf{0.816} \text{ N/mm}^2$

$v_{heel} < v_{c\_heel}$ - No shear reinforcement required

Design of pocket reinforced masonry retaining wall stem - BS5628-2:2000



Wall details

Thickness of outer leaf of wall $t_{outer} = \mathbf{105}$ mm

Thickness of inner leaf of wall $t_{inner} = \mathbf{1}$ mm

Typical wall thickness $t_{thick} = \mathbf{329}$ mm

Pocket details

Thickness of reinforced pocket $t_{pocket} = \mathbf{225}$ mm

Depth of stem reinforcement $d_{stem} = \mathbf{270}$ mm

Width of reinforced pocket $b_{pocket} = \mathbf{225}$ mm

Pocket spacing $s_{pocket} = \mathbf{660}$ mm

Masonry details

Masonry type **Aggregate concrete blocks no voids**

Compressive strength of units $p_{unit} = \mathbf{7.3} \text{ N/mm}^2$

Mortar designation **(ii)**

Category of manufactoring control of units **Category II**

Partial safety factor for material strength $\gamma_{mm} = \mathbf{2.3}$

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units $b_{unit} = \mathbf{100.0}$ mm

Height of masonry units $h_{unit} = \mathbf{215.0}$ mm

Ratio of height to least horizontal dimension ratio $= h_{unit} / b_{unit} = \mathbf{2.2}$

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength $f_k = \mathbf{6.4} \text{ N/mm}^2$

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **18.4** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **6** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **15.1** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **5.9** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **6.9** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **4.2** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **18.4** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **8.2** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **7.5** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **2** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **2.3** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **38.4** kNm/m

Total shear for design per pocket V_{stem} = **2.8** kN

Total moment for design per pocket M_{stem} = **25.4** kNm

Check maximum design moment for wall stem

Thickness of masonry flange $t_{flange} = \min(t_{thick}, 0.5 \times d_{stem})$ = **135** mm

Width of masonry flange $b_{flange} = \min(s_{pocket}, b_{pocket} + 12 \times t_{flange}, h_{stem} / 3)$ = **600** mm

Maximum design moment $M_{d\_stem} = f_k \times b_{flange} \times t_{flange} \times (d_{stem} - 0.5 \times t_{flange}) / \gamma_{mm}$ = **45.6** kNm

PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor $Q = M_{stem} / (b_{flange} \times d_{stem}^2)$ = **0.580** N/mm²

$Q = 2 \times c \times (1 - c) \times f_k / \gamma_{mm}$

Lever arm factor c = **0.882**

Lever arm $z_{stem} = \min(0.95, c) \times d_{stem}$ = **238.1** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} \times \gamma_{ms} / (f_y \times z_{stem})$ = **245** mm²

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b_{flange} \times t_{thick}$ = **257** mm²

Area of tension reinforcement required $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **257** mm²

Reinforcement provided **2 No.16 mm dia.bars per pocket**

Area of reinforcement provided $A_{s\_stem\_prov} = n_{stem} \times \pi \times \phi_{stem}^2 / 4$ = **402** mm²

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b_{flange} \times d_{stem})$ = **0.017** N/mm²

Basic characteristic shear strength of masonry $f_{vbas} = \min[0.35 + (17.5 \times A_{s\_stem\_prov} / (b_{flange} \times d_{stem})), 0.7] \times 1$ N/mm²

f_{vbas} = **0.393** N/mm²

Shear span $a = M_{stem} / V_{stem}$ = **9176.9** mm

Characteristic shear strength of masonry $f_v = \mathrm{Min}(f_{vbas} \times \max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75\ \mathrm{N/mm^2})$

f_v = **0.393** N/mm²

Allowable shear stress $v_{adm} = f_v / \gamma_{mv}$ = **0.197** N/mm²

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio $ratio_{max}$ = **18.00**

Actual span/effective depth ratio — $ratio_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = \mathbf{7.17}$

PASS - Span to depth ratio is acceptable

Axial load check

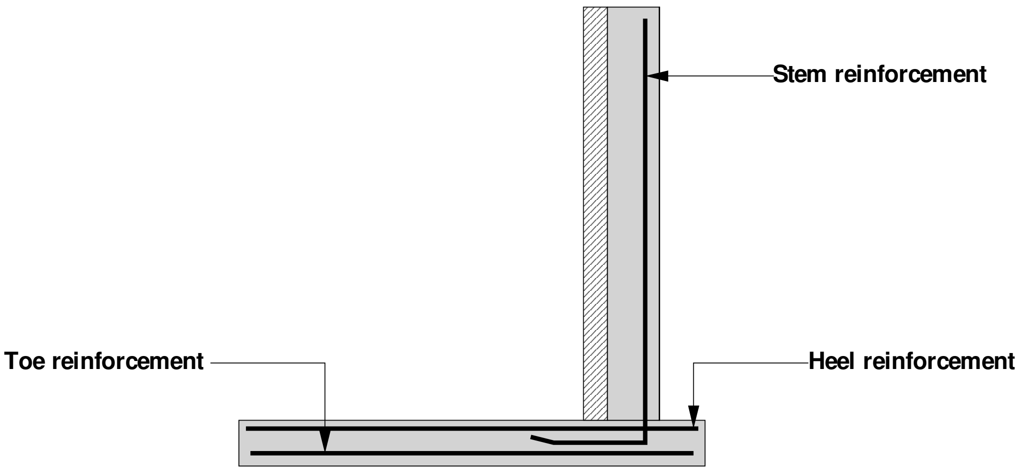
Factored axial load on wall — $N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f\_d}) + (W_{live} \times \gamma_{f\_l}) = \mathbf{19.6}$ kN/m

Limiting axial load — $N_{limit} = 0.1 \times f_k \times t_{wall} = \mathbf{211.2}$ kN/m

Applied axial load may be ignored - calculations valid

Price & Myers 30 Newman Street London W1T 1LT	Project 56 Croftdown Road			Job no.	
	Calcs for Light well pocket brick retaining wall			Start page no./Revision 10	
	Calcs by TP	Calcs date 14/12/2017	Checked by	Checked date	Approved by	Approved date

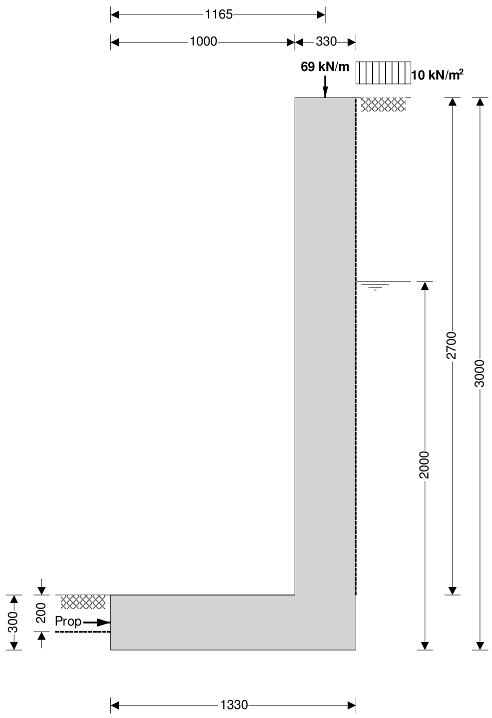
Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Heel bars - 12 mm dia.@ 100 mm centres - (1131 mm^2/m)
Stem bars - 2 No. 16 mm dia.bars per pocket - (402 mm^2)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **2700** mm
Thickness of wall stem	t_{wall} = **330** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1330** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **0** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3000** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **200** mm
Height of ground water behind wall	h_{water} = **2000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **1700** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3000** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **21.0** kN/m^3

Saturated density of retained material γ_s = **23.0** kN/m^3

Design shear strength ϕ' = **21.1** deg

Angle of wall friction δ = **16.1** deg

Base material details

Firm clay

Moist density γ_{mb} = **19.0** kN/m^3

Design shear strength ϕ'_b = **24.0** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **150** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.416}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.143}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.640**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **55.0** kN/m

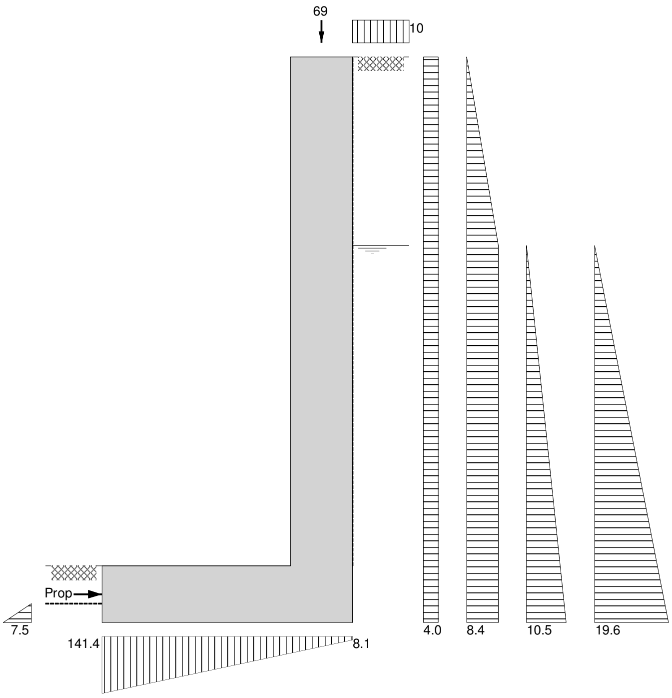
Applied vertical live load on wall W_{live} = **14.0** kN/m

Position of applied vertical load on wall l_{load} = **1165** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **21** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **9.4** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **69** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **99.4** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff}$ = **12** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **4.2** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **16.8** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **10.5** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.6** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **63.1** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **0.4** kN/m

Propping force $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop} = **34.0** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **18** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **9.8** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **16.8** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **7** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **13.1** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **64.7** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **24.5** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **6.3** kNm/m

Design vertical load $M_v = W_v \times l_{load}$ = **80.4** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_v$ = **111.1** kNm/m

Check bearing pressure

Total moment for bearing $M_{total} = M_{rest} - M_{ot}$ = **46.5** kNm/m

Total vertical reaction $R = W_{total}$ = **99.4** kN/m

Distance to reaction $x_{bar} = M_{total} / R$ = **467** mm

Eccentricity of reaction $e = \text{abs}((l_{base} / 2) - x_{bar})$ = **198** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **141.4** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **8.1** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **29.4** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **13.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **99.4** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **142** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **30.7** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **9.4** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **37.6** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **23.6** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **27.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **128.9** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **0.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **88.1** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **46.1** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **22** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **37.6** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **15.8** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **18.3** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **139.7** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **34.3** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **8.8** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **115.8** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **158.9** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **19.1** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **142.0** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **135** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **530** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **702.9** kN/m^2

Bearing pressure at heel p_{heel_f} = 0 kN/m^2 = **0** kN/m^2

Rate of change of base reaction rate $= p_{toe\_f} / (3 \times x_{bar\_f})$ = **1739.59** kN/m^2/m

Bearing pressure at stem / toe	$p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0\ kN/m^2) = \mathbf{0}\ kN/m^2$
Bearing pressure at mid stem	$p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) = \mathbf{0}\ kN/m^2$
Bearing pressure at stem / heel	$p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) = \mathbf{0}\ kN/m^2$

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete	$f_{cu} = \mathbf{40}\ N/mm^2$
Characteristic strength of reinforcement	$f_y = \mathbf{500}\ N/mm^2$

Base details

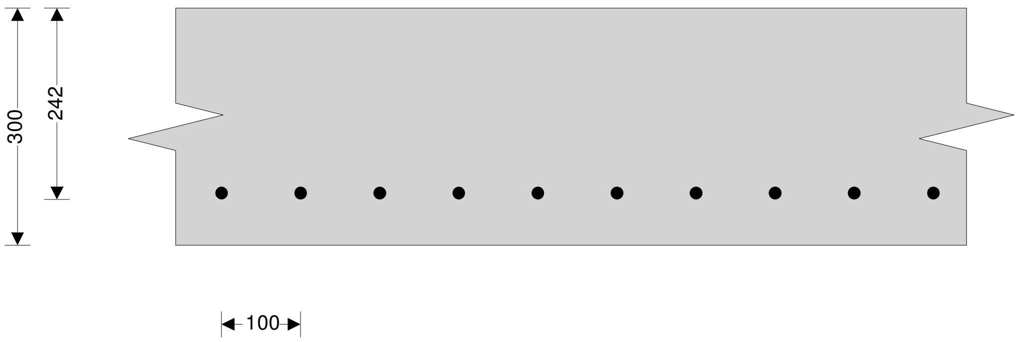
Minimum area of reinforcement	$k = \mathbf{0.13}\ \%$
Cover to reinforcement in toe	$c_{toe} = \mathbf{50}\ mm$

Calculate shear for toe design

Shear from bearing pressure	$V_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} / 2 = \mathbf{142}\ kN/m$
Shear from weight of base	$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{9.9}\ kN/m$
Total shear for toe design	$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{132.1}\ kN/m$

Calculate moment for toe design

Moment from bearing pressure	$M_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} \times (l_{toe} - x_{bar\_f} + t_{wall} / 2) / 2 = \mathbf{146.3}\ kNm/m$
Moment from weight of base	$M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{6.7}\ kNm/m$
Total moment for toe design	$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{139.6}\ kNm/m$



Check toe in bending

Width of toe	$b = \mathbf{1000}\ mm/m$
Depth of reinforcement	$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{242.0}\ mm$
Constant	$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.060}$
	Compression reinforcement is not required
Lever arm	$z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
	$z_{toe} = \mathbf{225}\ mm$
Area of tension reinforcement required	$As_{toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{1428}\ mm^2/m$
Minimum area of tension reinforcement	$As_{toe\_min} = k \times b \times t_{base} = \mathbf{390}\ mm^2/m$
Area of tension reinforcement required	$As_{toe\_req} = \mathrm{Max}(As_{toe\_des}, As_{toe\_min}) = \mathbf{1428}\ mm^2/m$
Reinforcement provided	**16 mm dia.bars @ 100 mm centres**
Area of reinforcement provided	$As_{toe\_prov} = \mathbf{2011}\ mm^2/m$
	PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress	$v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.546}\ N/mm^2$
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 = \mathbf{5.000}\ N/mm^2$
	PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.788** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **50** mm

Cover to reinforcement in wall c_{wall} = **50** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **27.6** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **9.4** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **32** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **17.1** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **19.8** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **17.9** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **41.5** kNm/m

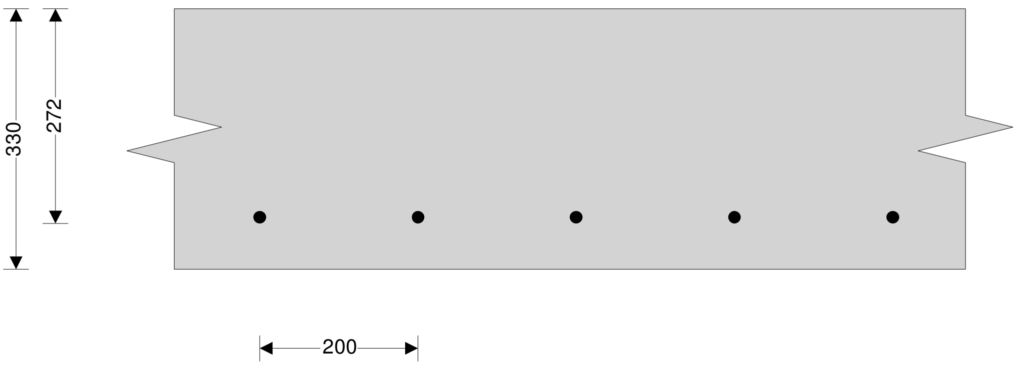
Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **20.5** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **27.2** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **9.7** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **11.2** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **110.1** kNm/m



Check wall stem in bending

Width of wall stem b = **1000** mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **272.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.037**

Compression reinforcement is not required

Lever arm $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **258** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **980** mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{429}$ mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{980}$ mm²/m

Reinforcement provided **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_stem\_prov} = \mathbf{1005}$ mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.066}$ N/mm²

Allowable shear stress $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5) \times 1 N/mm^2 = \mathbf{5.000}$ N/mm²

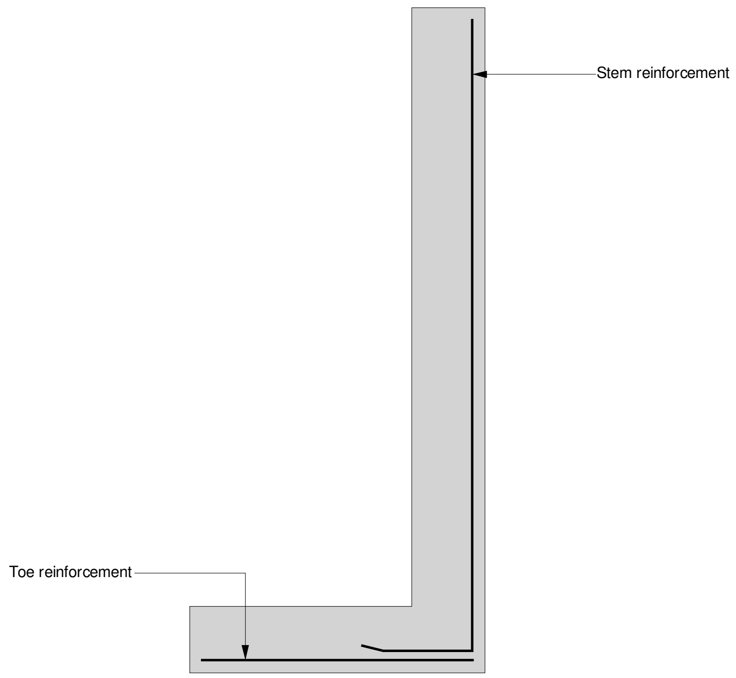
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_stem} = \mathbf{0.584}$ N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 100 mm centres - (2011 mm^2/m)

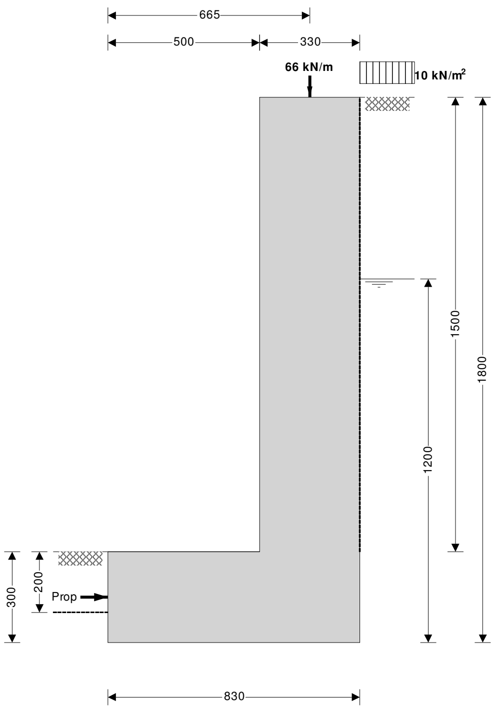
Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

Project				Job no.	
56 Croftdown Road				25293	
Calcs for				Start page no./Revision	
Rear retaining underpin				1 2	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
TP	14/12/2017				

TEKLA Tedds
Price & Myers
37 Alfred Place
London
WC1E 7DP

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **1500** mm
Thickness of wall stem	t_{wall} = **330** mm
Length of toe	l_{toe} = **500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **830** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **530** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1800** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **200** mm
Height of ground water behind wall	h_{water} = **1200** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **900** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **1800** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **21.0** kN/m^3

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	Calcs for Rear retaining underpin				Start page no./Revision 2 2	
	Calcs by TP	Calcs date 14/12/2017	Checked by	Checked date	Approved by	Approved date

Saturated density of retained material γ_s = **23.0** kN/m^3

Design shear strength ϕ' = **21.1** deg

Angle of wall friction δ = **16.1** deg

Base material details

Firm clay

Moist density γ_{mb} = **19.0** kN/m^3

Design shear strength ϕ'_b = **24.0** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **150** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.416}$

Passive pressure coefficient for base material

$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.143}$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = \mathbf{0.640}$

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **53.0** kN/m

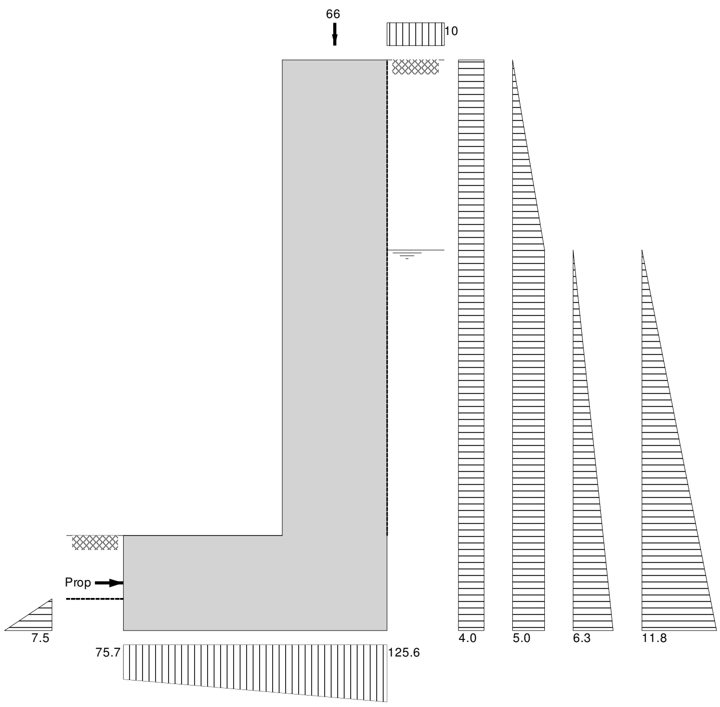
Applied vertical live load on wall W_{live} = **13.0** kN/m

Position of applied vertical load on wall l_{load} = **665** mm

Applied horizontal dead load on wall F_{dead} = **0.0** kN/m

Applied horizontal live load on wall F_{live} = **0.0** kN/m

Height of applied horizontal load on wall h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **11.7** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **5.9** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **66** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **83.6** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **7.2** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **1.5** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **6** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **3.8** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **7.1** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **25.6** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **0.4** kN/m
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0$ kN/m)
	F_{prop} = **1.5** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.5** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **2.1** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **3.6** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **1.5** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **2.8** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **16.6** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **7.8** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **2.4** kNm/m
Design vertical load	$M_v = W_v \times l_{load}$ = **43.9** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_v$ = **54.1** kNm/m

Check bearing pressure

Total moment for bearing	$M_{total} = M_{rest} - M_{ot}$ = **37.5** kNm/m
Total vertical reaction	$R = W_{total}$ = **83.6** kN/m
Distance to reaction	$x_{bar} = M_{total} / R$ = **449** mm
Eccentricity of reaction	$e = abs((l_{base} / 2) - x_{bar})$ = **34** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **75.7** kN/m²
Bearing pressure at heel	$p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **125.6** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

Earth and water pressure factor γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **16.4** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **8.2** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **95** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **119.6** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **18.4** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **3.4** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **13.5** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **8.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **9.9** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **53.8** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **0.5** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **20.0** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **16.6** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **4.7** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **8.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **3.4** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **4** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **36.8** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **10.9** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **3.4** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **63.2** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **77.5** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **40.6** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **119.6** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **340** mm

Eccentricity of reaction $e_f = abs((l_{base} / 2) - x_{bar\_f})$ = **75** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **222.3** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **65.9** kN/m²

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **188.45** kN/m²/m

TEKLA Tedds	Project				Job no.	
Price & Myers 37 Alfred Place London WC1E 7DP	56 Croftdown Road				25293	
	Calcs for				Start page no./Revision	
	Rear retaining underpin				5 2	
	Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
	TP	14/12/2017				

Bearing pressure at stem / toe $p_{stem\_toe\_f} = max(p_{toe\_f} - (rate \times l_{toe}), 0\ kN/m^2) =$ **128.1** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) =$ **97** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **65.9** kN/m^2

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete $f_{cu} =$ **40** N/mm^2

Characteristic strength of reinforcement $f_y =$ **500** N/mm^2

Base details

Minimum area of reinforcement $k =$ **0.13** %

Cover to reinforcement in toe $c_{toe} =$ **50** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **87.6** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **5** kN/m

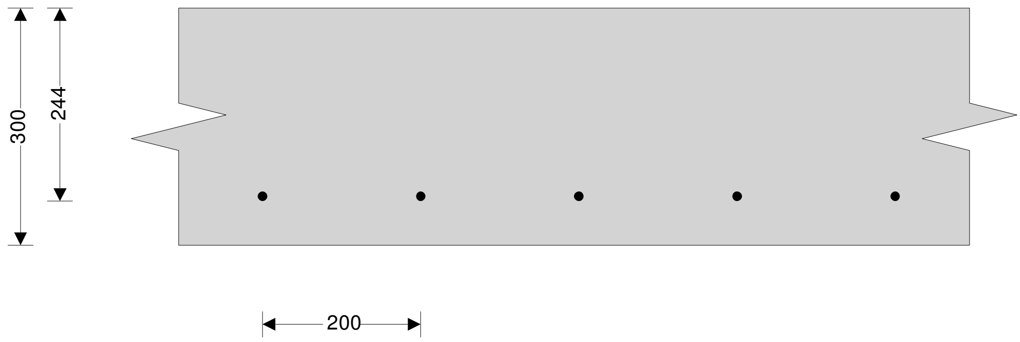
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **82.6** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **39.9** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **2.2** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **37.7** kNm/m



Check toe in bending

Width of toe $b =$ **1000** mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **244.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.016**

Compression reinforcement is not required

Lever arm $z_{toe} = min(0.5 + \sqrt{(0.25 - (min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

$z_{toe} =$ **232** mm

Area of tension reinforcement required $As_{toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **374** mm^2/m

Minimum area of tension reinforcement $As_{toe\_min} = k \times b \times t_{base} =$ **390** mm^2/m

Area of tension reinforcement required $As_{toe\_req} = Max(As_{toe\_des}, As_{toe\_min}) =$ **390** mm^2/m

Reinforcement provided **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $As_{toe\_prov} =$ **565** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) =$ **0.339** N/mm^2

Allowable shear stress $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 =$ **5.000** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.514** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **50** mm

Cover to reinforcement in wall c_{wall} = **50** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **15.4** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **3.4** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **10.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **4.8** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **5.6** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **19.3** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **13.8** kNm/m

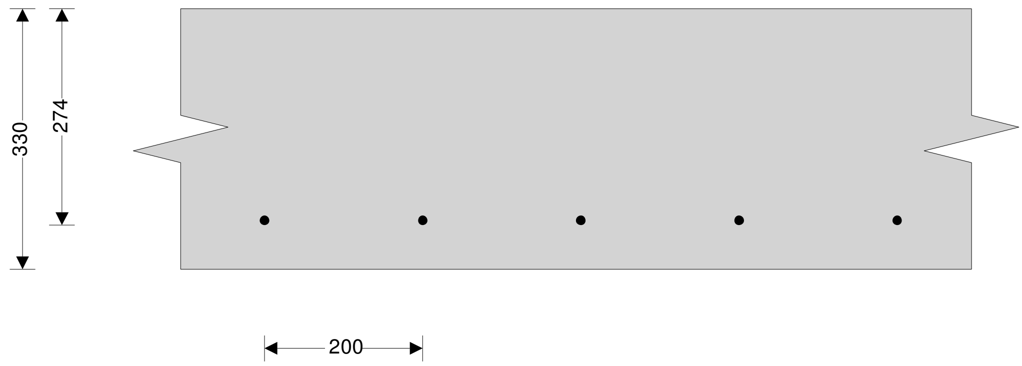
Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **4.2** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **4.6** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **1.4** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **1.7** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **25.7** kNm/m



Check wall stem in bending

Width of wall stem b = **1000** mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **274.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.009**

Compression reinforcement is not required

Lever arm $z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

z_{stem} = **260** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **227** mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{429}$ mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{429}$ mm²/m

Reinforcement provided **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_stem\_prov} = \mathbf{565}$ mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.070}$ N/mm²

Allowable shear stress $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5) \times 1 N/mm^2 = \mathbf{5.000}$ N/mm²

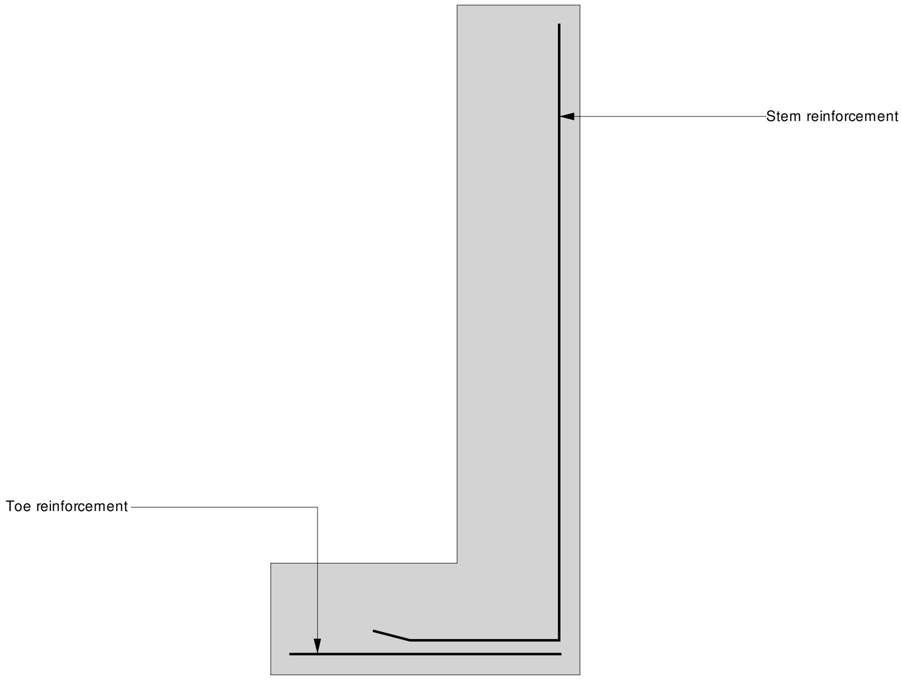
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_stem} = \mathbf{0.480}$ N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)

Stem bars - 12 mm dia.@ 200 mm centres - (565 mm^2/m)

Appendix B

Drawings CS02 RevA and CS03

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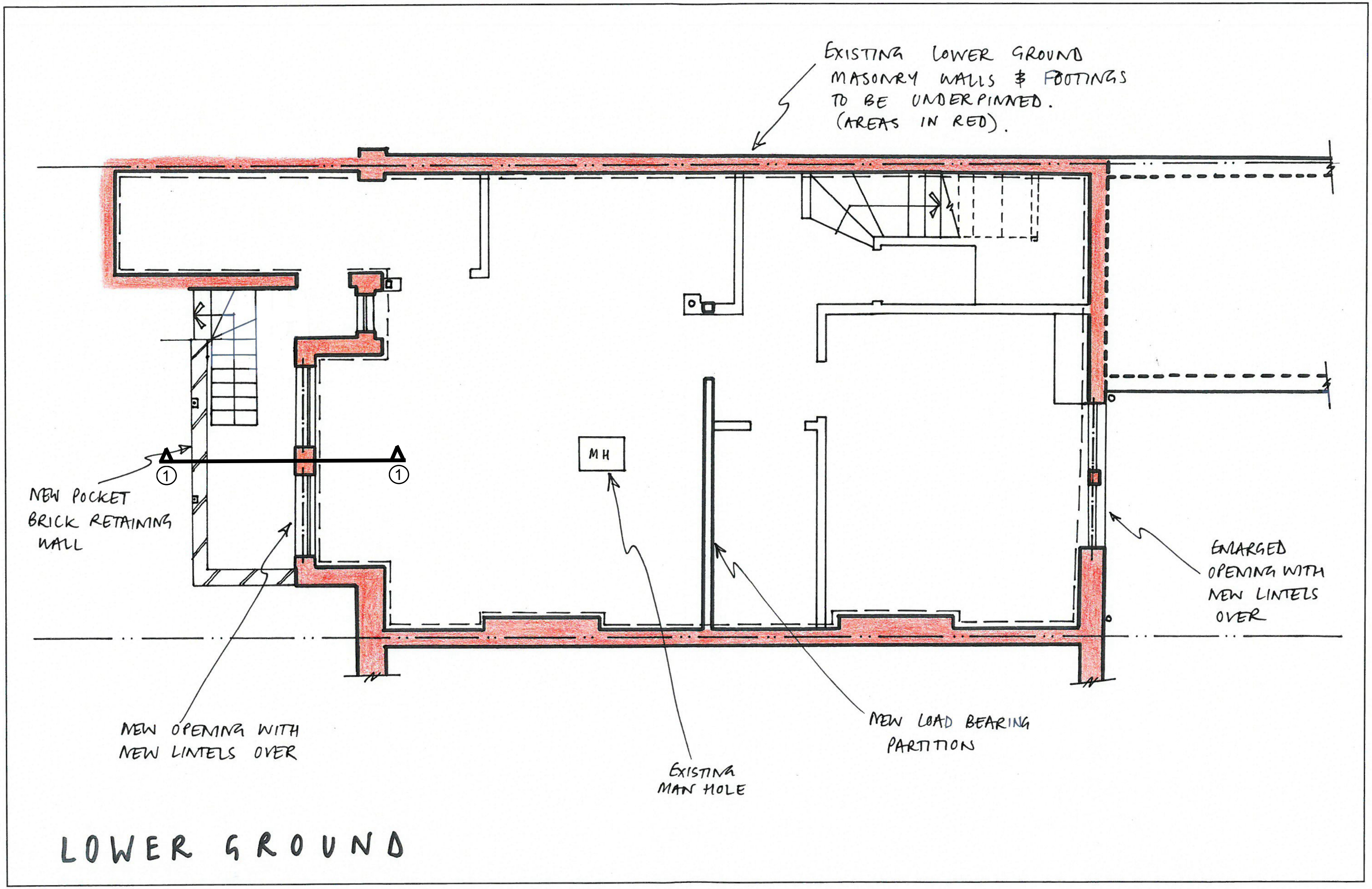
PRICE&MYERS
Consulting Engineers

Job No 25293 Page SK 2 Rev A
Date JUNE '16 Eng HRD Chd
Job 56 CROFTDOWN ROAD

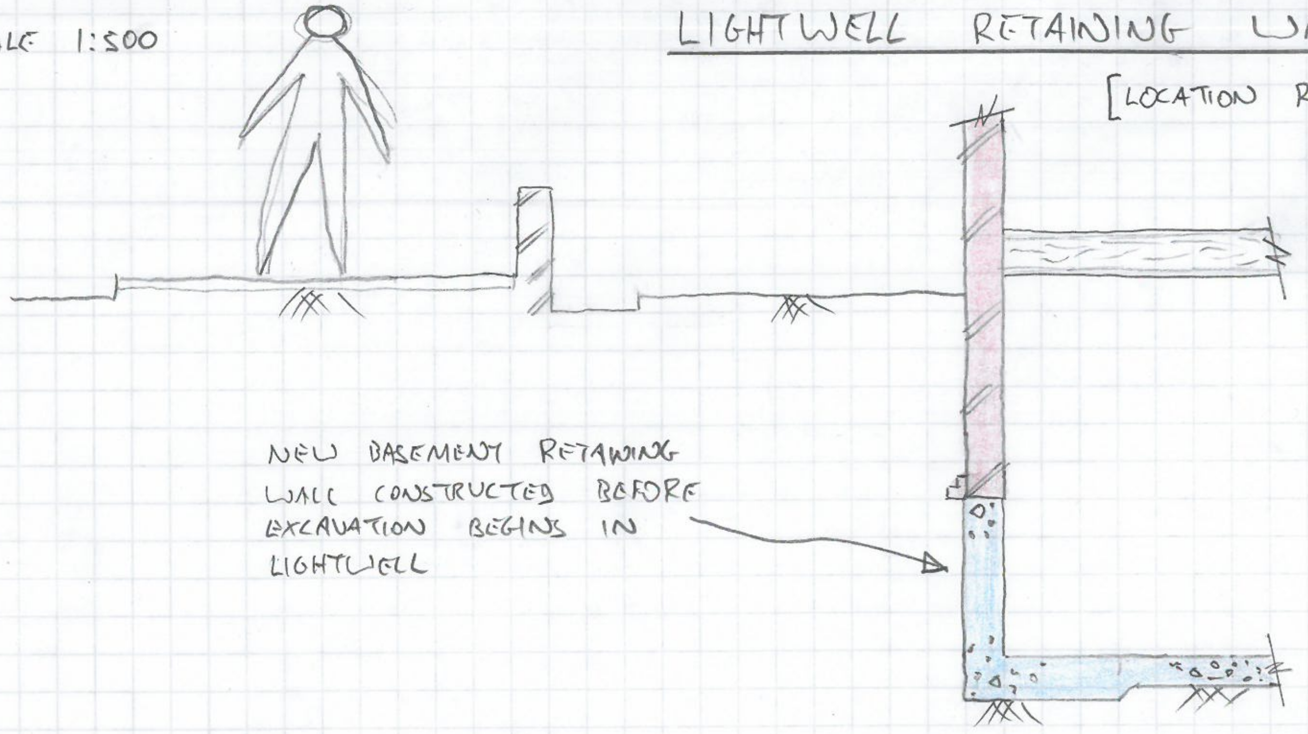


Job No	24922	Page	SK 3	Rev	
Date	15/11/17	Eng	TP	Chd	
Job	43 CROFTDOWN ROAD				

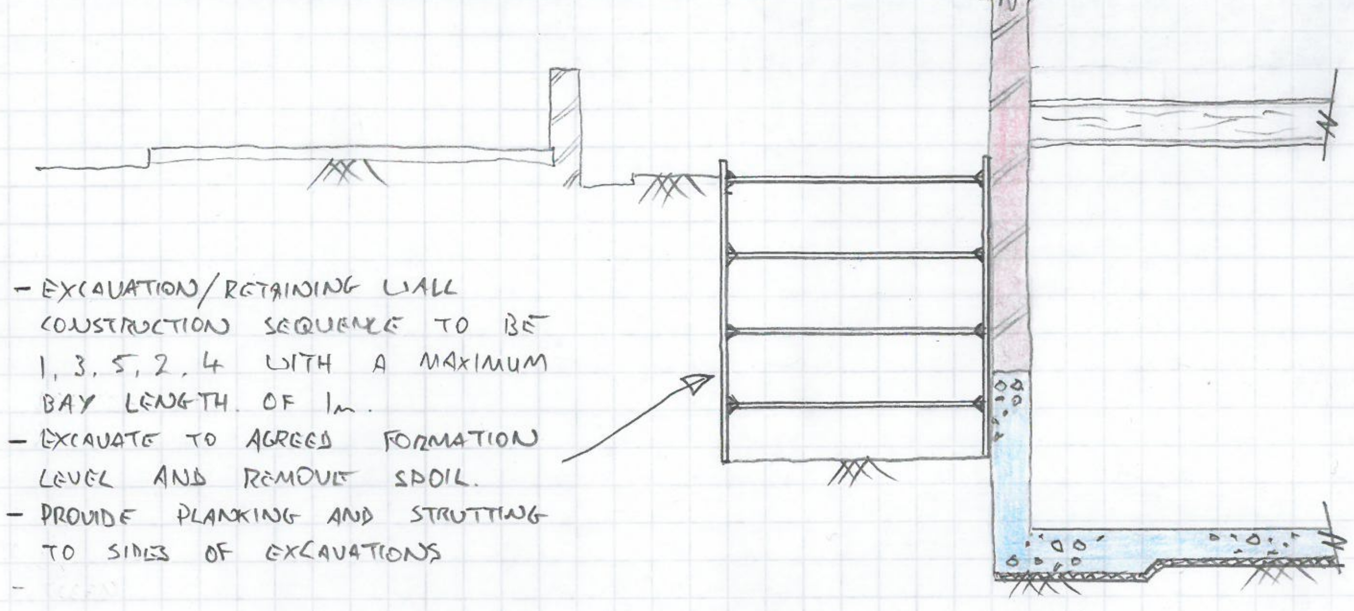
SCALE 1:500

LIGHTWELL RETAINING WALL CONSTRUCTION SEQUENCE

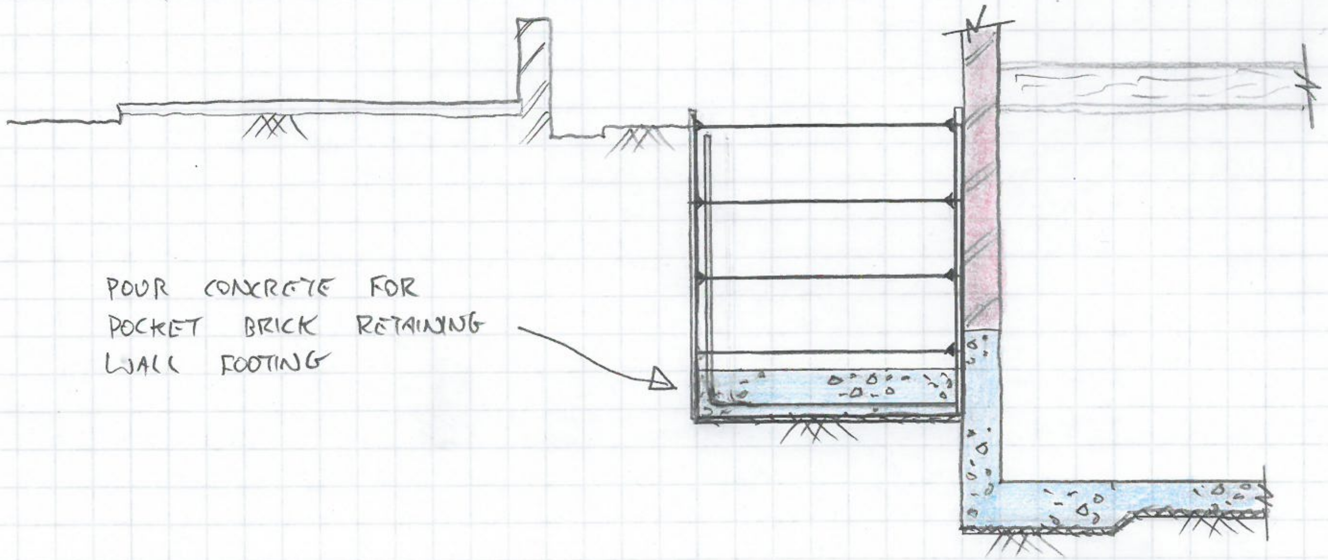
[LOCATION REF: SECTION 1-1 SK 2]



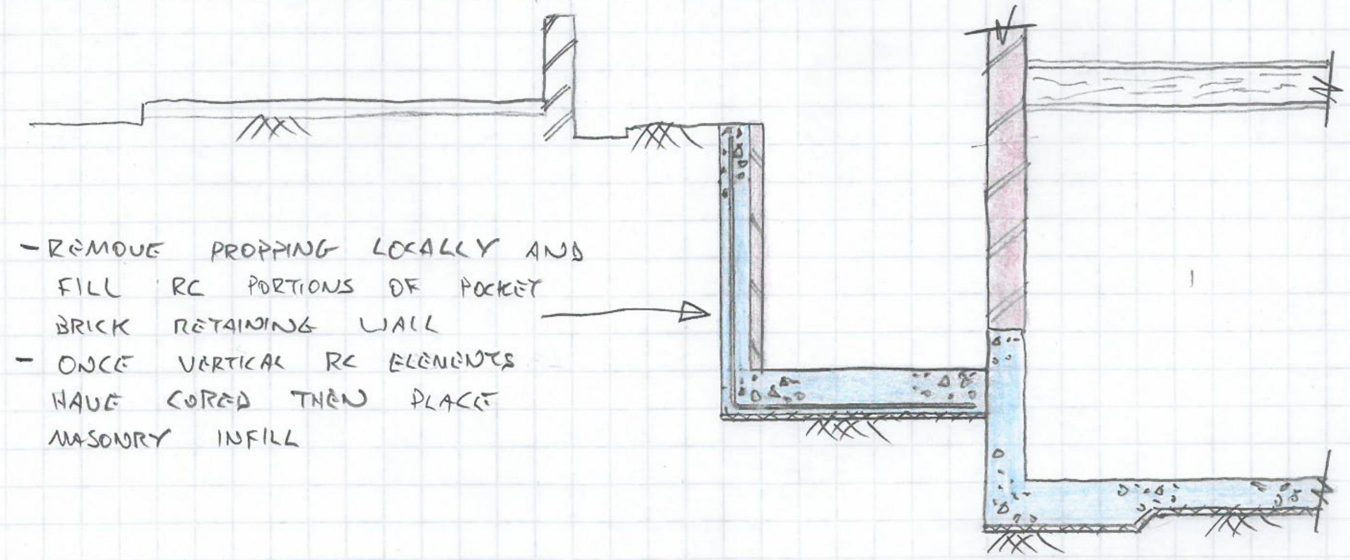
EXISTING



STEP ONE



STEP TWO



STEP THREE

Appendix C

Movement Monitoring Plan

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56 Croftdown Road - Movement monitoring plan

Monitoring overview

Masonry structures in London are likely to show some seasonal movement in addition to small daily movement. Combining these could easily cause 2mm to 3mm of movement vertically and 3mm to 5mm movement horizontally.

A number of base readings will be taken at different times of different days before excavation works starts on site (three base readings per survey point). A minimum of two datum points will be chosen apart from each other and outside of the site and cross-checked against each other.

Movement monitoring readings will have an individual tolerance of +/- 1.5mm.

Locations

The attached pages demonstrate the extent of movement monitoring targets on the Party Walls and front/rear elevations.

Monitoring frequencies

Targets will be monitored on a weekly basis

Trigger levels and actions

Trigger levels will include an allowance of 2mm for effects of tolerances, seasonal and daily movement.

<u>Amber trigger level: 7mm</u> – Action: submit proposals to ensure red trigger levels are not exceeded

<u>Red trigger level: 12mm</u> – Action: stop works and make safe. Inform all parties immediately and increase frequency of monitoring. Submit proposals for procedures as may be considered necessary. Work should not recommence until these have been agreed.

Note: the red trigger level is subject to review and revision by the project team at amber where the available data evaluation should lead to a clearer understanding of the actual behaviour of the structure(s)

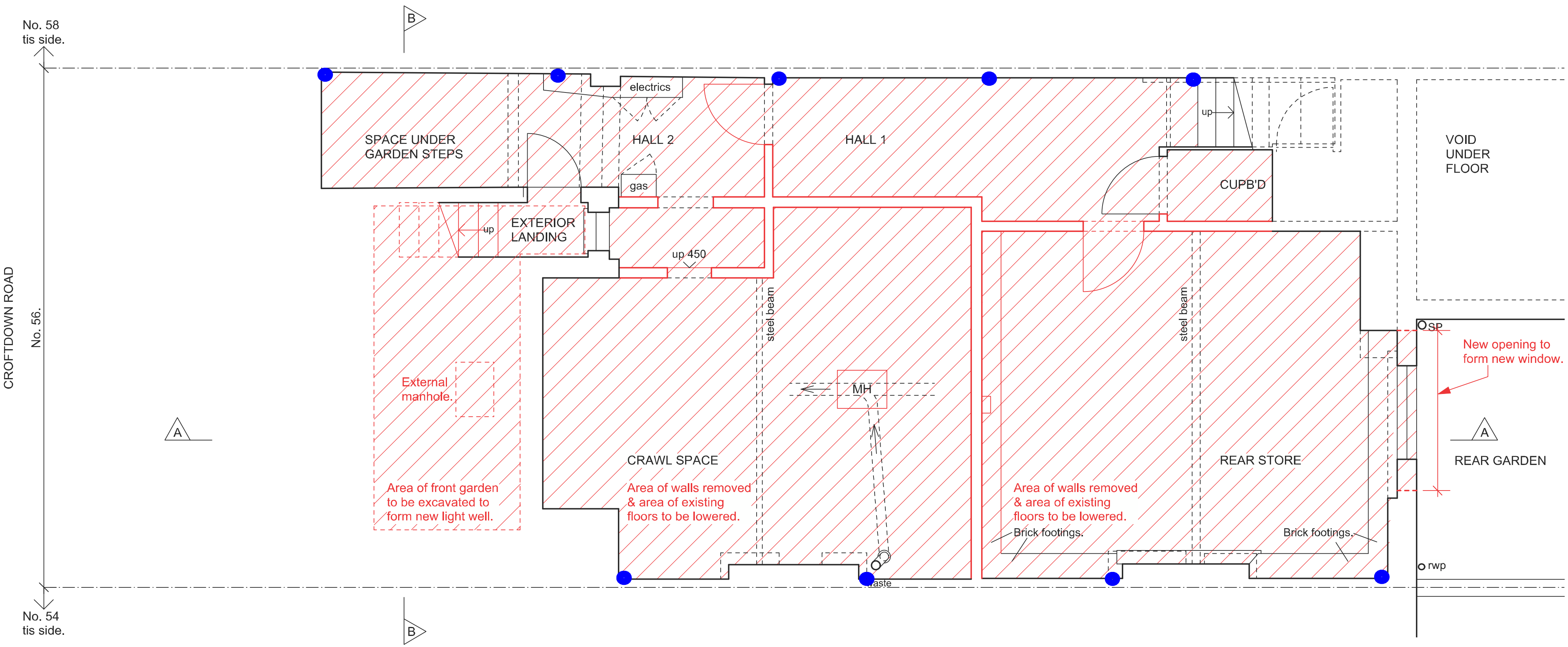
Additional actions if the amber level is exceeded:

- Check whether trigger level is being, or about to be exceeded by neighbouring targets and a view will be taken whether any target has 'slipped' or apparently moved independently of the structure.
- The survey measurements will be retaken if necessary for any further clarity needed which may include an early morning survey round and a late afternoon survey round or equivalent to assess movement due to daily temperature changes. This many also include a check on datum levels.
- The movement of the structure will be assessed together with the degree of differential movement and distortion with the causes determined as far as possible. The internal

condition of the structure will be checked as far as practicable to check for any unusual changes. If the distortion or differential movement is relatively small and there is no significant alteration to the internally observed condition the red trigger level may be increased or a new red trigger level for differential movement will be introduced by the project team. No change to red trigger levels will take place without agreement.

- Possible construction/demolition/temporary works measures to reduce further movements will be examined with a view to them being implemented if further movement takes place.

Lower ground level monitoring target locations



EXISTING LOWER
GROUND FLOOR PLAN

AREAS OF DEMOLITIONS INDICATED IN RED.

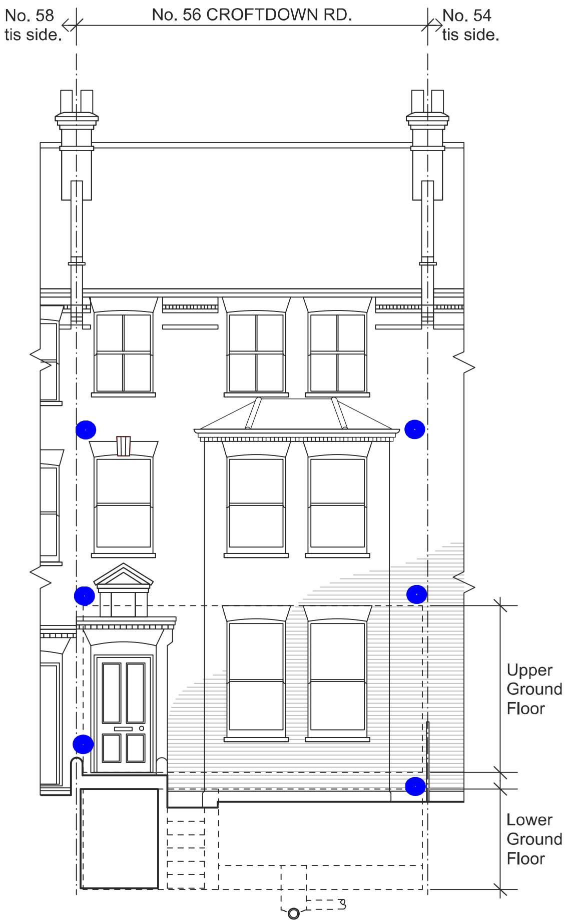
● : Movement monitoring target locations

Revision:
A 01.06.16 Add general info.

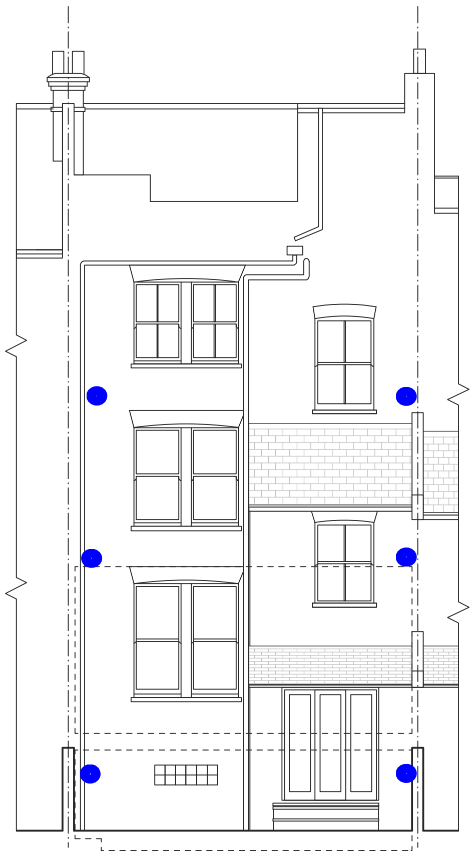
scealesgunn design LTD	6 North Grove London N6 4SL t: 020 8341 9605 m: 07900 491 428	Date: 29th Feb 2016 / Drawn/checked: dg /__
		Client: C & R Nuttall / Scale: 1:50 @A3
Project: 56 Croftdown Rd		EXISTING DRAWING
Drg. Title: Existing Lower Ground Floor Plan		No. 56CROFT -E- 102 Rev. A

0 1m

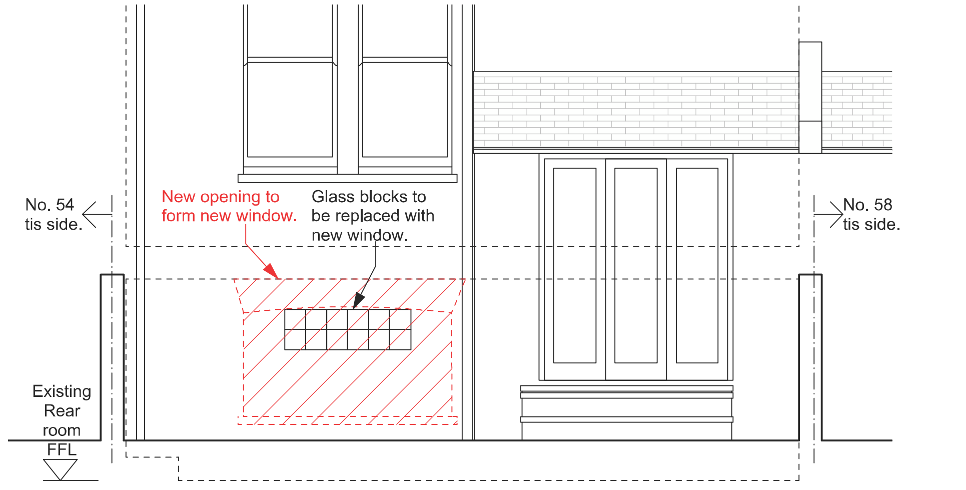
Front and rear elevation monitoring target locations



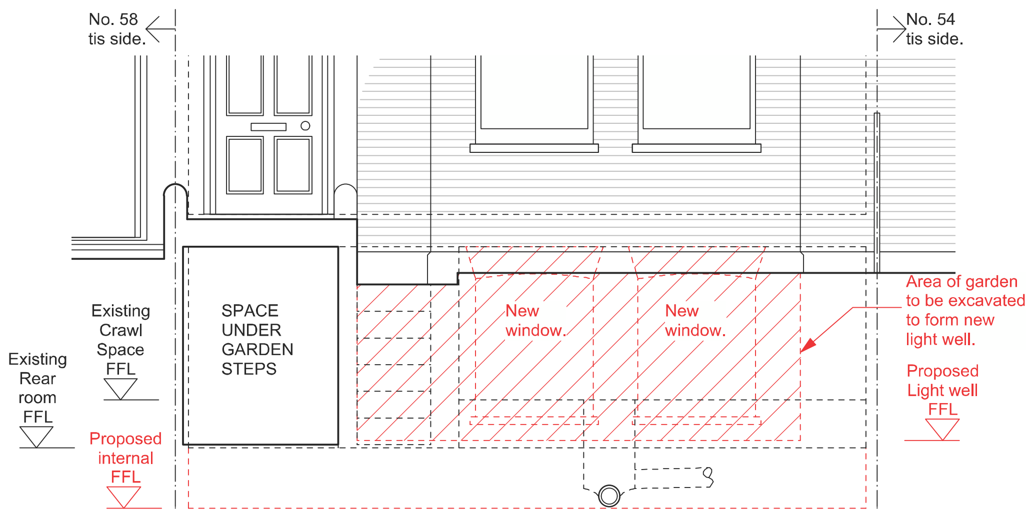
EXISTING FRONT ELEVATION
(scale 1:100 @ A3)
0 2m



EXISTING REAR ELEVATION
(scale 1:100 @ A3)
0 2m



EXISTING PART REAR ELEVATION
(scale 1:50 @ A3)
0 1m



EXISTING SECTION B-B
(scale 1:50 @ A3)
0 1m

AREAS OF DEMOLITIONS INDICATED IN RED.

●: Movement monitoring target locations

Revision:
A 01.06.16 Add general info.

sceales gunn design LTD	6 North Grove London N6 4SL t: 020 8341 9605 m: 07900 491 428	Date: 29th Feb 2016 / Drawn/checked: dg /__ Client: C & R Nuttall / Scale: 1:50@A1 / 1:100@A3
Project:	56 Croftdown Rd	EXISTING DRAWING
Drg. Title:	Existing Elevations	No. 56CROFT -E- 300 Rev. A

Appendix D

York Rise Zone: Flood Risk Assessment

PRICE&MYERS
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Sarah Watkins
Geotechnical & Environmental Associates
Widbury Barn
Widbury Hill
Ware, SG12 7QE

7th December 2017

Ref: 25293/2/DLin

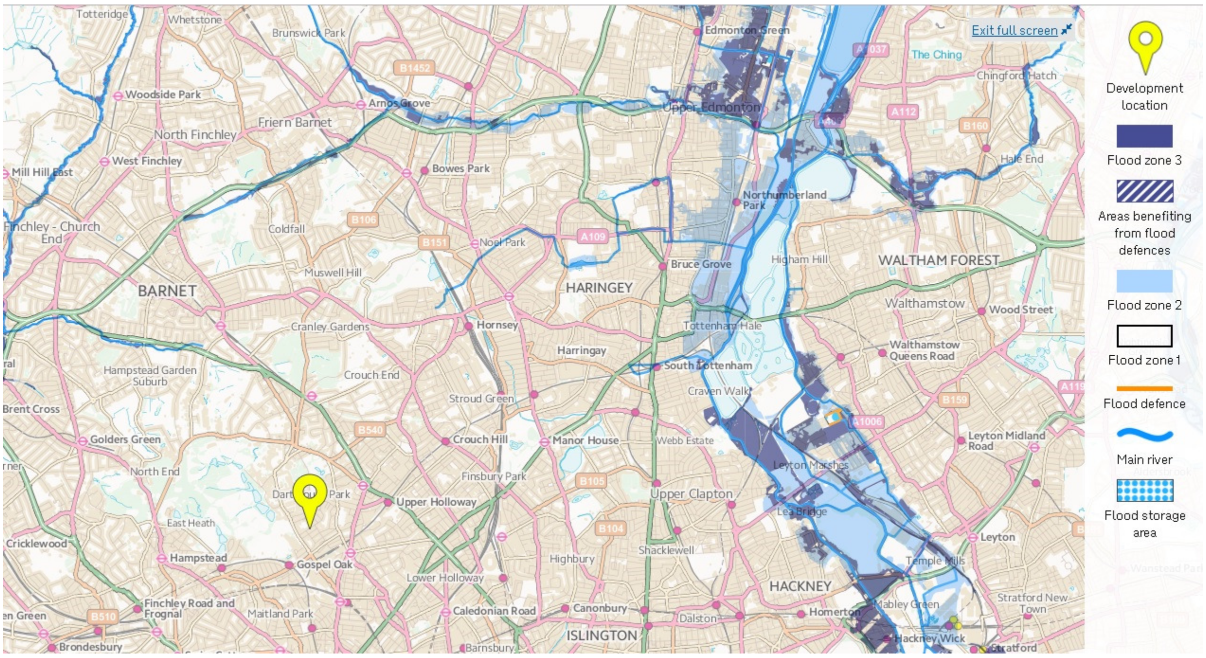
Dear Sarah,

Re:56 Croftdown Road, London, NW5 1EN – Flood Risk Assessment

Following your request for a Flood Risk Assessment (FRA) for the above site, please find below our findings.

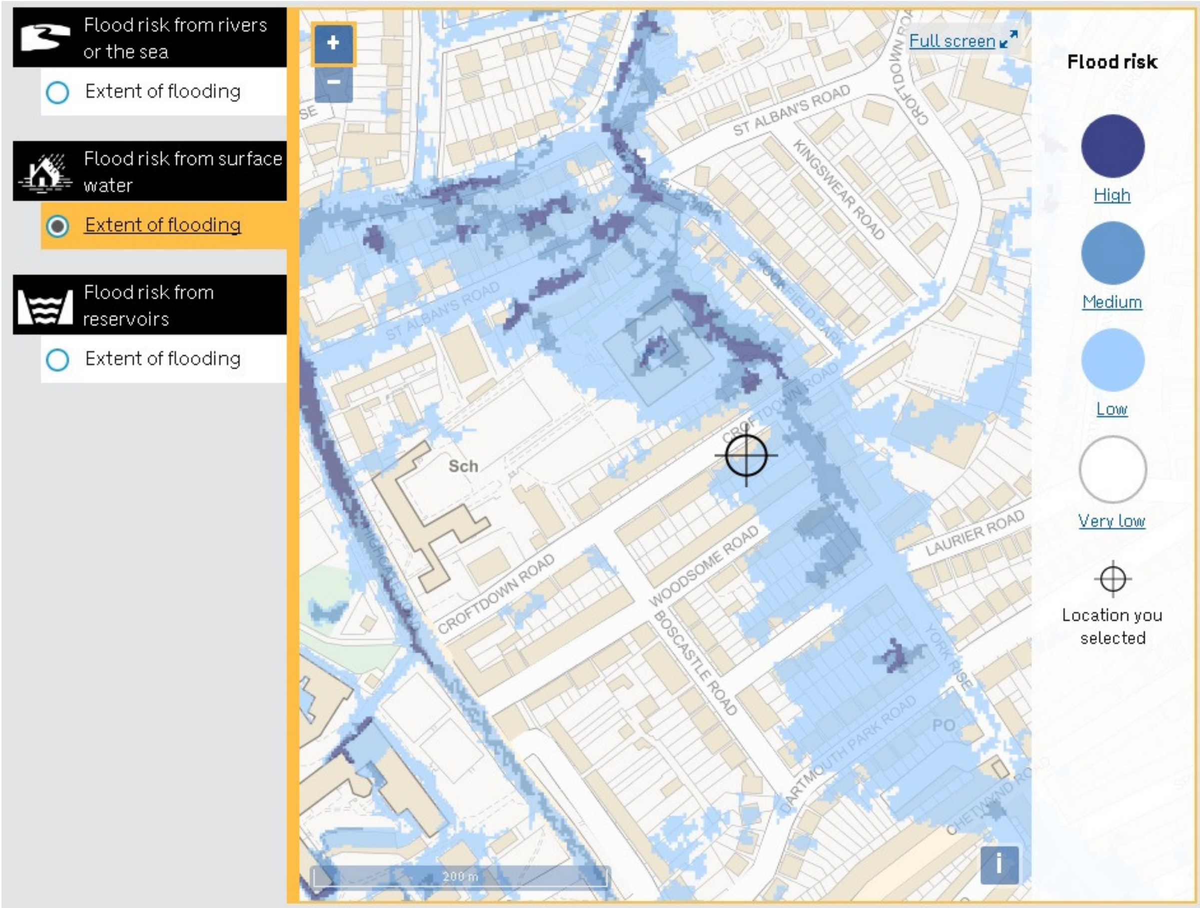
1 Flood Risk from Watercourses (Fluvial/Tidal)

The EA's indicative floodplain map shows that there is very low risk of tidal and/or fluvial flooding at this site location. The map shows that the site lies within Flood Zone 1, so the risk is less than a 1 in 1000 year event and is considered low.

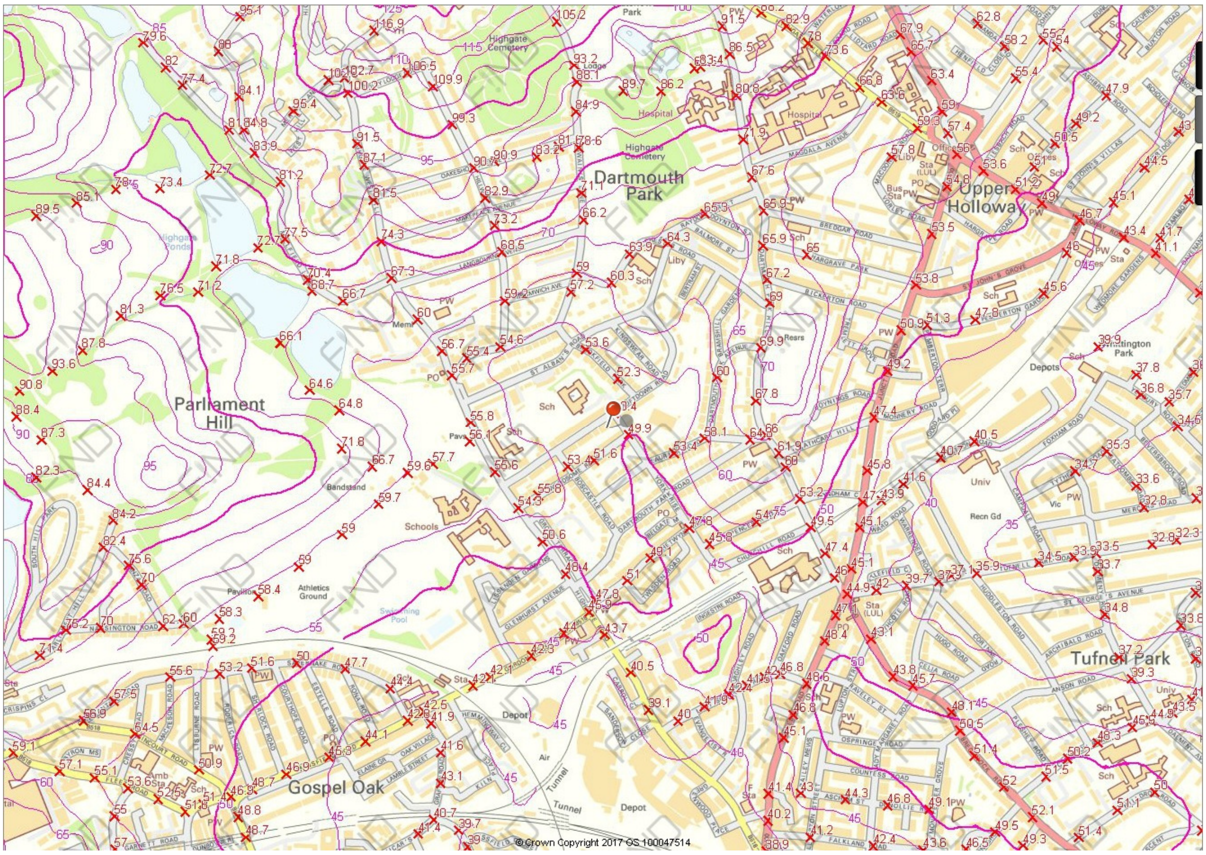


2 Flood Risk from Surface Water

The Government's surface water flood map shows that the majority of the site is at risk of flooding from surface water. Only the front side of the site is not at risk of flooding from surface water. The proposed works involve the construction of a new lightwell at the front side of the building. The existing steps will be repositioned to provide access from the new lightwell to Croftdown Road. However, the surface water flood map shows that there are no overland flow paths from Croftdown Road to the site which to transfer flood water to the lightwell.



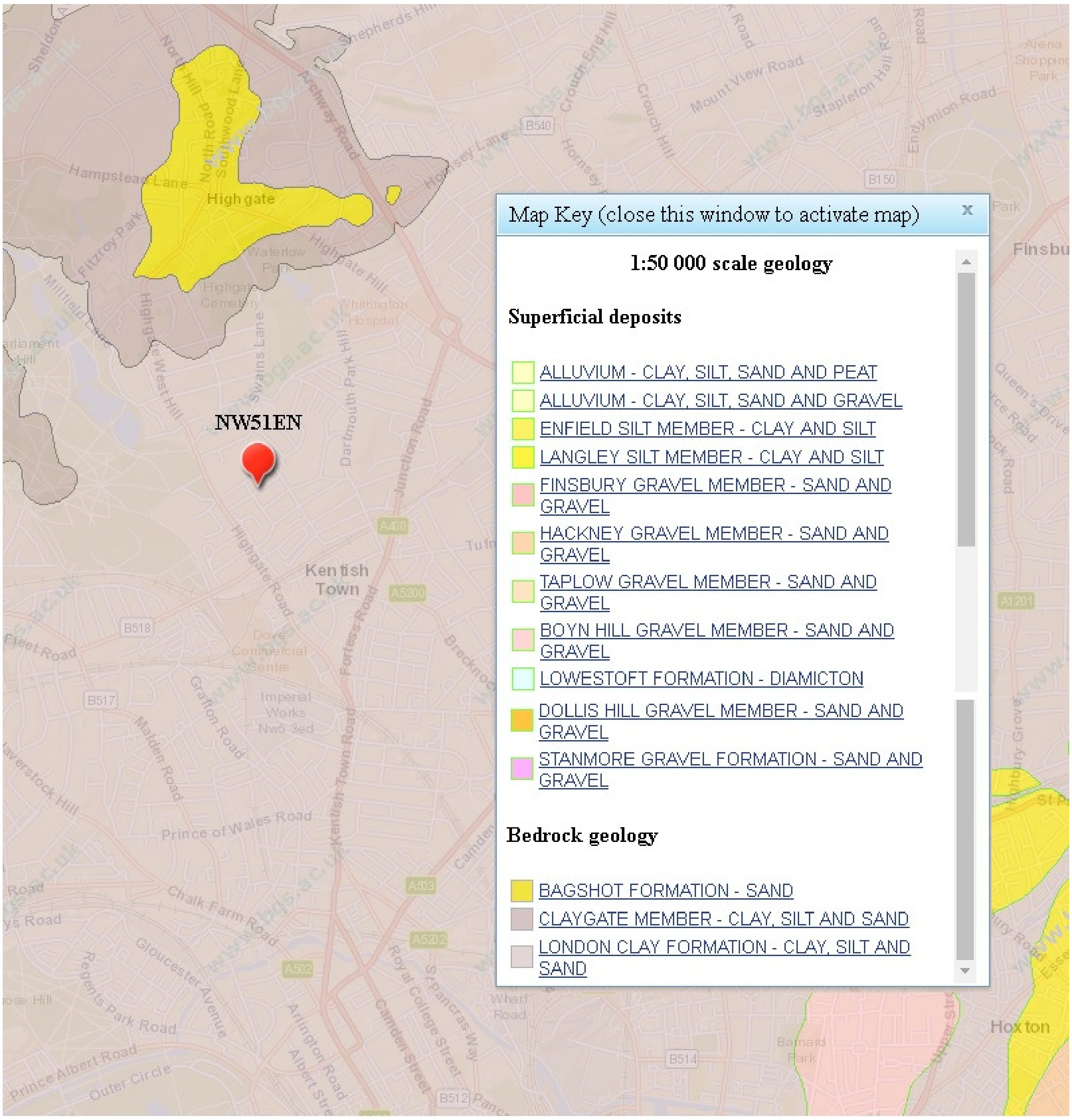
The local topography shows that the lowest levels on Croftdown Road are at its junction with York Rise. The topography then drops steeply to the south alongside York Rise. Therefore, any overland flows on Croftdown Road from any source, including surface water, sewers and burst water mains, will flow to the road's junction with York Rise and from there will flow to the south without ponding the site's front garden and lightwell. Any overland flows on Croftdown Road will flow within the road's channel to the east of the site.



After considering all the above, the flood risk from surface water and overland flows is considered low.

3 Flood Risk from Groundwater

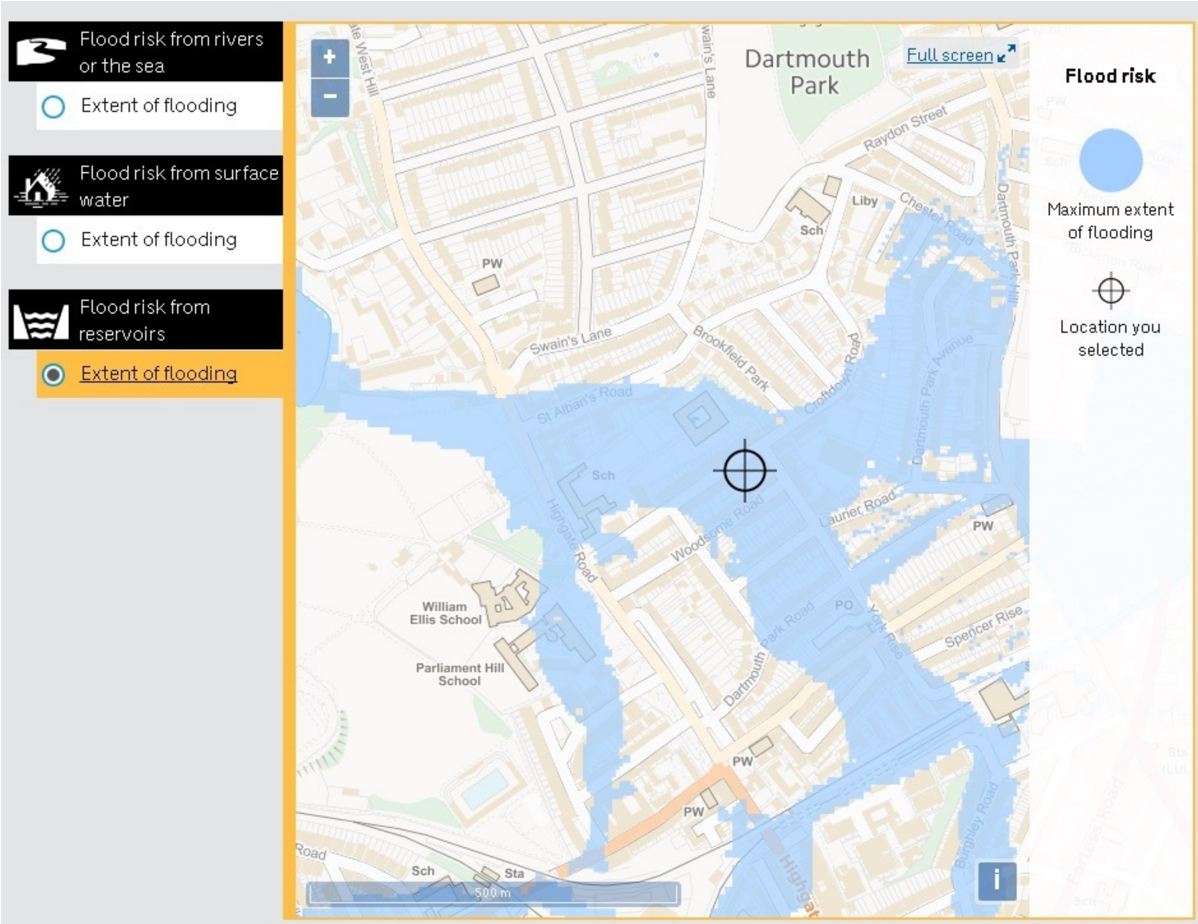
There are currently no reported incidents of flooding from groundwater to the existing basement. A site investigation report for the site was not available at the time of writing this report. The British Geological Survey maps show that there are no superficial deposits in this area and that the London Clay underlies the site. Therefore the local geology does not form a groundwater reservoir at this location and the impermeable nature of the London clay will prevent large volumes of groundwater from moving in any direction in this area. While the existing basement will be lowered and a new lightwell will be constructed, these works will not increase the flood risk from groundwater, as these works will take place in the same ground conditions that the existing basement was constructed. Engineering techniques such as waterproofing and cavity drainage will be provided to recuse further the risk from groundwater. Therefore, the flood risk from groundwater is considered low.



4 Flood Risk from Sewers & Infrastructure Failure

As section 2 states the local topography will direct any overland flows from any source, including sewers and burst water mains, to the junction of Croftdown Road with York Rise, and from there the water will flow to the south in low lying areas.

The Government's map below show that the site is at risk of flooding from reservoirs. The map shows that flood water from the Highgate ponds will flow to an eastern direction, where the topography falls, flooding the site and areas lying lower than the reservoirs' ground levels.



The EA and DEFRA "Guide to risk assessment for reservoir safety management – Report SC090001/R1" document states that reservoir owners are responsible for the operation, maintenance, monitoring and the preparation of risk assessments. These activities aim to reduce the risk of reservoir failure. These activities are enforced by the enforcement authority which is the EA in England. While the Government's map shows that the site is at risk of flooding from reservoir failure, the chances of this happening are extremely low, considering that there is an effective management and monitoring plan in place to safeguard the safety of such structures.

5 Climate Change

The site is not near the tidal or fluvial floodplain. Therefore, elevated flood water levels due to climate change will not affect the existing building.

6 Proposed Run-off

In principle, the proposed building modifications, including the basement, will not generate any run-off rate, as the proposed works will take place within a building which is served by an existing drainage system. Furthermore, the proposed lightwell will be constructed within an existing hardstanding area. The proposed lightwell occupies an area of approximately $6m^2$. Therefore, it will generate a peak run-off rate of 0.17 l/sec (calculated based on the modified rational method, Q = 2.78 x 0.0006 x 104 = 3.76 l/sec, where "A" is the catchment area in hectares and "i" is the rainfall intensity in mm/hr). Therefore, the run-off rate is negligible. The proposed works will not affect the existing surface water drainage system, which will be maintained.

The lightwell will be constructed on the proposed basement slab which will be formed on the London clay. Therefore, no infiltration systems can be used for surface water drainage. Attenuation techniques cannot apply, as the peak run-off rate is too low to be attenuated further. Surface water from the lightwell will be pumped to the below ground drainage network. A non-return valve will be fitted to the pump to reduce the flood risk from surcharged sewers.

7 Conclusion

Available information for the local area shows that the site is not at risk of tidal and/or fluvial flooding. While part of the site is at risk of flooding from surface water, the proposed works will not increase the flood risk to the basement level. The local topography confirms that overland flows from any source will not enter the new lightwell. The local geology indicates that the risk of flooding from groundwater is low. There is a risk of flooding from reservoirs, however effective maintenance, inspection and monitoring of such structures ensure that the chances of reservoir failure are extremely low. Furthermore, climate change will not increase the flood risk on site.

The proposed development will not increase the impermeable areas on site and subsequently the run-off rates and volumes to the public sewers.

Yours sincerely,
For Price & Myers LLP

Dimitris Linardatos BEng MSc CEng MICE FIHE
dlinardatos@pricemyers.com