PRICE&MYERS

REPORT

Croftdown Road, 17

Construction Method Statement

Contents

Appendices

Prepared by: **P. Goslin**
Job Number: **24555**

Date	Version	Notes / Amendments / Issue Purpose
April 2016	1	

30 Newman Street London W1T 1LT T 020 7631 5128 F 020 7462 1390 E mail@pricemyers.com www.pricemyers.com

1 Introduction

The existing site is located at 17 Croftdown Road. This Construction Method Statement has been prepared under the instruction of Susan Walker Architects, on behalf of the clients Jessica Pryce-Jones and David Shukman . It outlines the proposed basement to 17 Croftdown Road at planning application stage. This report should be read in conjunction with the Basement Impact Assessment report by Soiltechnics.

2 Surveys, Ground Conditions and Ground Water

Refer to the site-specific Ground Investigation and Basement Impact Assessment Report prepared by Soiltechnic; report reference STN3576D-BIA01, April 2016.

3 Proposals and Construction Methodology

Introduction

The existing superstructure is a three-storey, semi-detached house comprising of loadbearing masonry walls with timber floors spanning in between. There is an existing single-storey basement beneath the rear half of the house.

The houses next door, No 15 Croftdown Road and No. 17 Croftdown Road, have existing basements. No 19 has a basement extension similar to the one proposed at no 17 and No 15 has an existing basement in a similar arrangement to the existing at No 17.

Permanent Works

See Appendix A for the structural drawings which show the plans and sections of the proposed basement. The basement works will involve the excavation of the existing basement to the rear part of the house by lowering the slab level and the excavation of the front of the house forming a new slab level.

The existing external and internal loadbearing walls of the house will be resupported on new concrete and steel; beams, columns and walls. These in turn will be supported on new strip footings at basement slab level to bear the loads onto the London Clay formation. Reinforced concrete retaining walls will be constructed to retain the ground around the basement. Refer to Appendix C for the structural calculations for further preliminary information on the proposed permanent structure.

Temporary Works

The lower ground floor extension is to be constructed by a sequential underpinning process which is a quiet and gradual process, well known and understood. The normal Party Wall processes will be undertaken in due course to resolve any technical issues which might arise in the respect to structural movement and risk to the adjoining owners.

The temporary works and construction sequence will be discussed in detail with the contractor and the temporary works engineer. They will be planned such that bearing pressures, particularly differential pressures during the works, are managed carefully.

In addition, sequences and procedures will be discussed and rigorously managed, designed and agreed with the temporary works contractor and Soiltechnics Ltd. Heave, both during the construction and in the permanent structure will also be considered in more detail once the proposals are finalised.

In the meantime, we have prepared an assumed sequence of construction to demonstrate how the basement would most likely be constructed. Refer to Appendix B for the assumed sequence of construction.

Stage A
The front bay area and ground floor joists are to be temporarily supported with props. The temporary sheet pilling to be installed and the front area is then to be excavated allowing the new concrete columns, lintels stepped retaining wall to be installed. The excavation and then the stepped retaining wall will be propped until the ground slab is in place

Stage B
The front half, up to the buttressing column and ground beam, of the proposed basement is to be formed in a sequential underpinning process that are temporarily propped until stage C is completed.

Stage C
The internal ground level to the front half is to be lowered in stages whilst installing props to support the underpins and exposed excavation face. Once at proposed ground level the ground bearing slab is to be formed. The props to the underpins can be removed one the ground slab is fully cured.

Stage D
The steel beam at ground level is to be supported by props. Sections of the masonry spine wall foundation at either end are to be removed to allow the two buttressing columns, along with the associated underpins, can be formed. Once in place, the section 1.0m wide section between the buttress columns is to be excavated with props to the exposed excavations and underpins. The ground beam then can be formed.

Stage E
The rear half of the basement is to be formed in a sequential underpinning process.

Stage F
The internal ground level to the rear half is to be lowered in stages whilst installing props to support the underpins and exposed excavation face. Once at proposed ground level the ground bearing slab is to be formed. The props to the underpins can be removed one the ground slab is fully cured.

Stage G
The rear stepped retaining wall to be installed

Health & Safety
Health and Safety on site will be managed by the contractor, and they will need to carefully consider the risks of basement construction. The temporary works will be planned rigorously to mitigate any risks to the existing building and workers on site.

Site Logistics
Good access to the site is available off Highgate Road, approximately 100m west of the site. Site routes and deliveries will likely be off Croftdown Road, and the temporary suspension of parking bays may be required. There is space on the site in the front garden and rear garden where it is likely that materials will be delivered and stored.

Site Hoardings and Security

Site hoardings will be erected such that members of the public on Croftdown Road will be sufficiently protected from work to the house. The hoardings will be made secure, and any access restricted and locked whilst the site is not in use.

Appendix A

Proposed Structural Drawings

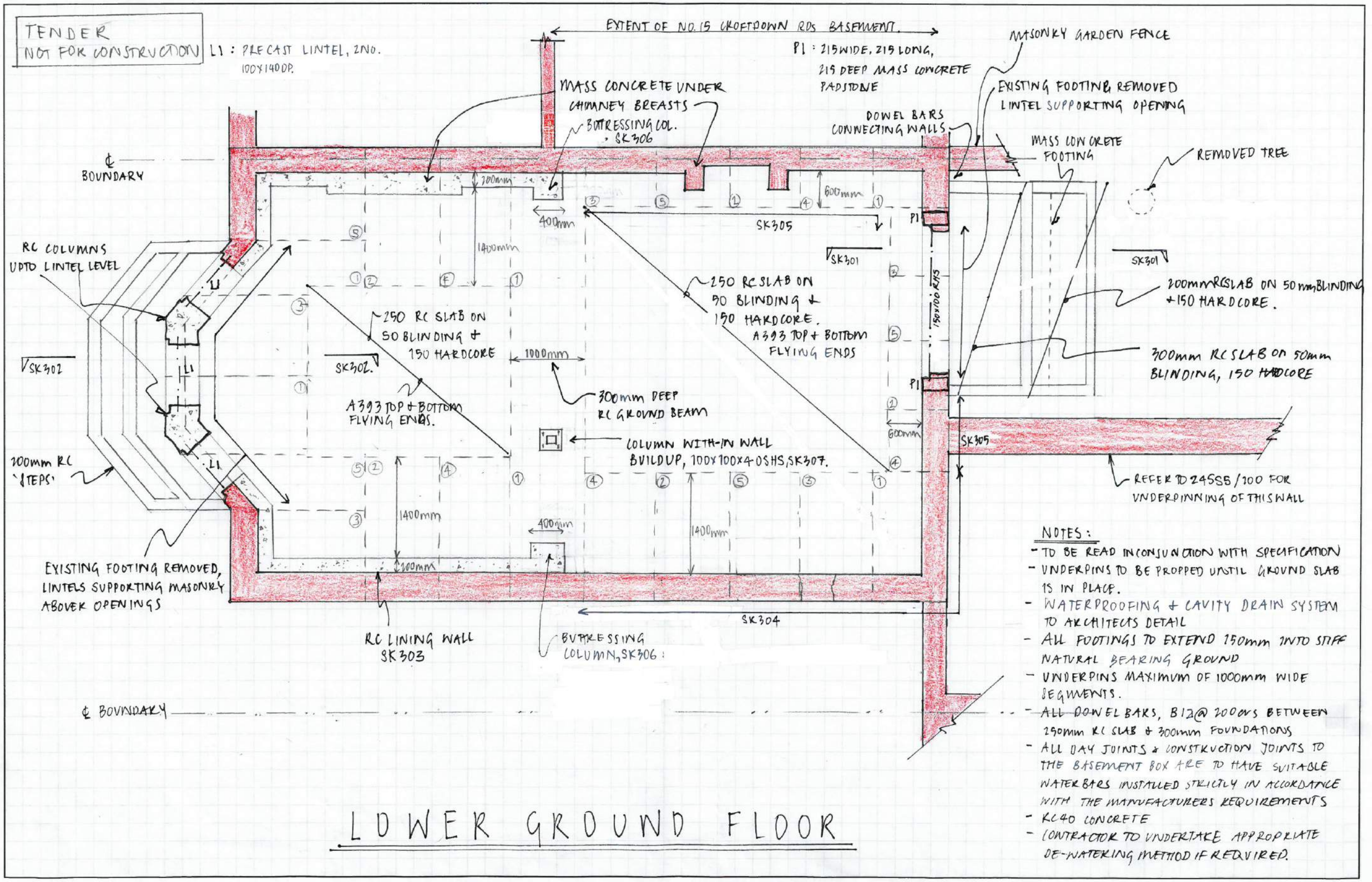
PRICE&MYERS

Consulting Engineers

Job No 24555 Page SK300 Rev C

Date 03/05/16 Eng PJG Chd

Job CROFTDOWN ROAD, 17

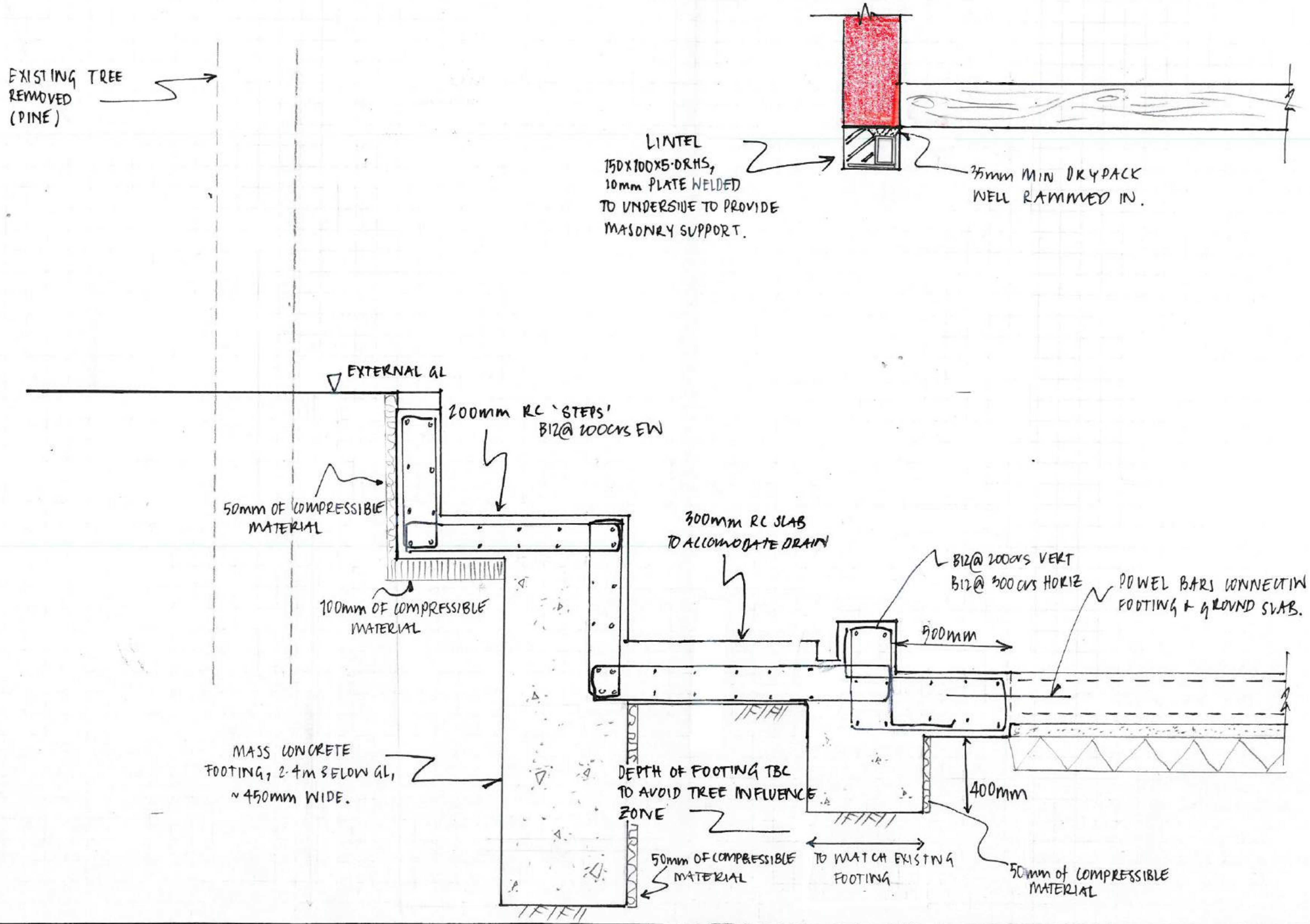


PRICE&MYERS
Consulting Engineers

Job No	24555	Page	SK301	Rev	C
Date	02/03/16	Eng	PJG	Chd	
Job	CROFTDOWN ROAD				

TENDER
NOT FOR CONSTRUCTION

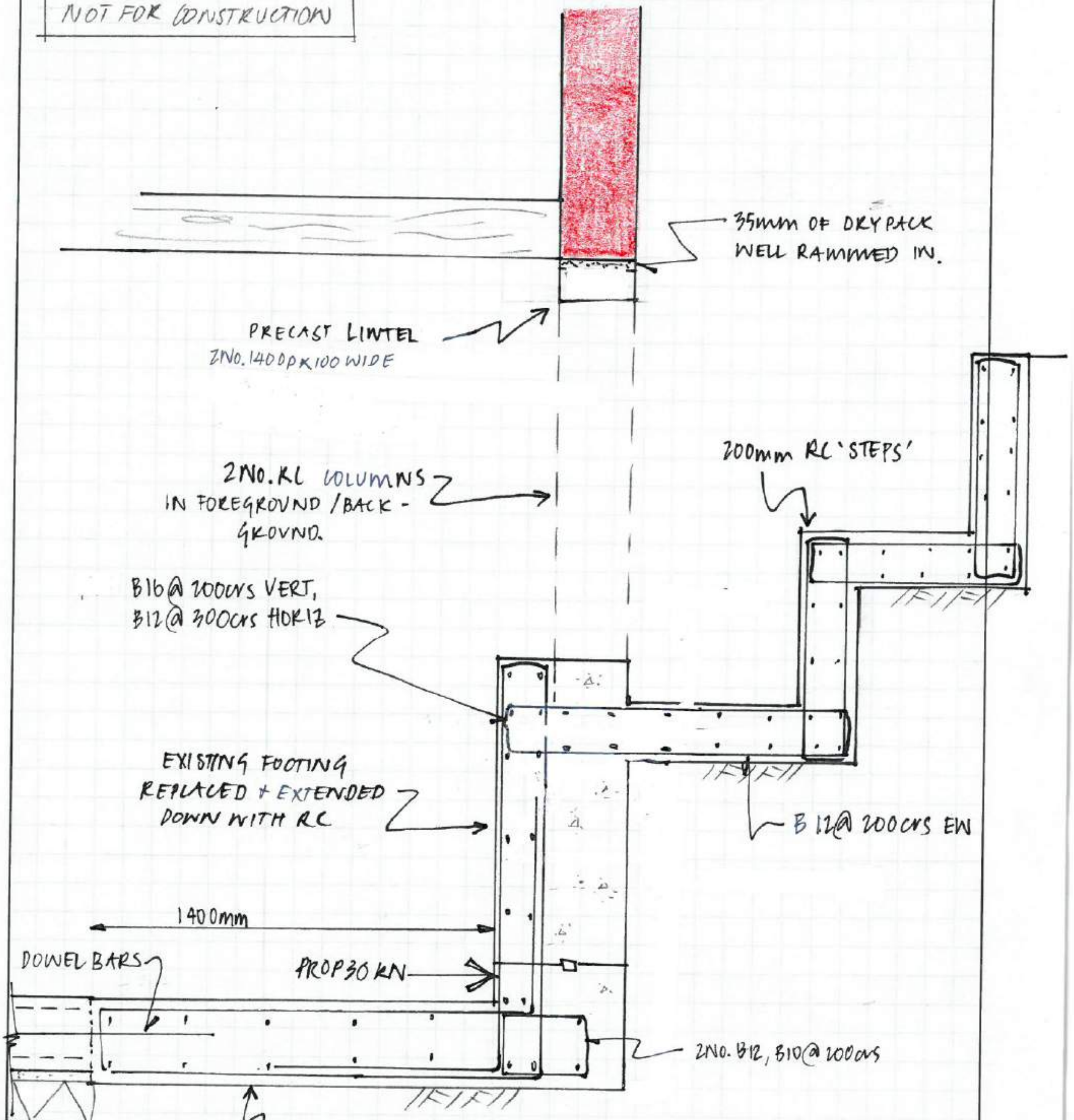
REAR BASEMENT ENTRANCE



PRICE&MYERS
Consulting Engineers

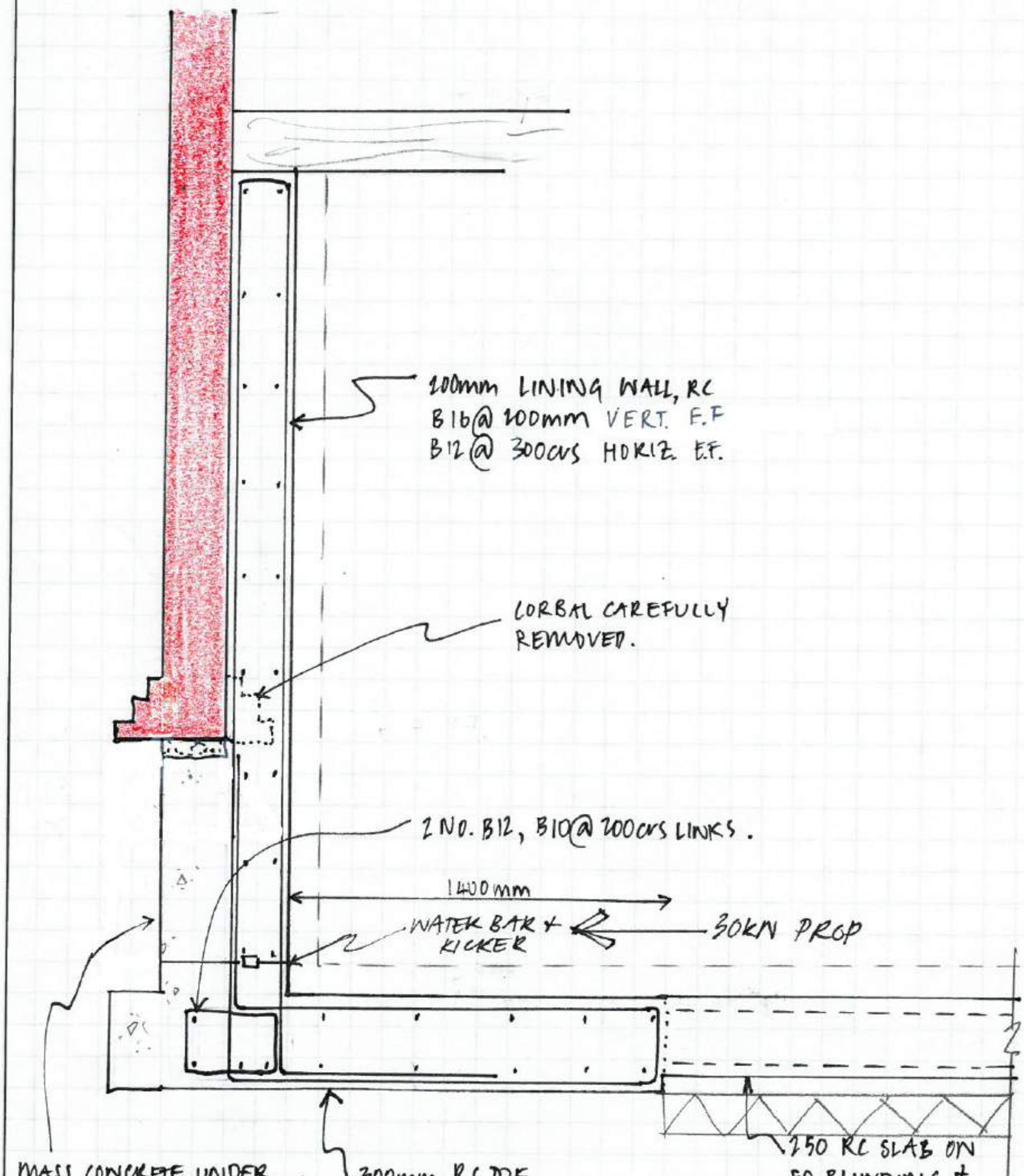
Job No 24555 | Page SK302 | Ver B
Date 03/05/16 | Eng PJG | Chd
Job CROFTDOWN ROAD, 17

TENDER
NOT FOR CONSTRUCTION

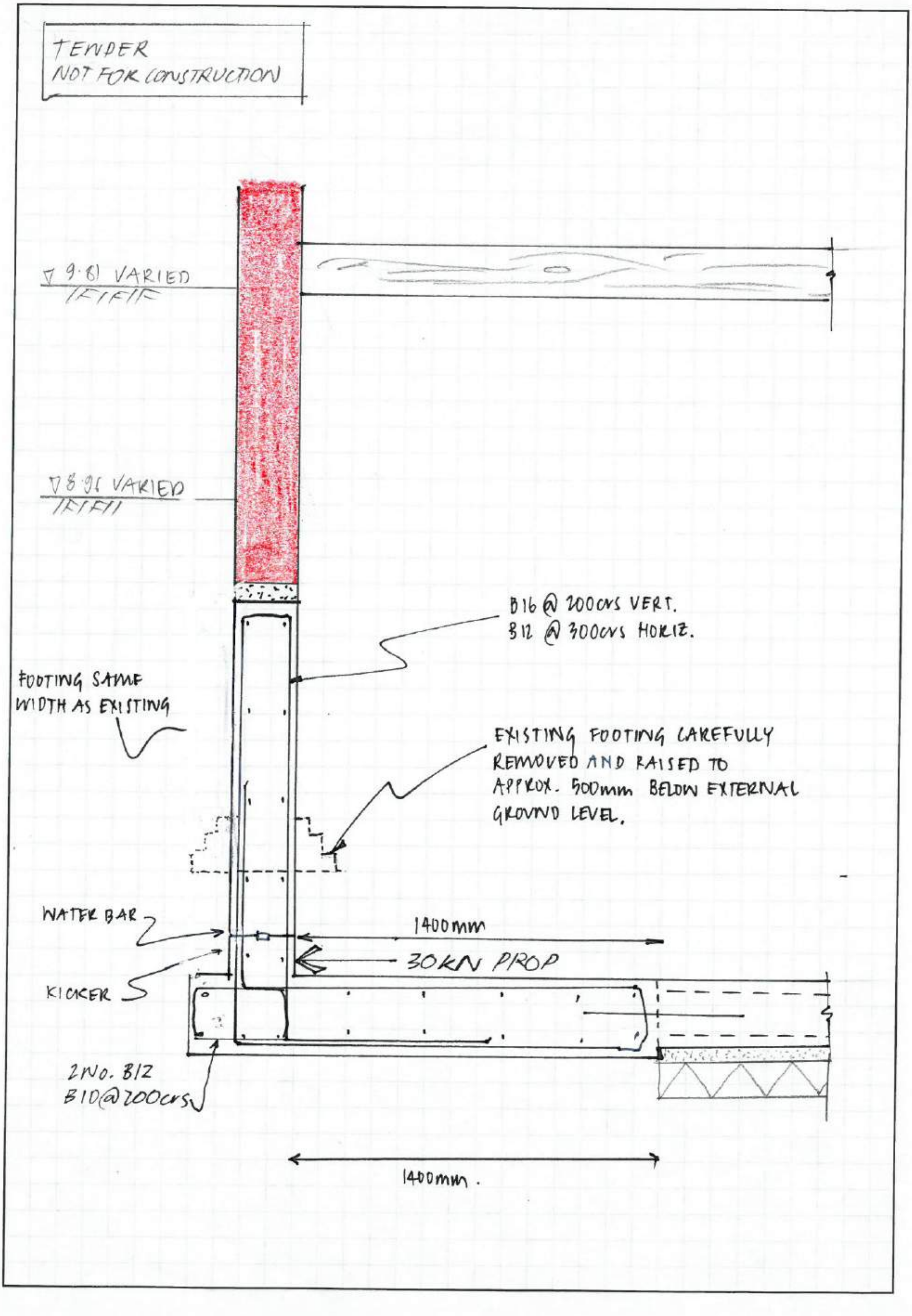


FRONT BAY WINDOW

TENDER
NOT FOR CONSTRUCTION



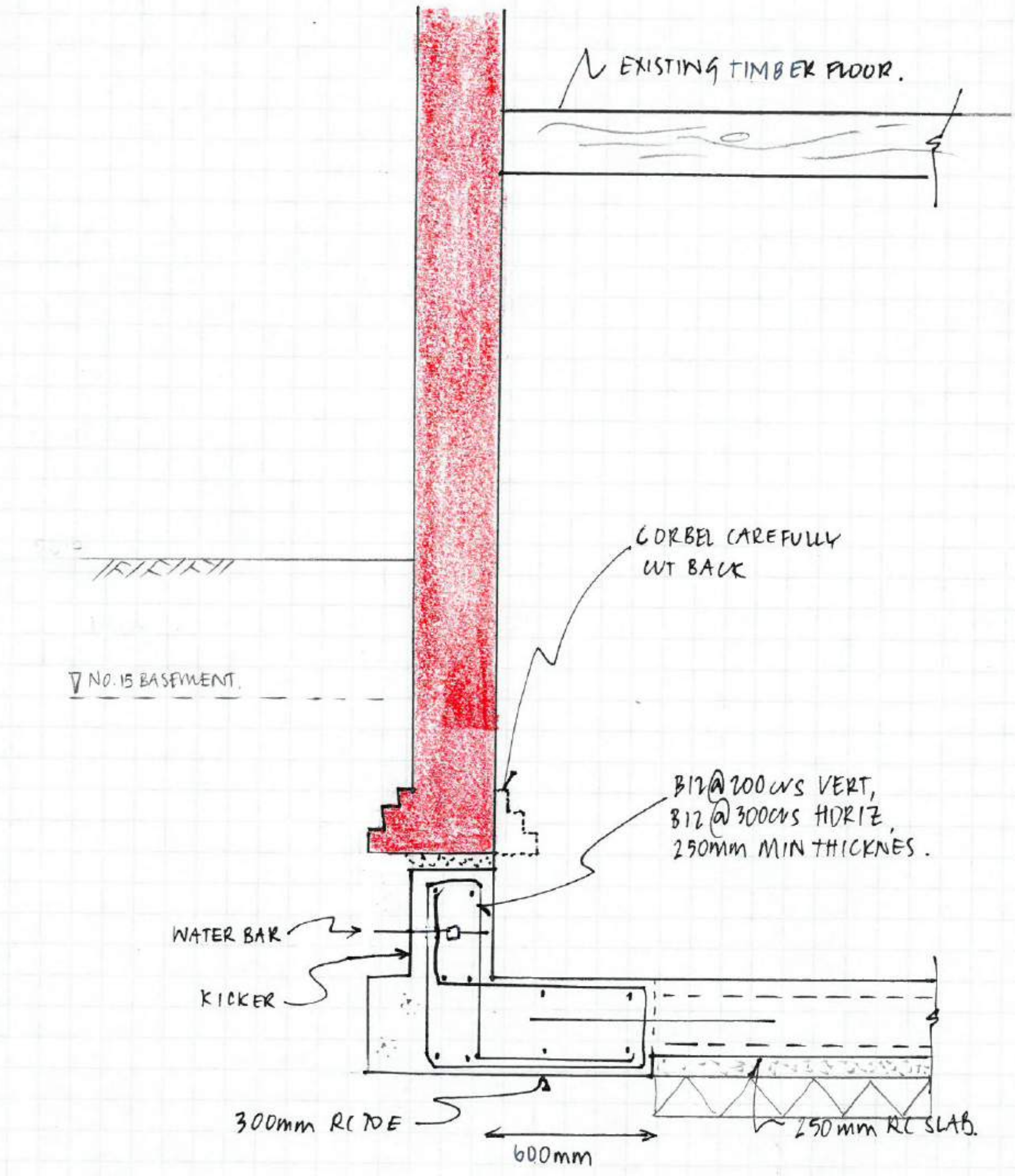
TYPICAL 'L' UNDERPIN


TENDER
NOT FOR CONSTRUCTION
∇ 9.81 VARIED
/F/F/F
∇ 8.96 VARIED
/F/F//
B16 @ 200crs VERT.
B12 @ 300crs HORIZ.
FOOTING SAME
WIDTH AS EXISTING
EXISTING FOOTING CAREFULLY
REMOVED AND RAISED TO
APPROX. 500mm BELOW EXTERNAL
GROUND LEVEL.
WATER BAR
1400mm
30KN PROP
KICKER
2No. B12
B10@200crs
1400mm.

PRICE&MYERS
Consulting Engineers

Job No 24555 Page SK305 Ver B
Date 03/05/16 Eng PJG Chd
Job CROFTDOWN ROAD

TENDER
NOT FOR CONSTRUCTION



TYPICAL UNDERPIN

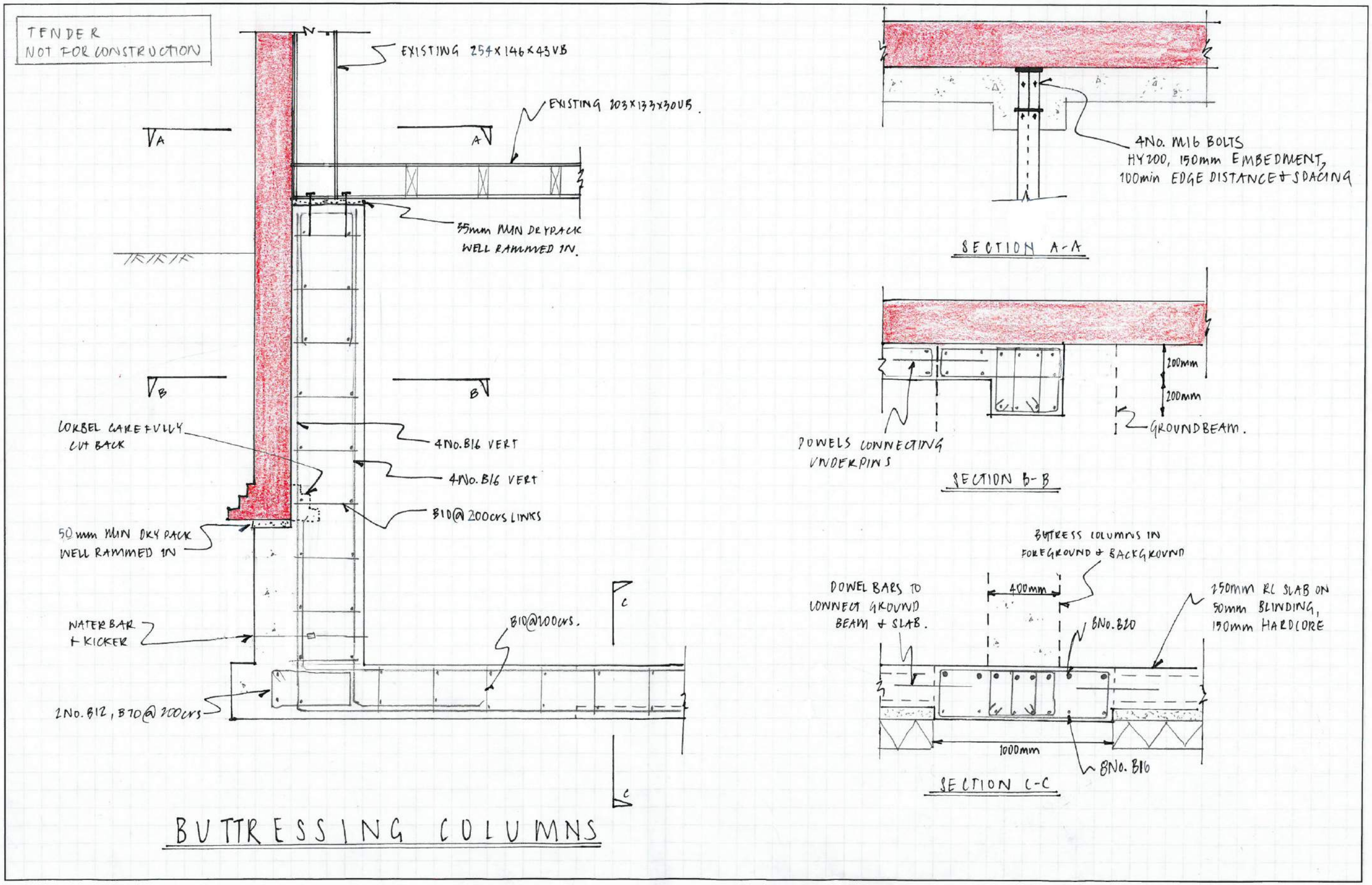
PRICE&MYERS

Consulting Engineers

Job No 24555 Page SK306 Rev B

Date 03/05/16 Eng PJG Chd

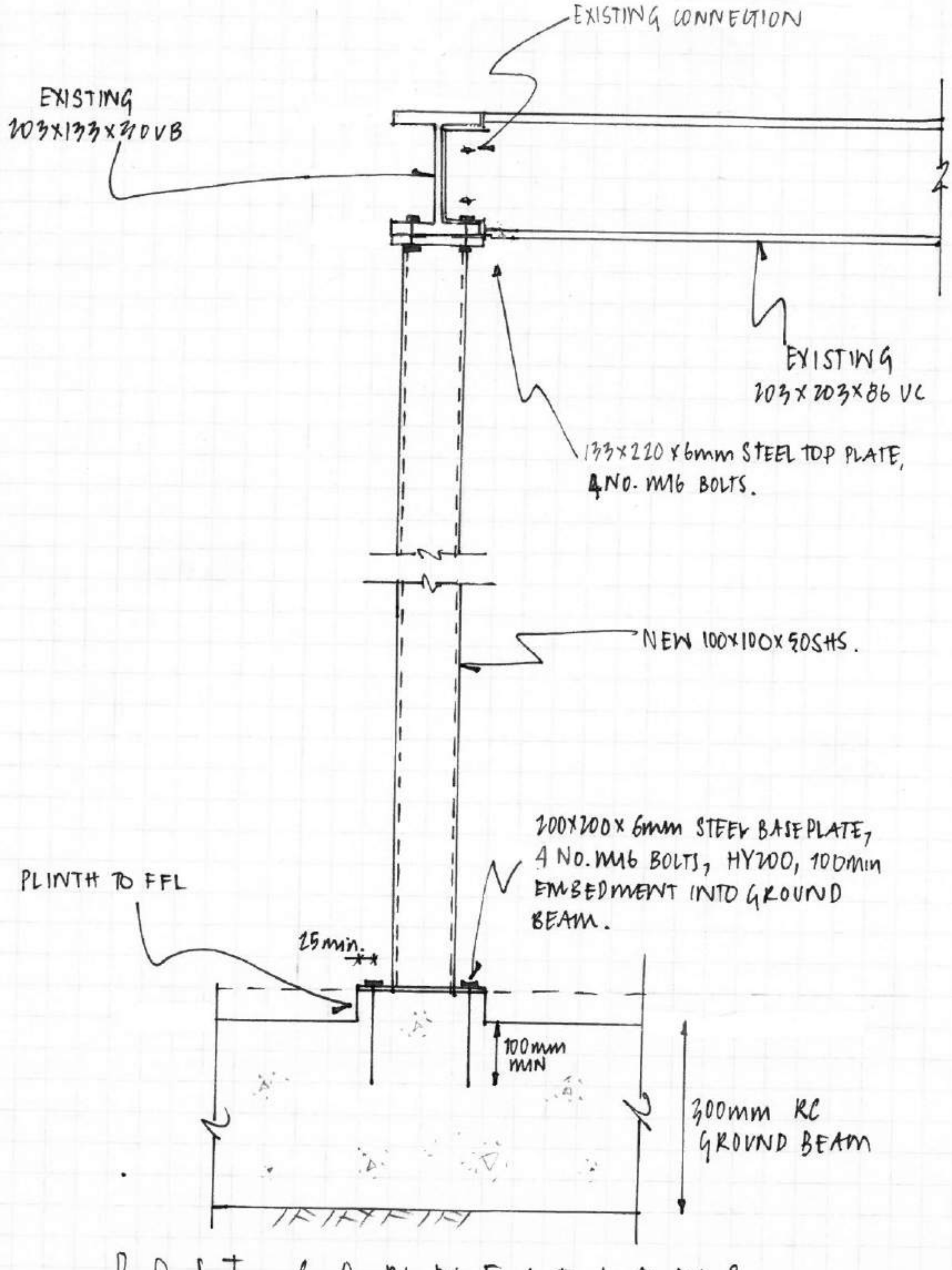
Job CROFTDOWN ROAD, 17



PRICE&MYERS
Consulting Engineers

Job No	24555	Page	SK307	Ver	B
Date	03/05/16	Eng	PJG	Chd	
Job	CROFTDOWN ROAD				

TENDER
NOT FOR CONSTRUCTION



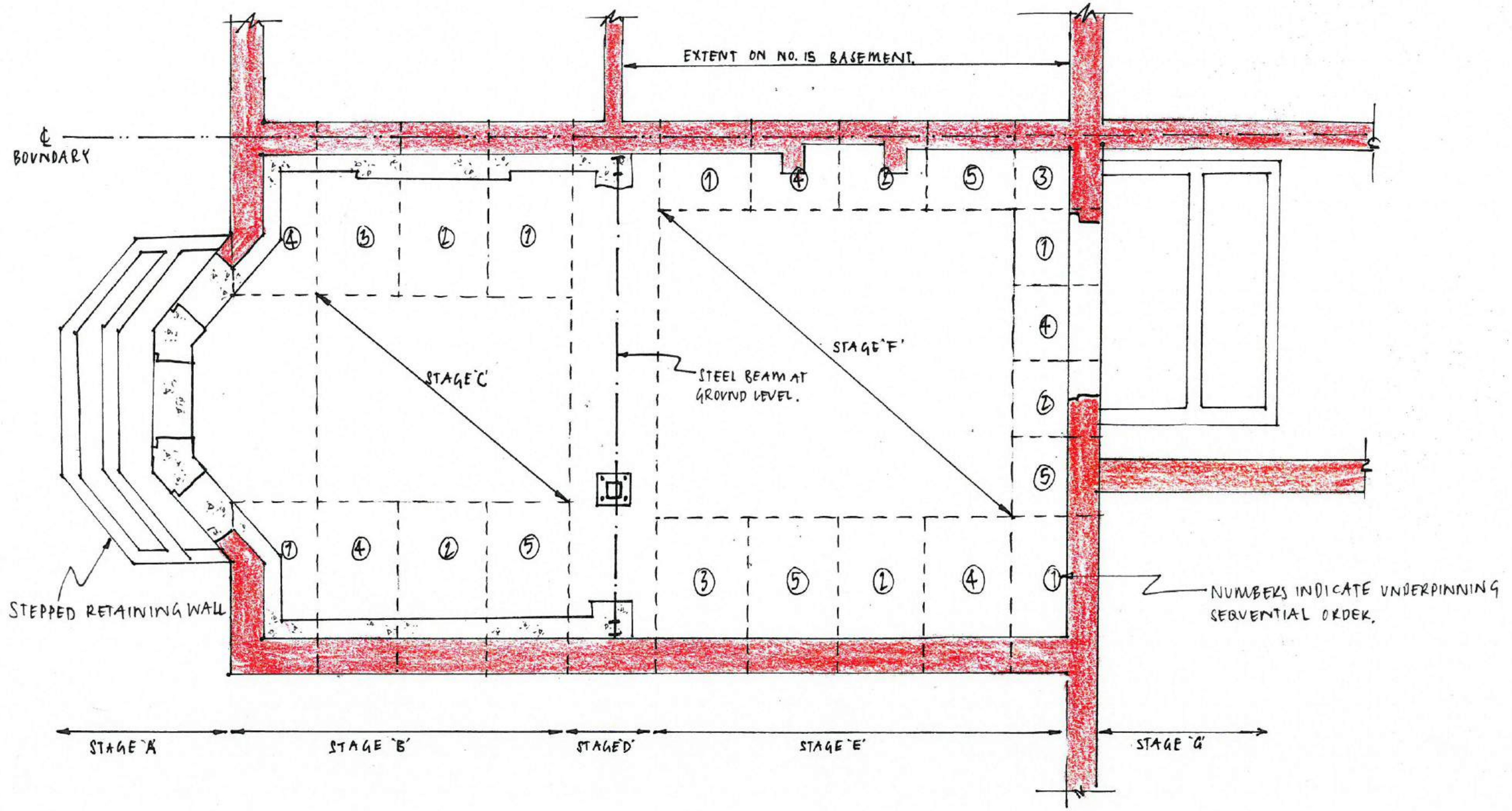
POST CONNECTIONS

Appendix B

Proposed Temporary Works Sequence and Drawings

PRICE&MYERS
Consulting Engineers

Job No 24555 Page SK400 Rev
Date 06/05/16 Eng PJG Chd
Job CROFT DOWN ROAD.



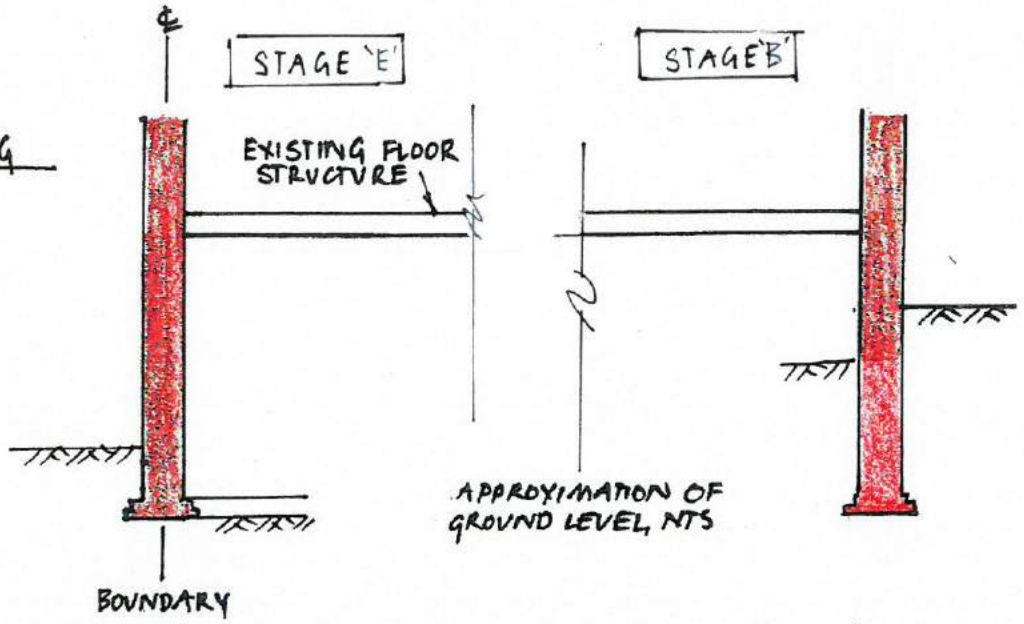
BASEMENT CONSTRUCTION STAGES.

PRICE&MYERS
Consulting Engineers

Job No 14555	Page SK401 Rev –
Date 06/05/16	Eng PJG Chd
Job CROFTDOWN ROAD, 17	

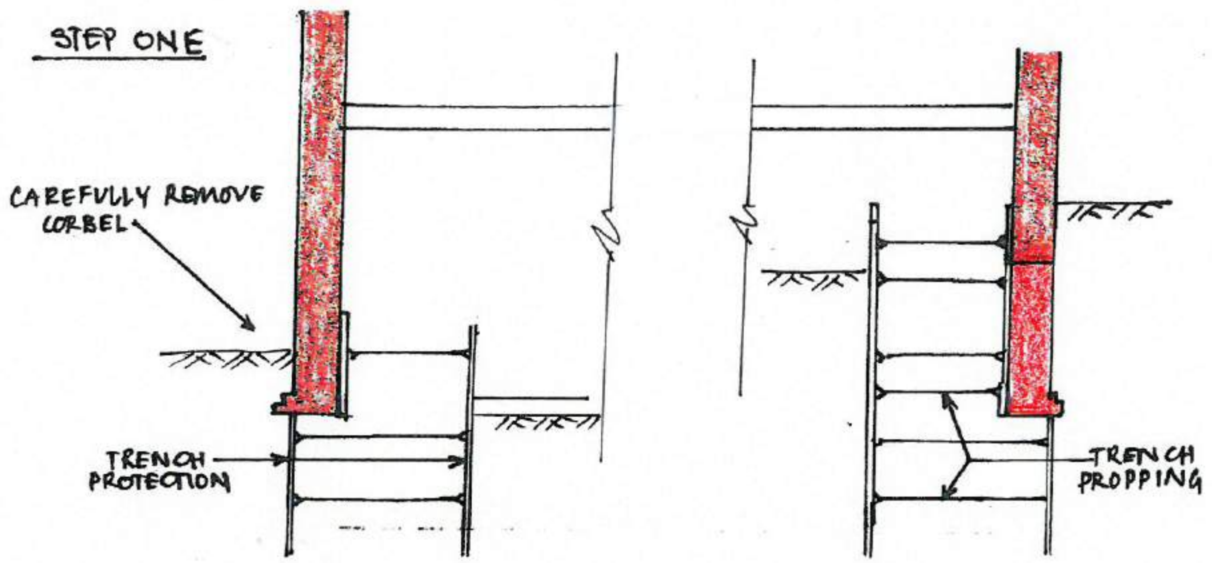
UNDERPINNING SEQUENCE

EXISTING



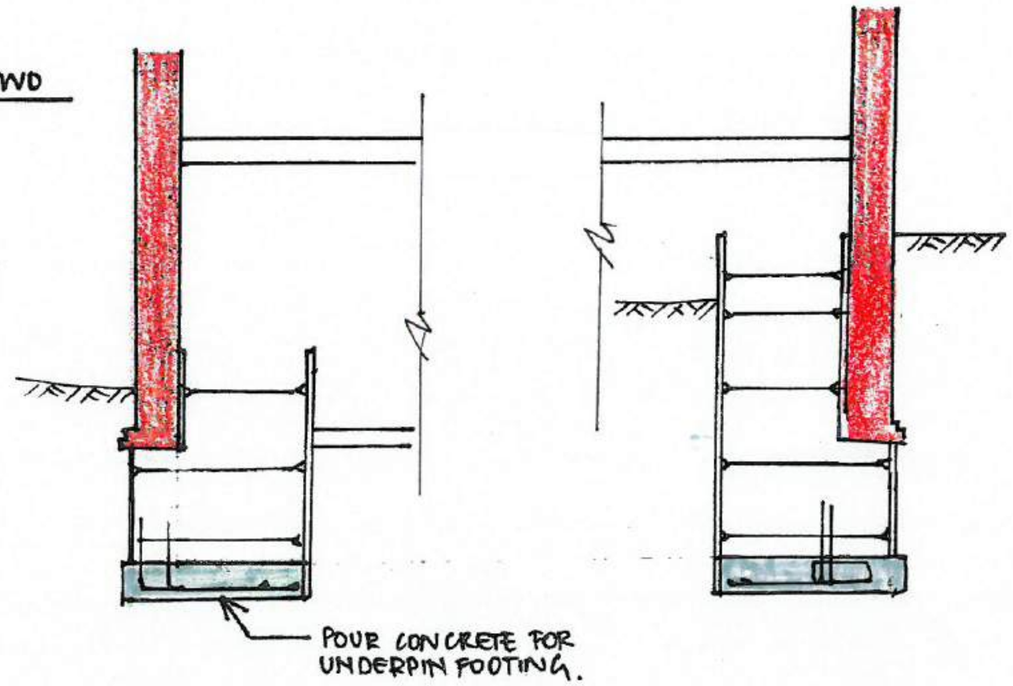
- Sequence of underpinning to be 1,2,3,4,5 maximum bay length to be 1.0m. Excavate access trench and initial heading for the first pin. Check the condition of the existing brickwork and foundation. If badly damaged, cracked or loose footings are encountered, provide temporary propping to the underside of the footing to ensure that the structure above the underpinning bay is fully supported as the excavation of the underpinning heading proceeds.

STEP ONE

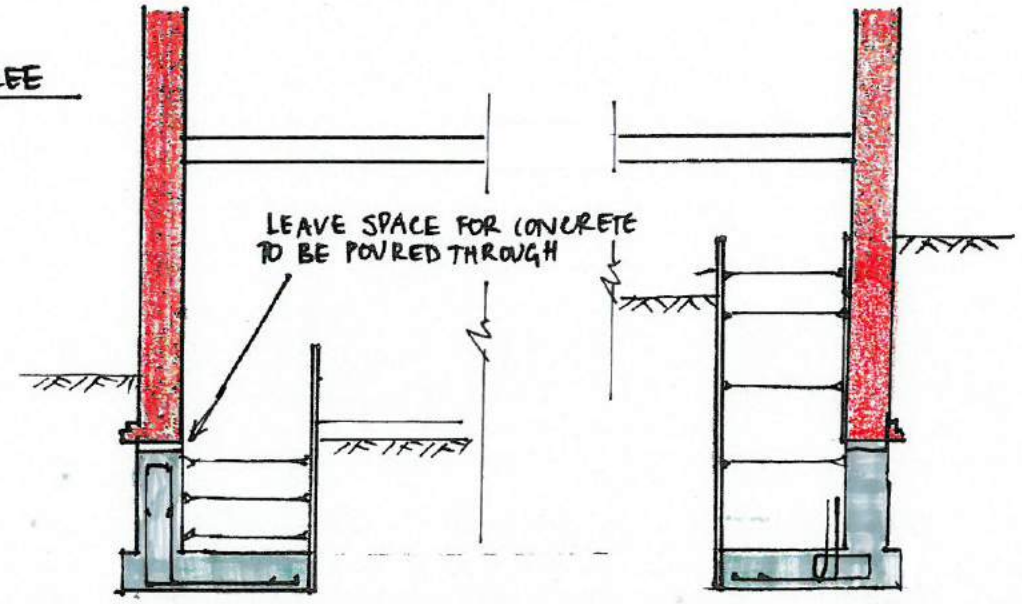


- Excavate to the agreed formation level and remove spoil.
- Provide planking and strutting to sides of excavations
- Clean off underside of existing foundation to receive pin up

STEP TWO



STEP THREE

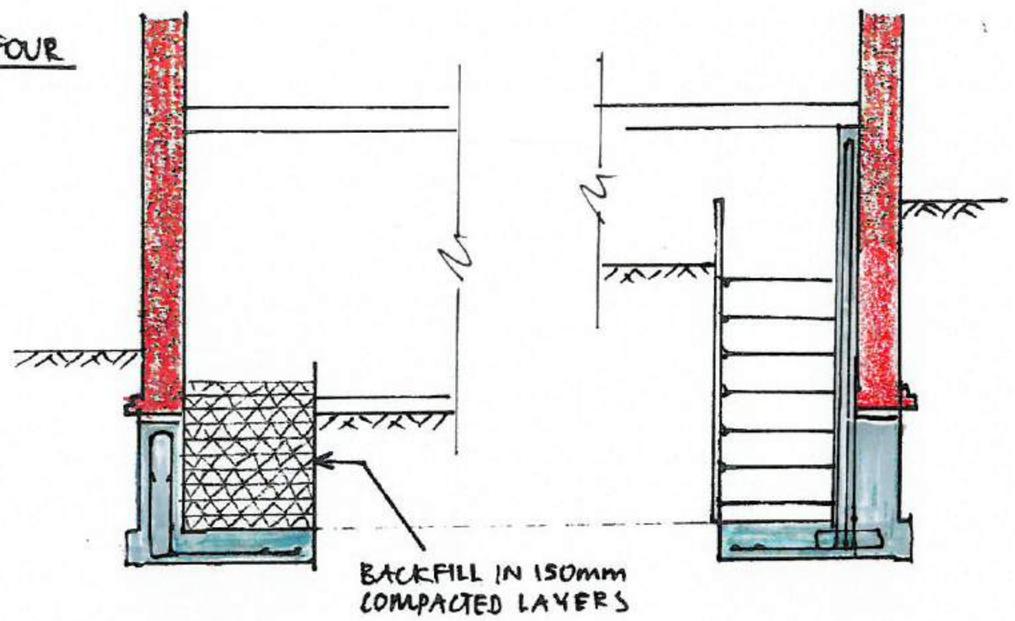


- Fill underpinning bay excavation with concrete to within 100mm of the underside of the existing foundation.

PRICE&MYERS
Consulting Engineers

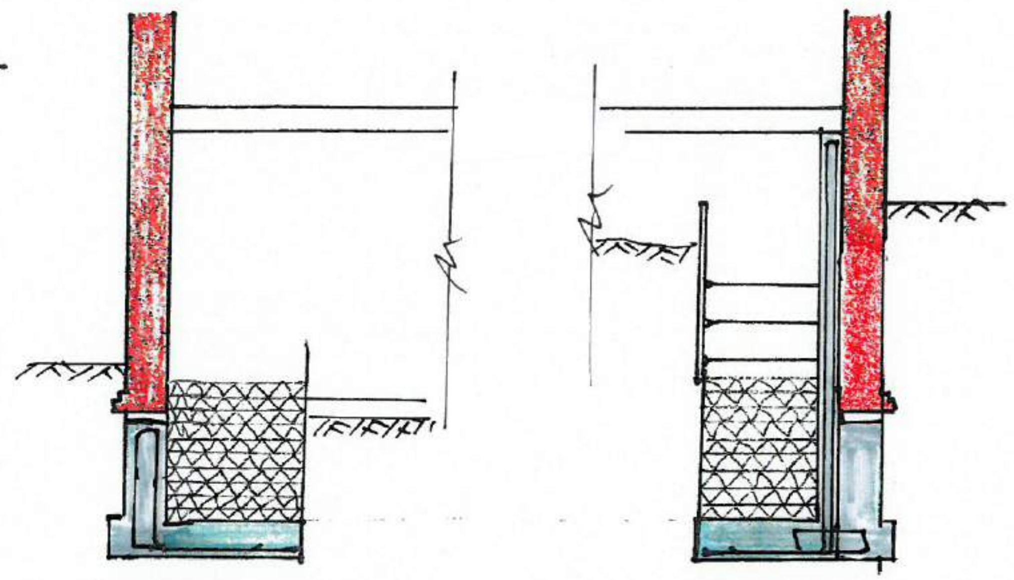
Job No	24555	Page	SK402	Rev	–
Date	06/05/16	Eng	PJG	Chd	
Job	CROFTDOWN ROAD, 17				

STEP FOUR



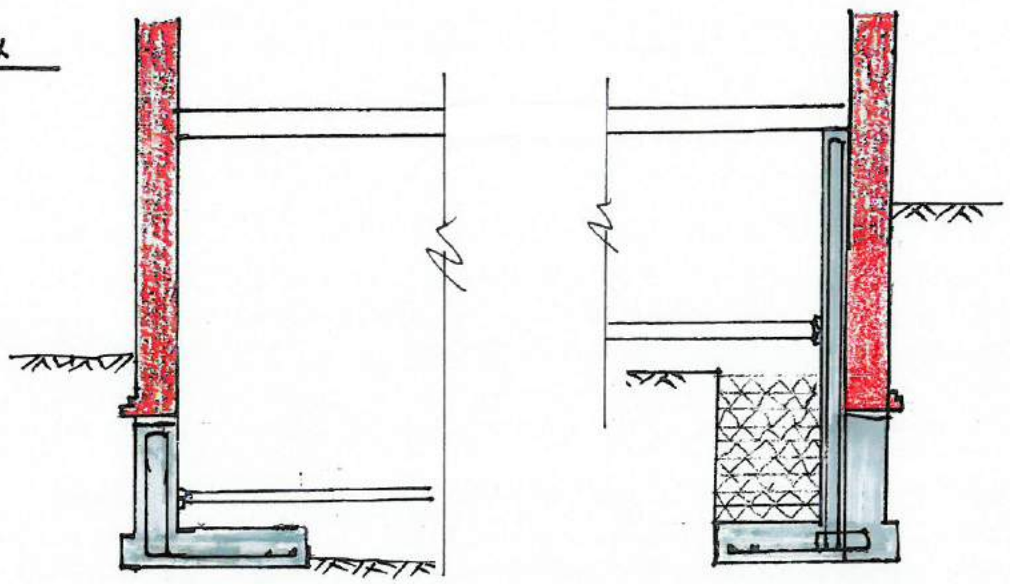
Following initial curing period of concrete (72 hours), pin up with semi dry sand cement mix between top of underpinning concrete and underside of existing foundation.
Backfill working space with compacted spoil material to required level.

STEP FIVE



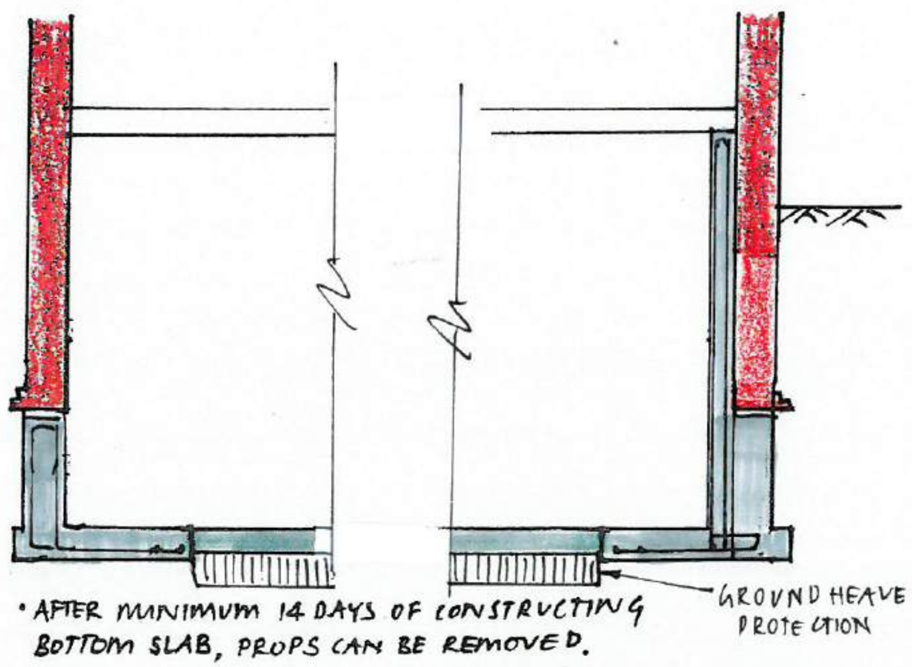
Repeat the above sequence for each underpinning bay, allowing a period of not less than two days between the dry packing of one bay and the excavation of adjoining bay.

STEP SIX



• REDUCE GROUND LEVEL INSTALLING PROPS TO SUPPORT UNDERPINS.

STEP SEVEN



• AFTER MINIMUM 14 DAYS OF CONSTRUCTING BOTTOM SLAB, PROPS CAN BE REMOVED.

Appendix C

Structural Design Calculations

PRICE&MYERS

30 Newman Street London W1T 1LT
Tel: 020 7631 5128 Fax: 020 7462 1390
Email: mtyler@pricemyers.com
www.pricemyers.com

Structural Calculations For

17 Croftdown Road
NW5 1EL
London

Job No. 24555

Contents

Project Description

24555/0.1

The existing structures is a three storey semi-detached house which includes 'room in the roof' accommodation. There is a partial basement some 2m deep over the rear foot print of the main house and an under croft about 1.1m deep under the front of the main house. The construction consists primarily of masonry load bearing walls on corbelled foundations. The spin wall has been replaced with a two story steel box frame. The remaining walls, floors and roof are timber framed.

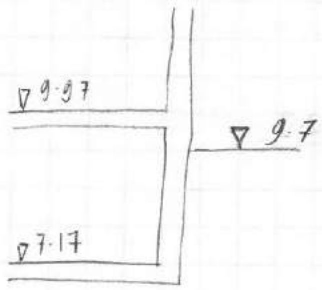
It is proposed to deepen the existing basement to the rear of the house by about 0.5m and deepen the under croft by about 2.0m with two light wells out the front and back of the structure. There is to be a new reinforced concrete ground bearing slab on the lower ground level. The existing masonry loading bearing foundations are to be underpinned by concrete extended down to the lower ground floor level.

Standards Used

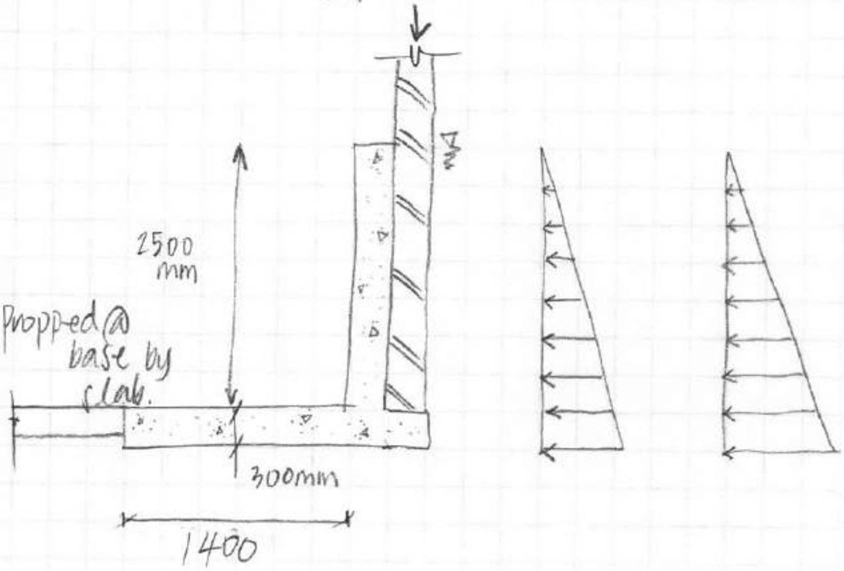
BS 5268 Pt2 2002	Structural Use of Timber
BS 5628 Pt1 2005	Code of Practice for Structural Use of Unreinforced Masonry
BS 5950 Pt1 2000	Structural Use of Steelwork
BS 6399 Pt1 1996	Code of Practice for Dead and Imposed Loads
BS 6399 Pt2 1997	Code of Practice for Wind Loads
BS 6399 Pt3 1988	Code of Practice for Imposed Roof Loads
BS 8110 Pt1 1997	Structural Use of Concrete – Code of practice for design and construction
BS 8110 Pt2 1985	Structural Use of Concrete – Code of practice for special circumstances

UNDERPINS - FRONT ROOM

2.5 mm SSL LOWER GROUND TO GROUND SSL



RETAINING H. = 9.57 - 7.17
= 2.4m



Surcharge = 5kPa

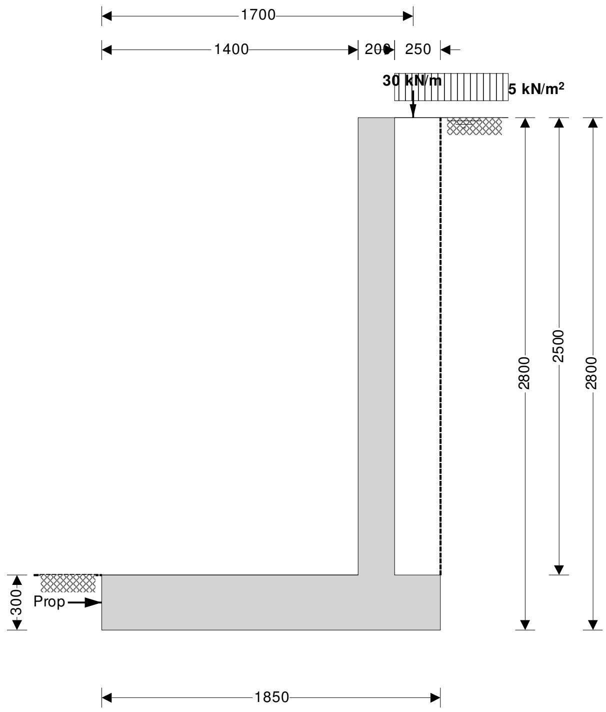
GWT = Ground level

Mas. Load = [0.215 × ~ 10m × 18] × 80% (20% windows etc)
= 30kN/m

	Project			Job no.	
	Croftdown Road			24555	
	Calcs for			Start page no./Revision	
	Typical Underpin			1	
	Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
	PJG	03/05/2016				

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} = **2500** mm
Thickness of wall stem	t_{wall} = **200** mm
Length of toe	l_{toe} = **1400** mm
Length of heel	l_{heel} = **250** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1850** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **700** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **2800** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **2800** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **2500** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **2800** mm

Retained material details

Mobilisation factor	M = **1.5**

Project				Job no.	
Croftdown Road				24555	
Calcs for				Start page no./Revision	
Typical Underpin				2	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
PJG	03/05/2016				

Moist density of retained material γ_m = **20.0** kN/m^3

Saturated density of retained material γ_s = **20.0** kN/m^3

Design shear strength ϕ' = **22.0** deg

Angle of wall friction δ = **22.0** deg

Base material details

Hard clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **22.0** deg

Design base friction δ_b = **22.0** deg

Allowable bearing pressure $P_{bearing}$ = **110** kN/m^2

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 = **0.455**

Passive pressure coefficient for base material $K_p = (1 + \sqrt{[1 - (\cos(\phi'_b))^2]}) / (1 - \sqrt{[1 - (\cos(\phi'_b))^2]})$ = **2.198**

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.625**

Loading details

Surcharge load on plan Surcharge = **5.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **30.0** kN/m

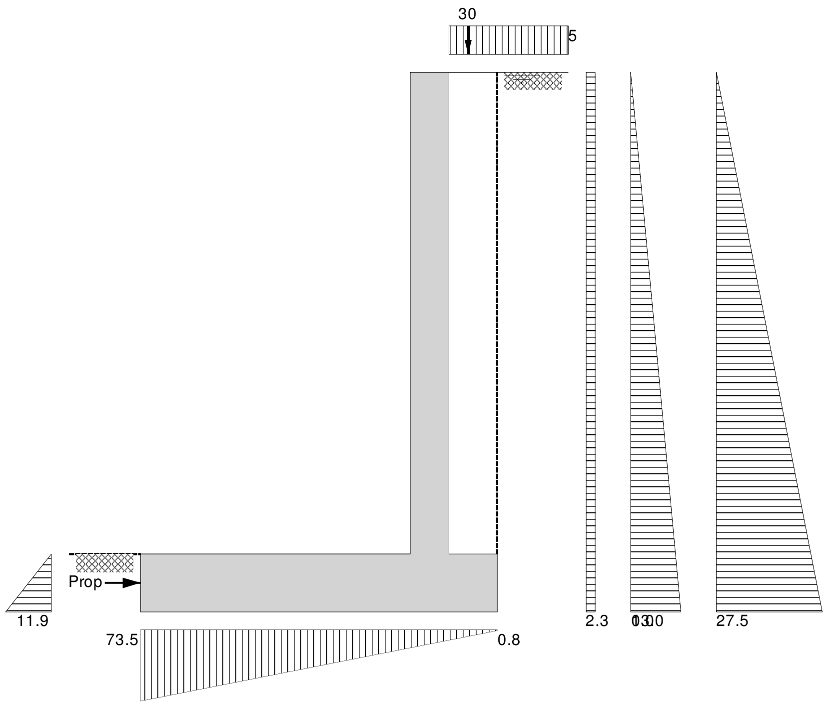
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **1700** 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 — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **11.8** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **13.1** kN/m

Surcharge — w_{sur} = Surcharge $\times l_{heel}$ = **1.3** kN/m

Saturated backfill — $w_s = l_{heel} \times h_{sat} \times \gamma_s$ = **12.5** kN/m

Applied vertical load — $W_v = W_{dead} + W_{live}$ = **30** kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + w_{sur} + w_s + W_v$ = **68.6** kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times$ Surcharge $\times h_{eff}$ = **6.4** kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **18.2** kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **38.5** kN/m

Total horizontal load — $F_{total} = F_{sur} + F_s + F_{water}$ = **63** kN/m

Calculate propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **1.8** kN/m

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

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

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **8.9** kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **17** kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.9** kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_s + M_{water}$ = **61.8** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **17.7** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2$ = **12.1** kNm/m

Saturated backfill — $M_{s\_r} = w_s \times (l_{base} - l_{heel} / 2)$ = **21.6** kNm/m

Design vertical dead load — $M_{dead} = W_{dead} \times l_{load}$ = **51** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_{s\_r} + M_{dead}$ = **102.4** kNm/m

Check bearing pressure

Surcharge — $M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **2.2** kNm/m

Total moment for bearing — $M_{total} = M_{rest} - M_{ot} + M_{sur\_r}$ = **42.8** kNm/m

Total vertical reaction — $R = W_{total}$ = **68.6** kN/m

Distance to reaction — $x_{bar} = M_{total} / R$ = **623** mm

Eccentricity of reaction — $e = \text{abs}((l_{base} / 2) - x_{bar})$ = **302** mm

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **73.5** kN/m^2

Bearing pressure at heel — $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **0.8** kN/m^2

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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **16.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **18.3** kN/m

Surcharge $w_{sur\_f} = \gamma_{f\_l} \times Surcharge \times l_{heel}$ = **2** kN/m

Saturated backfill $w_{s\_f} = \gamma_{f\_d} \times l_{heel} \times h_{sat} \times \gamma_s$ = **17.5** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **42** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{s\_f} + W_{v\_f}$ = **96.4** kN/m

Factored horizontal active forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_a \times Surcharge \times h_{eff}$ = **10.2** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **25.4** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **53.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{s\_f} + F_{water\_f}$ = **89.5** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **2.5** kN/m

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

F_{prop_f} = **48.9** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **14.3** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **23.7** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **50.2** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{s\_f} + M_{water\_f}$ = **88.3** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **24.8** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **17** kNm/m

Surcharge $M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2)$ = **3.5** kNm/m

Saturated backfill $M_{s\_r\_f} = w_{s\_f} \times (l_{base} - l_{heel} / 2)$ = **30.2** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **71.4** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{s\_r\_f} + M_{v\_f}$ = **146.8** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **58.5** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **96.4** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **607** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **318** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f})$ = **105.8** kN/m^2

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

Rate of change of base reaction $rate = p_{toe\_f} / (3 \times x_{bar\_f})$ = **58.06** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0\text{ kN/m}^2)$ = **24.5** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = \mathbf{18.7} \text{ kN/m}^2$

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = \mathbf{12.9} \text{ kN/m}^2$

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

Material properties

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

Characteristic strength of reinforcement $f_y = \mathbf{500} \text{ N/mm}^2$

Base details

Minimum area of reinforcement k = **0.00** %

Cover to reinforcement in toe $c_{toe} = \mathbf{40}$ mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{91.2}$ kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{13.9}$ kN/m

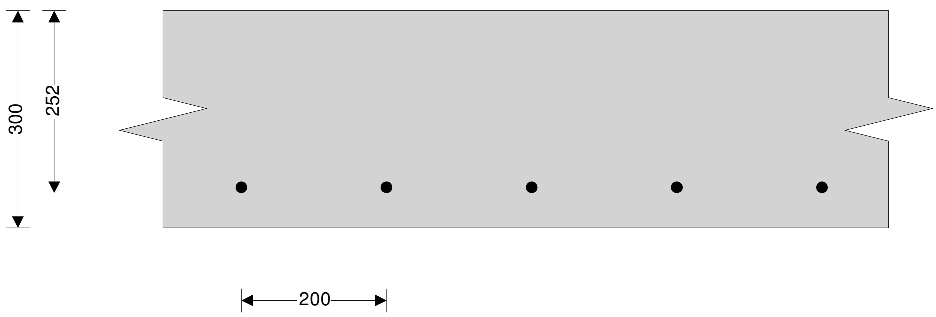
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{77.3}$ kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{86.3}$ kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{11.2}$ kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{75.2}$ kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{252.0}$ mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.030}$

Compression reinforcement is not required

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

$z_{toe} = \mathbf{239}$ mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{722} \text{ mm}^2\text{/m}$

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{0} \text{ mm}^2\text{/m}$

Area of tension reinforcement required $A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{722} \text{ mm}^2\text{/m}$

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

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{1005} \text{ mm}^2\text{/m}$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.307} \text{ N/mm}^2$

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_toe} = **0.611** N/mm^2

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

<u>Design of reinforced concrete retaining wall heel (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

Base details

Minimum area of reinforcement k = **0.00** %

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

Calculate shear for heel design

Shear from bearing pressure $V_{heel\_bear} = p_{stem\_heel\_f} \times ((3 \times x_{bar\_f}) - l_{toe} - t_{wall}) / 2 =$ **1.4** kN/m

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base} =$ **2.5** kN/m

Shear from weight of saturated backfill $V_{heel\_wt\_s} = w_{s\_f} =$ **17.5** kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f} =$ **2** kN/m

Total shear for heel design $V_{heel} = - V_{heel\_bear} + V_{heel\_wt\_base} + V_{heel\_wt\_s} + V_{heel\_sur} =$ **20.5** kN/m

Calculate moment for heel design

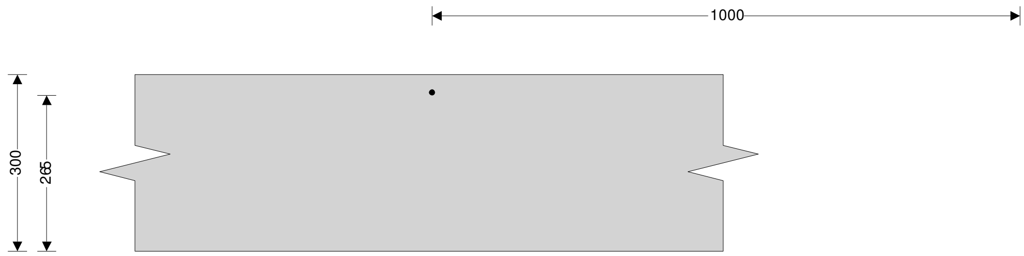
Moment from bearing pressure $M_{heel\_bear} = p_{stem\_mid\_f} \times ((3 \times x_{bar\_f}) - l_{toe} - t_{wall} / 2)^2 / 6 =$ **0.3** kNm/m

Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) =$ **0.6** kNm/m

Moment from weight of saturated backfill $M_{heel\_wt\_s} = w_{s\_f} \times (l_{heel} + t_{wall}) / 2 =$ **3.9** kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2 =$ **0.5** kNm/m

Total moment for heel design $M_{heel} = - M_{heel\_bear} + M_{heel\_wt\_base} + M_{heel\_wt\_s} + M_{heel\_sur} =$ **4.7** kNm/m



Check heel in bending

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

Depth of reinforcement $d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) =$ **265.0** mm

Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) =$ **0.002**

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} = **252** mm

Area of tension reinforcement required $A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel}) =$ **43** mm^2/m

Minimum area of tension reinforcement $A_{s\_heel\_min} = k \times b \times t_{base} =$ **0** mm^2/m

Area of tension reinforcement required $A_{s\_heel\_req} = \text{Max}(A_{s\_heel\_des}, A_{s\_heel\_min}) =$ **43** mm^2/m

Reinforcement provided **10 mm dia.bars @ 1000 mm centres**

Area of reinforcement provided $A_{s\_heel\_prov}$ = **79** mm^2/m

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel})$ = **0.078** N/mm²

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/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_heel} = **0.254** N/mm²

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

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Wall details

Minimum area of reinforcement k = **0.00** %

Cover to reinforcement in stem c_{stem} = **40** mm

Cover to reinforcement in wall c_{wall} = **40** mm

Factored horizontal active forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_a \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **9.1** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_a \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **20.3** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **42.9** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **23.4** kN/m

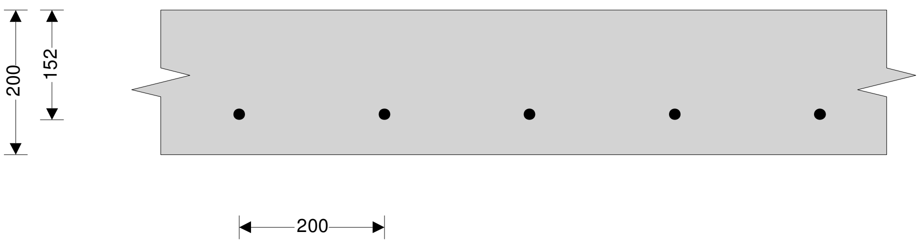
Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **12.7** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **16.9** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **35.8** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water}$ = **65.4** kNm/m



Check wall stem in bending

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

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **152.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.071**

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} = **139** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **1082** mm²/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **0** mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **1082** mm²/m

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

Area of reinforcement provided $A_{s\_stem\_prov}$ = **1005** mm^2/m

FAIL - Reinforcement provided at the retaining wall stem is inadequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.154** 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

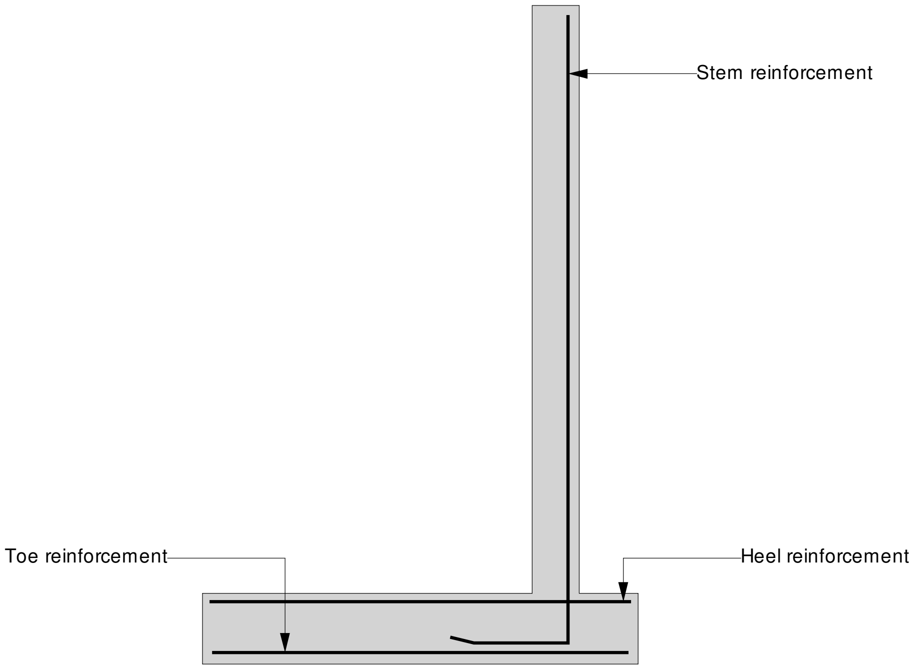
PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_stem} = **0.820** N/mm^2

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

Indicative retaining wall reinforcement diagram

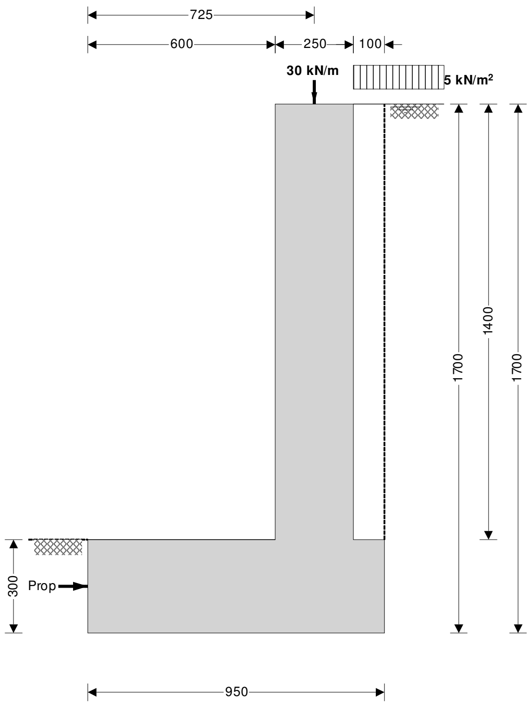


Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)
Heel bars - 10 mm dia.@ 1000 mm centres - (79 mm^2/m)
Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)

	Project				Job no.	
	Croftdown Road				24555	
	Calcs for				Start page no./Revision	
	Small Retaining Wall				1	
	Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
	PJG	29/04/2016				

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} = **1400** mm
Thickness of wall stem	t_{wall} = **250** mm
Length of toe	l_{toe} = **600** mm
Length of heel	l_{heel} = **100** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **950** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **400** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **1700** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **1700** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **1400** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **1700** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **20.0** kN/m^3

Saturated density of retained material γ_s = **20.0** kN/m^3

Design shear strength ϕ' = **22.0** deg

Angle of wall friction δ = **22.0** deg

Base material details

Moist density γ_{mb} = **20.0** kN/m^3

Design shear strength ϕ'_b = **22.0** deg

Design base friction δ_b = **22.0** deg

Allowable bearing pressure $P_{bearing}$ = **110** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.396}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.193}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = \mathbf{0.625}$

Loading details

Surcharge load on plan Surcharge = **5.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **30.0** kN/m

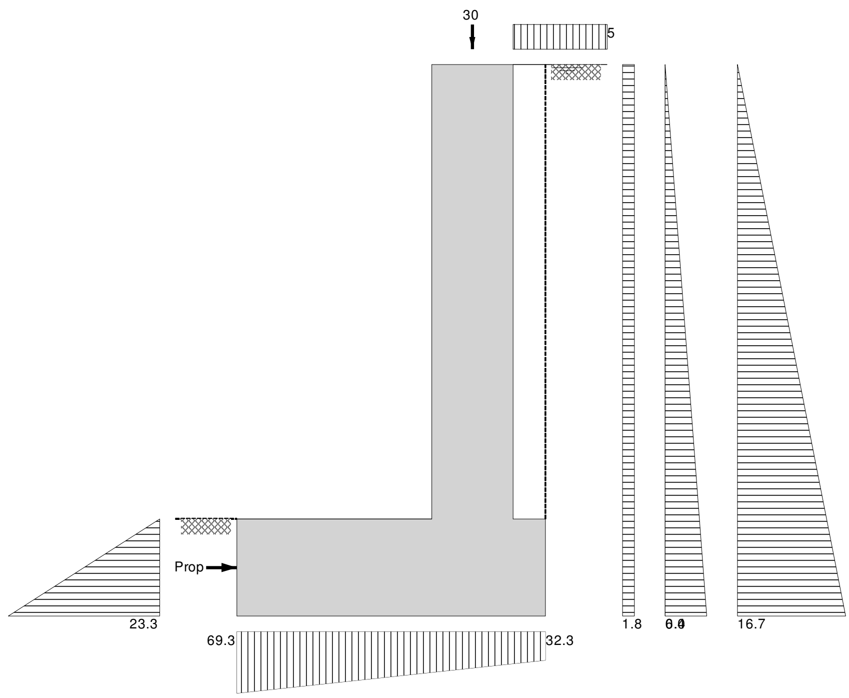
Applied vertical live load on wall W_{live} = **0.0** kN/m

Position of applied vertical load on wall l_{load} = **725** 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 $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **8.3** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **6.7** kN/m

Surcharge $w_{sur} = Surcharge \times l_{heel}$ = **0.5** kN/m

Moist backfill to top of wall $w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **0** kN/m

Saturated backfill $w_s = l_{heel} \times h_{sat} \times \gamma_s$ = **2.8** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **30** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + w_s + W_v$ = **48.3** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **3.1** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **0** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **5.4** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **14.2** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_b} + F_s + F_{water}$ = **22.7** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **3.5** kN/m

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

F_{prop} = **0.0** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **2.7** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **0** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **3.1** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **8** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_b} + M_s + M_{water}$ = **13.8** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **6** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **3.2** kNm/m

Moist backfill $M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3))$ = **0** kNm/m

Saturated backfill $M_{s\_r} = w_s \times (l_{base} - l_{heel} / 2)$ = **2.5** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **21.8** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{m\_r} + M_{s\_r} + M_{dead}$ = **33.5** kNm/m

Check bearing pressure

Surcharge $M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **0.5** kNm/m

Total moment for bearing $M_{total} = M_{rest} - M_{ot} + M_{sur\_r}$ = **20.2** kNm/m

Total vertical reaction $R = W_{total}$ = **48.3** kN/m

Distance to reaction $x_{bar} = M_{total} / R$ = **417** mm

Eccentricity of reaction $e = abs((l_{base} / 2) - x_{bar})$ = **58** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **69.3** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **32.3** 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	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **11.6** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **9.4** kN/m
Surcharge	$w_{sur\_f} = \gamma_{f\_l} \times Surcharge \times l_{heel}$ = **0.8** kN/m
Moist backfill to top of wall	$w_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **0** kN/m
Saturated backfill	$w_{s\_f} = \gamma_{f\_d} \times l_{heel} \times h_{sat} \times \gamma_s$ = **3.9** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **42** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{m\_w\_f} + w_{s\_f} + W_{v\_f}$ = **67.7** kN/m

Factored horizontal active forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **5** kN/m
Moist backfill below water table	$F_{m\_b\_f} = \gamma_{f\_e} \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **0** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **7.6** kN/m
Water	$F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **19.8** kN/m
Total horizontal load	$F_{total\_f} = F_{sur\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **32.4** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.9** kN/m
Propping force	$F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - w_{sur\_f}) \times \tan(\delta_b), 0\ kN/m)$
	F_{prop_f} = **0.5** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **4.2** kNm/m
Moist backfill below water table	$M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **0** kNm/m
Saturated backfill	$M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **4.3** kNm/m
Water	$M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **11.2** kNm/m
Total overturning moment	$M_{ot\_f} = M_{sur\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **19.8** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **8.4** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **4.5** kNm/m
Surcharge	$M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2)$ = **0.7** kNm/m
Moist backfill	$M_{m\_r\_f} = (w_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + w_{m\_s\_f} \times (l_{base} - l_{heel} / 3))$ = **0** kNm/m
Saturated backfill	$M_{s\_r\_f} = w_{s\_f} \times (l_{base} - l_{heel} / 2)$ = **3.5** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **30.5** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} + M_{s\_r\_f} + M_{v\_f}$ = **47.6** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **27.8** kNm/m
Total vertical reaction	$R_f = W_{total\_f}$ = **67.7** kN/m
Distance to reaction	$x_{bar\_f} = M_{total\_f} / R_f$ = **410** mm
Eccentricity of reaction	$e_f = abs((l_{base} / 2) - x_{bar\_f})$ = **65** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = \mathbf{100.4}$ kN/m^2

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2) = \mathbf{42.1}$ kN/m^2

Rate of change of base reaction rate $= (p_{toe\_f} - p_{heel\_f}) / l_{base} = \mathbf{61.40}$ kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0\ \text{kN/m}^2) = \mathbf{63.6}$ kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0\ \text{kN/m}^2) = \mathbf{55.9}$ kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall})), 0\ \text{kN/m}^2) = \mathbf{48.2}$ 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 $k = \mathbf{0.00}$ %

Cover to reinforcement in toe $c_{toe} = \mathbf{30}$ mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{49.2}$ kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{5.9}$ kN/m

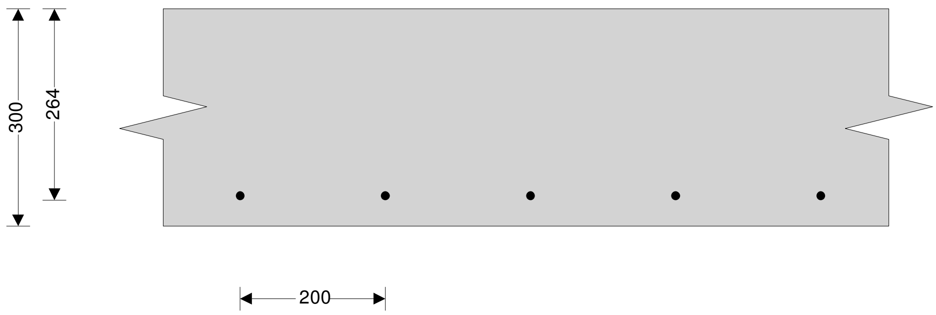
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{43.3}$ kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{22.5}$ kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{2.6}$ kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{19.9}$ kNm/m



Check toe in bending

Width of toe $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{264.0}$ mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.007}$

Compression reinforcement is not required

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

$z_{toe} = \mathbf{251}$ mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{182}$ mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{0}$ mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{182}$ mm^2/m

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

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{565}$ mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.164** N/mm²

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/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_toe} = **0.491** N/mm²

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

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Base details

Minimum area of reinforcement k = **0.00** %

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

Calculate shear for heel design

Shear from bearing pressure $V_{heel\_bear} = (p_{heel\_f} + p_{stem\_heel\_f}) \times l_{heel} / 2$ = **4.5** kN/m

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base}$ = **1** kN/m

Shear from weight of moist backfill $V_{heel\_wt\_m} = w_{m\_w\_f}$ = **0** kN/m

Shear from weight of saturated backfill $V_{heel\_wt\_s} = w_{s\_f}$ = **3.9** kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f}$ = **0.8** kN/m

Total shear for heel design $V_{heel} = - V_{heel\_bear} + V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_wt\_s} + V_{heel\_sur}$ = **1.2** kN/m

Calculate moment for heel design

Moment from bearing pressure $M_{heel\_bear} = (2 \times p_{heel\_f} + p_{stem\_mid\_f}) \times (l_{heel} + t_{wall} / 2)^2 / 6$ = **1.2** kNm/m

Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2)$ = **0.3** kNm/m

Moment from weight of moist backfill $M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2$ = **0** kNm/m

Moment from weight of saturated backfill $M_{heel\_wt\_s} = w_{s\_f} \times (l_{heel} + t_{wall}) / 2$ = **0.7** kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2$ = **0.1** kNm/m

Total moment for heel design $M_{heel} = - M_{heel\_bear} + M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_wt\_s} + M_{heel\_sur}$ = **-0.1** kNm/m

As the moment is negative the design of the retaining wall heel is beyond the scope of this calculation

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Wall details

Minimum area of reinforcement k = **0.00** %

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

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

Factored horizontal active forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **4.1** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **0** kN/m

Saturated backfill — $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 =$ **5.1** kN/m

Water — $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 =$ **13.5** kN/m

Calculate shear for stem design

Shear at base of stem — $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f} =$ **22.2** kN/m

Calculate moment for stem design

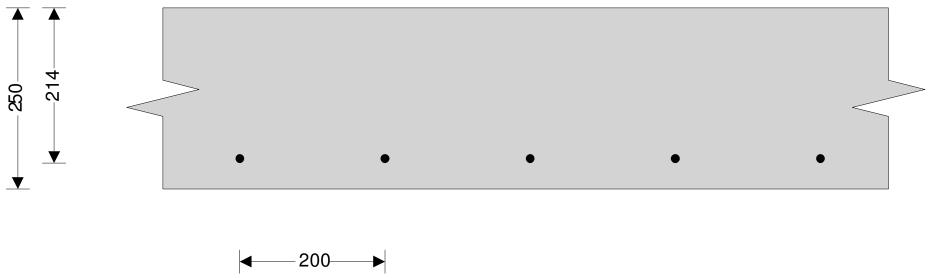
Surcharge — $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2 =$ **3.5** kNm/m

Moist backfill below water table — $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2 =$ **0** kNm/m

Saturated backfill — $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3 =$ **2.4** kNm/m

Water — $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3 =$ **6.3** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_sur} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water} =$ **12.2** kNm/m



Check wall stem in bending

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

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) =$ **214.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) =$ **0.007**

Compression reinforcement is not required

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

$z_{stem} =$ **203** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) =$ **138** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall} =$ **0** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) =$ **138** mm²/m

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

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

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem}) =$ **0.104** N/mm²

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/mm²

PASS - Design shear stress is less than maximum shear stress

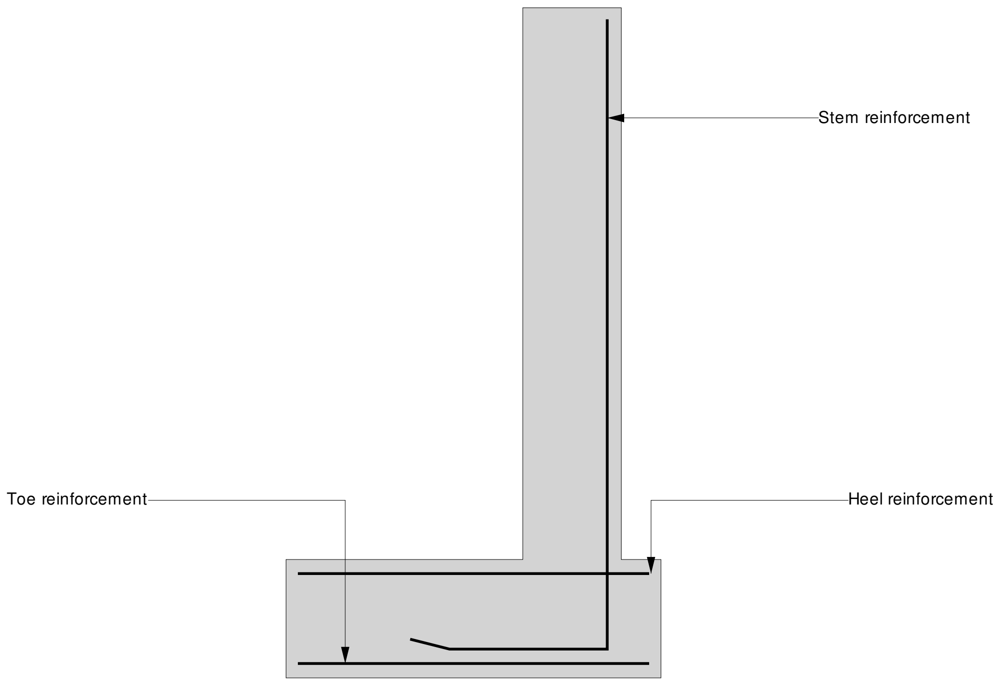
From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress — $v_{c\_stem} =$ **0.555** N/mm²

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

	Project Croftdown Road				Job no. 24555	
	Calcs for Small Retaining Wall				Start page no./Revision 8	
	Calcs by PJG	Calcs date 29/04/2016	Checked by	Checked date	Approved by	Approved date

Indicative retaining wall reinforcement diagram



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

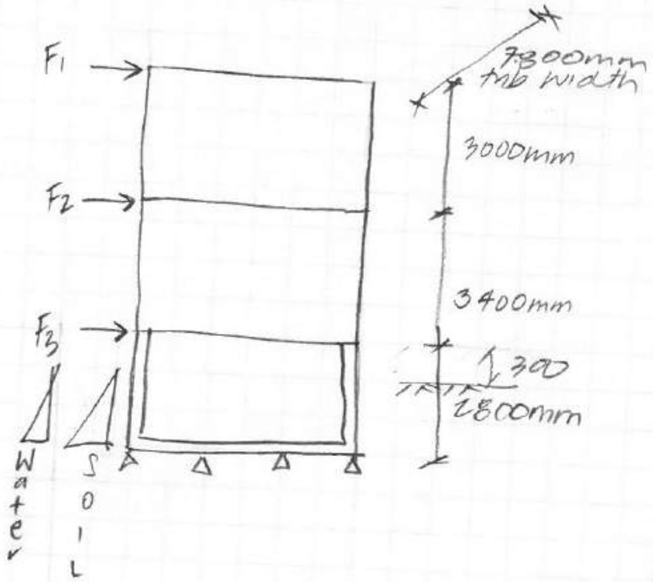
The design of the retaining wall heel is beyond the scope of this calculation!

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

BRACING OF BOX FRAME IN BASEMENT

W = 0.4kPa.

NHF = 0.5%



WIND

$W_{TOT} = 0.4 \times (3.0 + 3.4) \times 7.8$

$= 20kN.$

NOTIONAL LOAD

$NHF_1 = 1.2kN$ } from orginal calcs

$NHF_2 = 1.1kN$ }

$NHF_3 \sim 1.2kN$ — by inspection

Bracing load at ground level

$F_{TOT} = 20kN + 3.5kN$

$= 23.5kN$

$F_{water} = 2.5 \times 9.81$

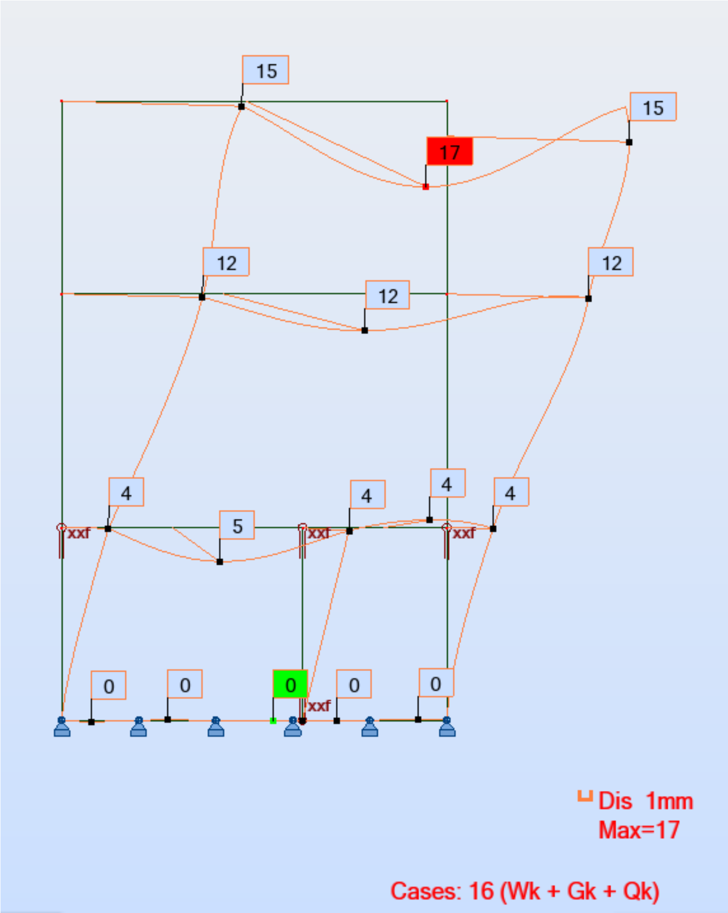
$= 26kN/m$ ← joined with wind load

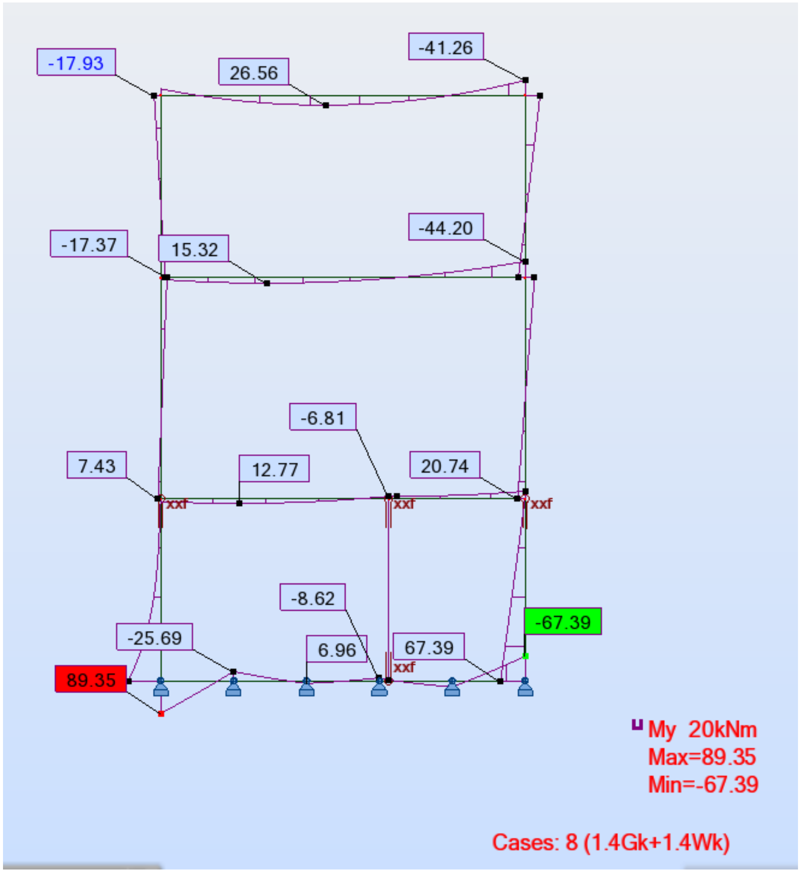
$F_{SOIL} = 2.5 \times 19 \times 0.455$

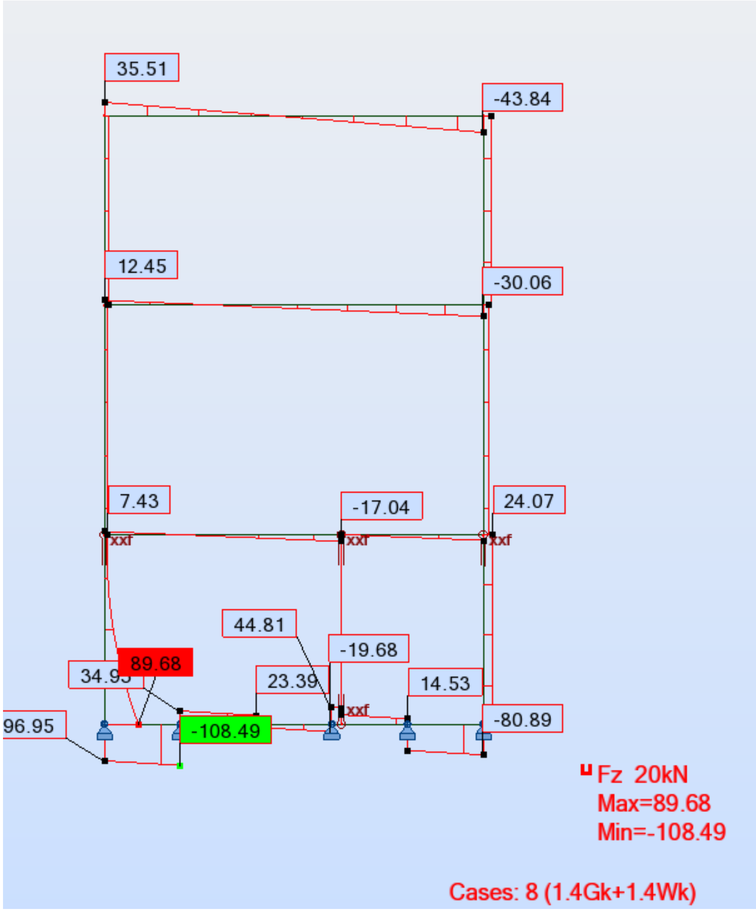
$= 21.6kN/m$

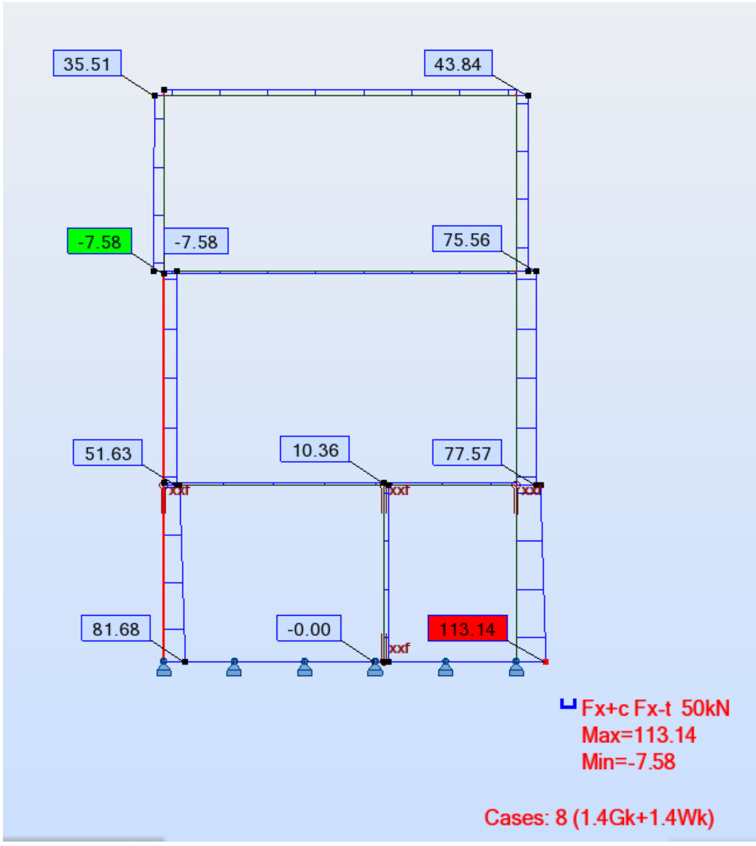
1000mm of retaining wall plus load of box frame above – 400x400mm RC COL

Icrack = 0.6






35.51
-43.84
12.45
-30.06
7.43
-17.04
24.07
xxf
44.81
-19.68
89.68
34.95
23.39
14.53
96.95
-108.49
-80.89
Fz 20kN
Max=89.68
Min=-108.49
Cases: 8 (1.4Gk+1.4Wk)


35.51
43.84
-7.58
-7.58
75.56
51.63
10.36
77.57
xxf
81.68
-0.00
113.14
Fx+c Fx-t 50kN
Max=113.14
Min=-7.58
Cases: 8 (1.4Gk+1.4Wk)

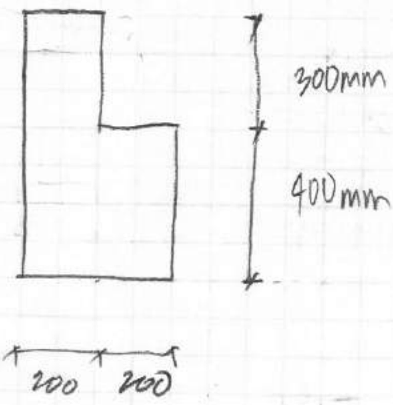
PRICE&MYERS
Consulting Engineers

Job No 24555 Page Ver

Date 15/04/16 Eng PJG Chd

Job CROFTDOWN ROAD, 17

CONCRETE WALLS & GROUND BEAM



M_{ULS} = 89kN/m
(1.4Gk + 1.4Wk)
(rom of retaining wall)

N^* = 113kN.
(1.4Gk + 1.4Wk.)

$K = 89 \times 10^6 / 40 \times 400 \times (400 - 30)^2$

$= 0.041$

$z = (400-30) \times (0.5 + (0.25 - 0.041/0.9))$

$= 368$ mm

$A_s = 89 \times 10^6 / (0.87 \times 500 \times 368)$

$= 555 mm^2$

→ 4No. B16 = 804mm² ✓OK

δ_{SLS} = 4mm = Height/700.

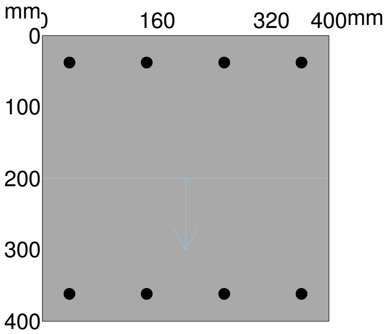
→ 400x400mm col
8No B16 vert.
4 legs of B10@200crs

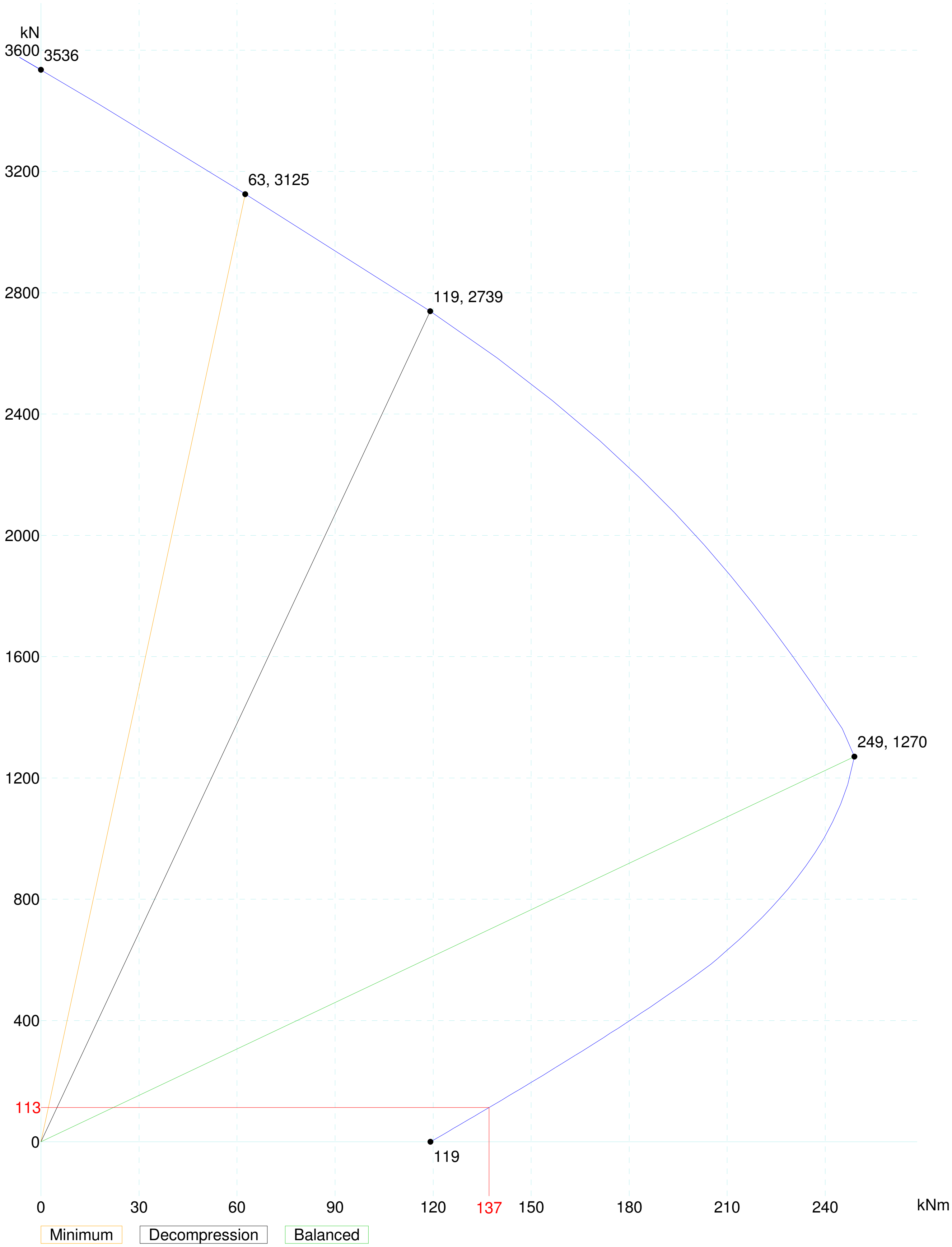
RAPT - Version: 6.3.15.0
Reinforced And Post-Tensioned Concrete Analysis & Design Package

Licensee
Price _Myers
30 Newman Street
London W1T 1LT
United Kingdom
56826220906URN4

General Interaction Diagram

Square 400mm
Reinforcement Bar, 8 T16
Reinforcement Ratio - 1.00%
United Kingdom - BS 8110
United Kingdom - United Kingdom Materials
Concrete Strength - 40MPa
Rotation 0.00 degrees clockwise. - Top Face in Compression





GROUND BEAM:

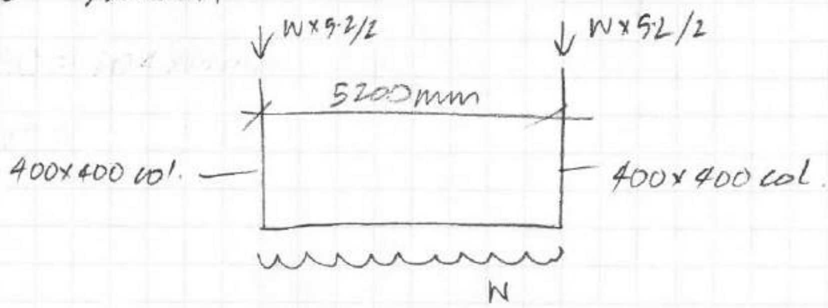
Original Spin Wall Load

DL = 9.7kN/m + 5.0kN/m + 5.0kN/m
= 19.7kN/m

LL = 9.8kN/m + 7.0kN/m + 5.0kN/m
= 21.8kN/m

W_{ULS} = 1.4DL + 1.6LL
= 55.0kN/m

L = 5200mm



→ 1000×300dp
8No B20 top
8No B16 bottom
6 legs of B10@ 200crs

RAPT - Version: 6.3.15.0
Reinforced And Post-Tensioned Concrete Analysis & Design Package

Licensee
Price _Myers
30 Newman Street
London W1T 1LT
United Kingdom
56826220906URN4

Input

General

Design Code	List	United Kingdom - BS 8110
Material	List	United Kingdom - United Kingdom Materials
Reinforcement Type	List	Reinforced
Member Type	List	Beam
Panel Type	List	Internal
Strip Type	List	One way - Nominal Width
Column Stiffness	List	Equivalent Column
Concrete - Spanning Members	List	40MPa
Concrete - Columns	List	40MPa
Top Reinforcement Cover	mm	40
Bottom Reinforcement Cover	mm	40
Top Reinforcement Axis Depth Limit	mm	30
Bottom Reinforcement Axis Depth Limit	mm	30
Concrete Unit Weight	kn/m3	25
Self Weight Definition	List	Program Calculated
Pattern Live Load	Y/N	
Earthquake Design	List	None
Moment Redistribution	%	0
Design Surface Levels	List	Extreme Surfaces

Span

Span	Span Length	Slab Depth	Panel Width Left	Panel Width Right
	mm	mm	mm	mm
LE	0			
1	5200	300	1000	1000
RE	0			

Columns

Column	Column Grid Reference	Support Type	Transverse Column spacing	Transverse v'c
	A	List	mm	MPa
1	1	Knife-Edge	1000	
2	2	Knife-Edge	1000	

Beams

Beam Number	Beam Depth	Beam Width at Slab	Beam Width	Effective Flange Width
	mm	mm	mm	mm
1	300	1000	1000	1000

Load Cases

Load Case	Load Type	Load Definition	Live Load Deflection Case	Description
	List	List	Y/N	A
1	Self Weight	Applied Loads		

Load Case	Load Type	Load Definition	Live Load Deflection Case	Description
	List	List	Y/N	A
2	Initial Dead Load	Applied Loads		
3	Live Load	Applied Loads	Y	

1. Self Weight - Line

Load	Left End Reference Column	Left end of load from reference column	Load at left end	Right End reference column	Right end of load from reference column	Load at right end	Description
	#	mm	kN/m	#	mm	kN/m	A
1	1	0	7.5	2	0	7.5	

2. Initial Dead Load - Panel

Load	Left End reference column	Left end of load from reference column	Load at left end	Right End reference column	Right end of load from reference column	Load at right end	Description
	#	mm	kN/m2	#	mm	kN/m2	A
1	1	0	20	2	0	20	

3. Live Load - Panel

Load	Left End reference column	Left end of load from reference column	Load at left end	Right End reference column	Right end of load from reference column	Load at right end	Live Load reduction	Description
	#	mm	kN/m2	#	mm	kN/m2	#.#	A
1	1	0	22	2	0	22	1	

Load Combinations : Ultimate

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Live Load	1.4	1.4	1.6
2	Live Load	1	1	1.6
3	Dead Load	1.5	1.5	0

Load Combinations : Short Term Service

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Live Load	1	1	1

Load Combinations : Permanent Service

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Live Load	1	1	0.25

Load Combinations : Deflection

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Short Term - Deflection	1	1	1
2	Permanent - Deflection	1	1	0.25
3	Initial - Deflection	1	1	0

Load Combinations : Transfer Prestress

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Transfer	1	0	0

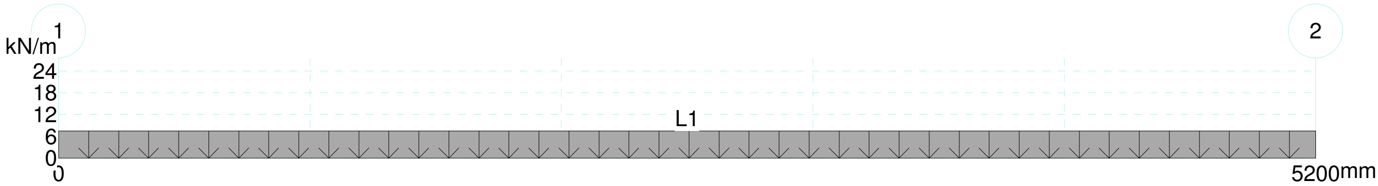
Load Combinations : Pre Existing

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Pre Existing	1	0	0

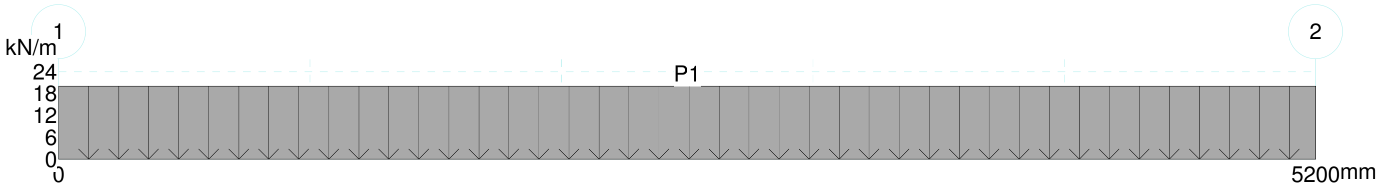
Load Combinations : Construction

Load Combination	Description	1. Self Weight	2. Initial Dead Load	3. Live Load
	A	#.#	#.#	#.#
1	Construction	1	0	0

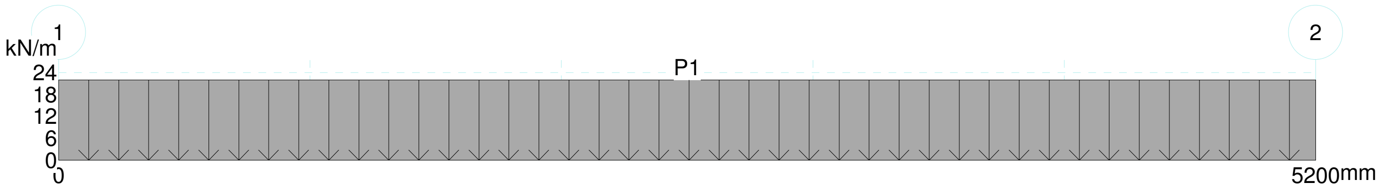
Load Case 1 : 1. Self Weight



Load Case 2 : 2. Initial Dead Load



Load Case 3 : 3. Live Load



Reinforcement

Reinforcement Use	Reinforcement Type	Preferred Bar Size	Number of Legs
	List	List	#
Flexural Bar	T 460MPa		
Flexural Mesh	A 460MPa		
Shear Option 1	T 460MPa	12	4
Shear Option 2	T 460MPa	12	6
Shear Option 3	T 460MPa	12	2
Punching Shear	T 460MPa	10	2

Reinforcement

	Maximum Bar Spacing	Minimum Bar Spacing	Minimum Continuous Reinforcement	Minimum Span Reinforcement into End Support	Minimum Span Reinforcement into Internal Support	Infill Bars	Stagger Bars
	mm	mm	#.#	#.#	#.#	Y/N	Y/N
Support Reinforcement	300	60	0			N	N
Span Reinforcement	300	60		0	0	N	N

Design Zones : Top

Layer Number	Steel type	Left End Reference Column	Distance to left end of bar	Bar stagger length at left end	Top Cover at left end	Right End Reference Column	Distance to right end of bar	Bar stagger length at right end	Top Cover at Right end	Maximum Bar Size	Minimum Bar Size	Preferred bar size
	List	#	mm	mm	mm	#	mm	mm	mm	List	List	List
1	Bar	1	0	0	40	2	0	0	40	16	12	12

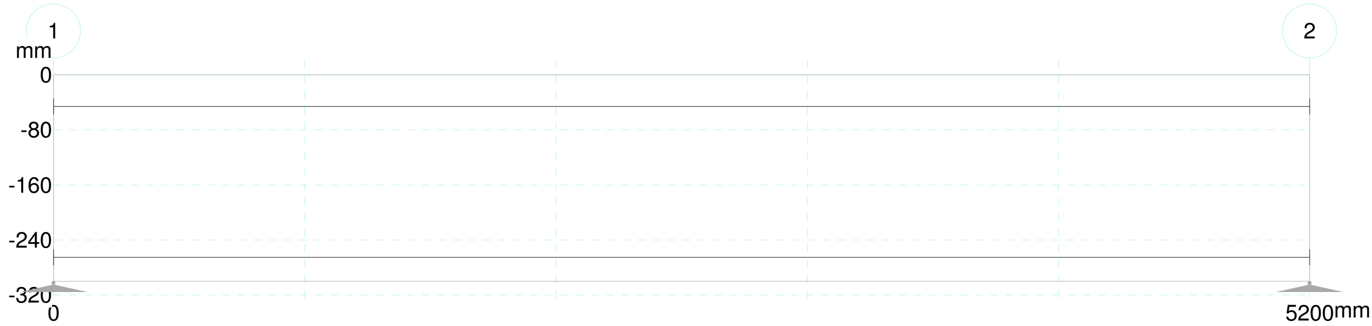
Layer Number	Minimum Number of Bars	Maximum Spacing of Bars	Minimum Steel area as %	Minimum Reinforcement placed at	% in Flange
	#	mm	%	List	%
1	4	0	0	All Points	0

Design Zones : Bottom

Layer Number	Steel type	Left End Reference Column	Distance to left end of bar	Bar stagger length at left end	Bottom Cover at left end	Right End Reference Column	Distance to right end of bar	Bar stagger length at right end	Bottom Cover at Right End	Maximum Bar Size	Minimum Bar Size	Preferred bar size
	List	#	mm	mm	mm	#	mm	mm	mm	List	List	List
1	Bar	1	0	0	25	2	0	0	25	25	16	20

Layer Number	Minimum Number of Bars	Maximum Spacing of Bars	Minimum Steel area as %	Minimum Reinforcement placed at	% in Flange
	#	mm	%	List	%
1	4	0	0	All Points	0

Reinforcement Design Zones



Design Data

Capacity Reduction factor (phi) for Flexure	#.#	1
Capacity Reduction factor (phi) for Shear	#.#	1
Material Factor for Concrete in Flexure	#.#	1.5
Material Factor for Concrete in Shear	#.#	1.25
Material Factor for Reinforcement	#.#	1.05
Maximum Ratio of Neutral Axis Depth for Ductility	#.#	0.5
Ductility Limit - Strain	#.#	0
Ductility Check at Left End Column	Y/N	Y
Ductility Check at Right End Column	Y/N	Y
Minimum Reinforcement Strength Limit - #.## x M*	#.#	0
Flexural Critical Section - Consider Transverse Beams	Y/N	Y
Flexural Critical Section - Distance from centre of Support	#.#	-1
Beam Left Sideface Cover (Internal)	mm	25
Beam Right Sideface cover	mm	40
Prestress Minimum Reinforcement Basis	List	Program Default
Shear Enhancement at Supports	Y/N	Y
Ast Value in Shear Calculations	List	Calculated
Maximum Shear Stress for BS8110	MPa	0
Limit Reinforcement Strain	Y/N	N
Beam Shear Critical Section Location	List	Code Critical Section

Maximum Service Stress Change - Prestressed Sections	MPa	200
Maximum Service Stress Change - Reinforced Sections	MPa	0
Relative Humidity	%	50
Average Temperature	C.	20
Prestress Losses Calculations based on	List	Program Default
Crack Width Calculations	List	Code default
AS3600 Shrinkage and Temperature Reinforcement	List	Moderate
Degree of Restraint in Primary Direction	%	0
Degree of Restraint in Secondary Direction	%	0
Concrete Strength Gain Rate	List	N

Concrete Tensile Strength for Deflection Calculations- #.## x (Fc)n	#.#	-1
Maximum Value of Ieff/Igross for Deflection Calculations	#.#	0.6
Total Deflection Warning Limit - Maximum Span/Deflection	#.#	250
Total Deflection Warning Limit - Maximum Deflection	mm	20
Incremental Deflection Warning Limit - Maximum Span/Deflection	#.#	350
Incremental Deflection Warning Limit - Maximum Deflection	mm	20
Time of Loading in days	#.#	10
Age Adjustment Factor	#.#	0.76
Concrete Strength at Time of Loading	MPa	33.8
Loaded Period in years	#.#	30
Tension stiffening Approach	List	Modified Concrete Tensile Modulus Method

Live Load Pattern Factor	#.#
Pattern Live Load for Ultimate Strength	Y/N
Pattern Live Load for Crack Control	Y/N
Pattern Live Load For Deflections	Y/N
Pattern Live Load for Deflection Permanent Load Combination	Y/N

Material Properties

Concrete

Description	40MPa
Characteristic Compressive Strength	40
Mean Compressive Strength	46.53
Lower Characteristic Tensile Strength	3.16
Upper Characteristic Tensile Strength	5.69
Concrete Density	2447
Design Concrete Modulus	28000
Mean Concrete Modulus	29305
Basic Shrinkage Strain	0
Shrinkage Multiplier	1
Basic Creep Factor	0
Concrete Strain at Peak Stress	0.002
Squash Load Factor	0.85
Concrete Strain Limit	0.004

Reinforcement Bar

Designation	Type	Yield Stress	Elastic Modulus	Ductility	Peak Strain	Peak Stress	Design Strain Limit	Material Factor Flexure	Material Factor Shear	Material Capacity Reduction Factor - Flexure	Material Capacity Reduction Factor - Shear	Include as Flexural Reinforcement for Shear
T	Deformed	460	2e5	N	0.05	496.8	90	-1	-1	-1	-1	Y

Description

Nominal Bar Size	Bar Diameter	Bar Area	Bar Inertia	Bar Weight	Stock Length
A	mm	mm2	mm4	kg/m	mm
8	8	50.3	201.14	0.4	12000
10	10	78.5	491.07	0.62	12000
12	12	113	1018.29	0.89	12000
16	16	201	3218.29	1.58	12000
20	20	314	7857.14	2.47	12000
25	25	491	19182.5	3.85	12000
32	32	804	51492.6	6.31	12000
40	40	1260	1.257e5	9.86	12000

Elevation view

Plan view

Warnings

Input

No errors or warnings were found.

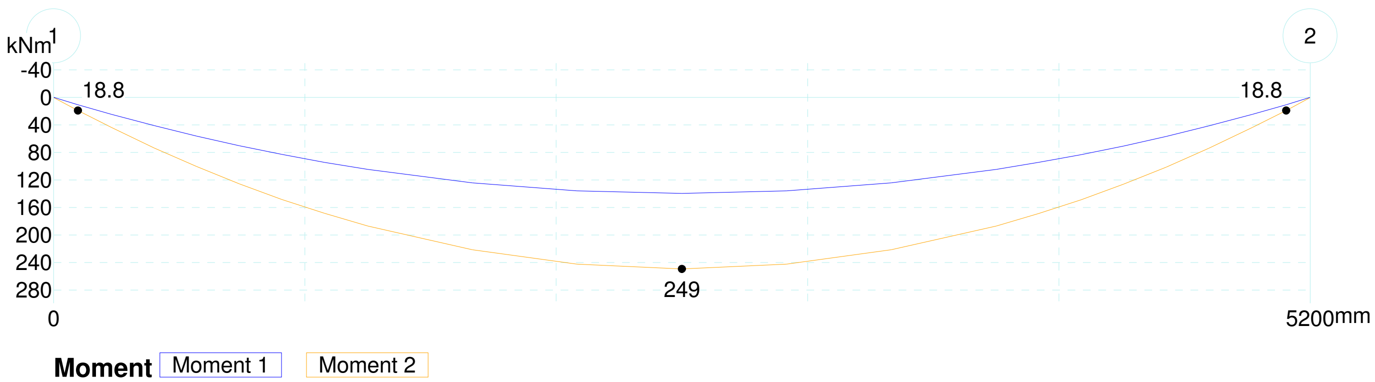
Output

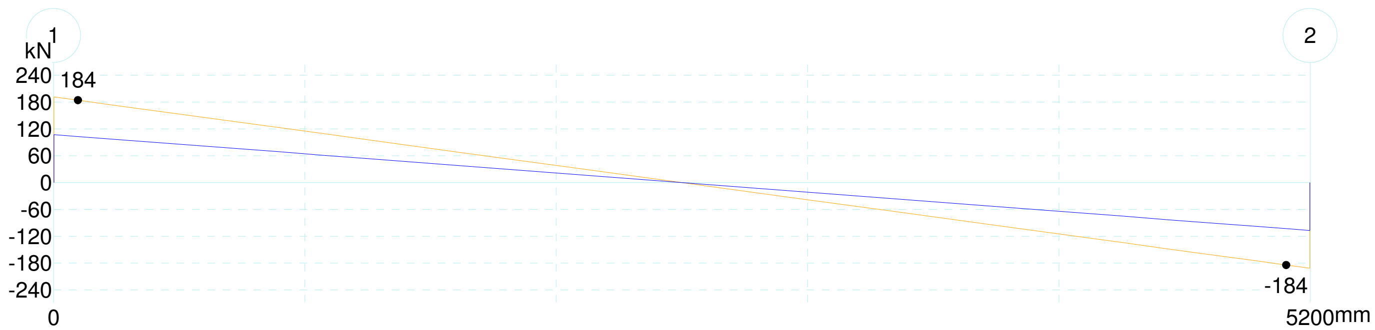
Warning:At 416mm, the moment curvature calculations did not converge on the design moment within our set limits after 100 iterations. We have adopted the nearest solution. This normally only occurs at points of very low moment and is not normally a problem so we have continued with the design.
Warning:Incremental Deflection span/deflection ratio in at least one span is less than defined limit.
Warning:Total Deflection span/deflection ratio in at least one span is less than defined limit.
Warning:Incremental deflection in at least one span is greater than defined limit.
Warning:Total deflection in at least one span is greater than defined limit.

Bending Moments

Load Combinations

Ultimate Flexure





Flexural Design

Reinforcement

Span 1

	Top Design (1)		Bott Design (1)	
Locat	Area	Depth	Area	Depth
mm	mm2	mm	mm2	mm
100	452	46	1256	265
240	452	46	1256	265
416	452	46	1256	265
592	452	46	1256	265
768	452	46	1256	265
944	452	46	1365.78	265
1120	452	46	1569.18	265
1300	452	46	1757.45	265
1733	452	46	2121.02	265
2166	452	46	2346.33	265
2600	452	46	2422.91	265
3033	452	46	2346.68	265
3466	452	46	2121.7	265
3900	452	46	1757.45	265
4076	452	46	1573.59	265
4252	452	46	1370.6	265
4428	452	46	1256	265
4604	452	46	1256	265
4780	452	46	1256	265
4960	452	46	1256	265
5100	452	46	1256	265

Ultimate

Span 1

		Design Moment		Initial Condition		Final Design Condition				Reinforcement	
Locat	Min Width	M*	Mmin	Phi Mu	ku	Phi Mu	ku	dtens	Max Strain Ratio	Top	Bottom
mm	mm	kNm	kNm	kNm	mm/mm	kNm	mm/mm	mm	#.#	mm2	mm2
100	1000	18.79	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
240	1000	43.87	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
416	1000	73.34	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
592	1000	100.52	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
768	1000	125.43	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
944	1000	148.05	56.92	0	0	148.74	0.166	255.7	0.367	452	1365.78
1120	1000	168.39	56.92	0	0	168.75	0.1756	265	0.3286	452	1569.18
1300	1000	186.83	56.92	0	0	187.15	0.1909	265	0.2967	452	1757.45
1733	1000	221.41	56.92	0	0	222.06	0.2221	265	0.2451	452	2121.02
2166	1000	242.17	56.92	0	0	243.24	0.2425	265	0.2187	452	2346.33
2600	1000	249.11	56.92	0	0	250.35	0.2496	265	0.2105	452	2422.91
3033	1000	242.2	56.92	0	0	243.27	0.2425	265	0.2186	452	2346.68
3466	1000	221.47	56.92	0	0	222.12	0.2222	265	0.245	452	2121.7
3900	1000	186.83	56.92	0	0	187.15	0.1909	265	0.2967	452	1757.45
4076	1000	168.83	56.92	0	0	169.18	0.176	265	0.3278	452	1573.59
4252	1000	148.54	56.92	0	0	149.21	0.1662	256	0.3661	452	1370.6
4428	1000	125.97	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
4604	1000	101.12	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
4780	1000	73.98	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
4960	1000	43.87	56.92	0	0	137.79	0.1625	249	0.3886	452	1256
5100	1000	18.79	56.92	0	0	137.79	0.1625	249	0.3886	452	1256

Service

Span 1

	Design Moment		Gross Concrete Stress				Cracked Sect Results							
Locat	Mser	Msmod	P/A	Top	Bottom	Igross Transform	Comp Stress	Kdser	Tension Stress Change	Extra Tension Reinforcement	Maximum Spacing	Maximum Bar Size	Cracked Inertia	Concrete Compression Face Strain
mm	kNm	kNm	MPa	MPa	MPa	mm4	MPa	mm	MPa	mm2	mm	mm	mm4	mm/mm
100	12.62	12.62	0	0.81	-0.78	2.38e9	0.72	149.2	40.83	0	300	0	4.61e8	0
240	29.46	29.46	0	1.88	-1.83	2.38e9	1.67	149.2	95.5	0	300	0	4.59e8	0.0001
416	49.26	49.26	0	3.14	-3.06	2.38e9	3.62	110.6	158.38	0	300	0	4.61e8	0.0003
592	67.52	67.52	0	4.31	-4.2	2.38e9	5.58	93.6	219.55	0	300	0	4.55e8	0.0004
768	84.24	84.24	0	5.38	-5.24	2.38e9	7.35	85.7	274.32	0	300	0	4.54e8	0.0005

	Design Moment		Gross Concrete Stress				Cracked Sect Results							
Locat	Mser	Msmod	P/A	Top	Bottom	Igross Transform	Comp Stress	Kdser	Tension Stress Change	Extra Tension Reinforcement	Maximum Spacing	Maximum Bar Size	Cracked Inertia	Concrete Compression Face Strain
mm	kNm	kNm	MPa	MPa	MPa	mm4	MPa	mm	MPa	mm2	mm	mm	mm4	mm/mm
944	99.44	99.44	0	6.33	-6.15	2.39e9	8.58	85.5	296.75	0	249.2	0	4.89e8	0.0006
1120	113.1	113.1	0	7.18	-6.93	2.41e9	9.32	89.3	295.92	0	236.3	0	5.47e8	0.0007
1300	125.48	125.48	0	7.93	-7.62	2.42e9	9.96	92.7	294.54	0	229.9	0	6e8	0.0007
1733	148.71	148.71	0	9.34	-8.88	2.45e9	11.08	98.9	291.23	0	225.2	0	6.97e8	0.0008
2166	162.65	162.65	0	10.18	-9.61	2.47e9	11.72	102.5	289.53	0	225.2	0	7.54e8	0.0009
2600	167.31	167.31	0	10.46	-9.85	2.47e9	11.92	103.7	288.93	0	225.6	0	7.73e8	0.0009
3033	162.67	162.67	0	10.18	-9.61	2.47e9	11.72	102.5	289.53	0	225.2	0	7.54e8	0.0009
3466	148.75	148.75	0	9.35	-8.88	2.45e9	11.08	98.9	291.22	0	225.2	0	6.98e8	0.0008
3900	125.48	125.48	0	7.93	-7.62	2.42e9	9.96	92.7	294.54	0	229.9	0	6e8	0.0007
4076	113.39	113.39	0	7.19	-6.95	2.41e9	9.34	89.3	295.91	0	236.2	0	5.48e8	0.0007
4252	99.76	99.76	0	6.35	-6.17	2.39e9	8.6	85.6	296.73	0	248.8	0	4.91e8	0.0006
4428	84.61	84.61	0	5.4	-5.26	2.38e9	7.39	85.6	275.51	0	300	0	4.54e8	0.0005
4604	67.91	67.91	0	4.33	-4.22	2.38e9	5.62	93.4	220.85	0	300	0	4.55e8	0.0004
4780	49.69	49.69	0	3.17	-3.09	2.38e9	3.67	110	159.96	0	300	0	4.61e8	0.0003
4960	29.46	29.46	0	1.88	-1.83	2.38e9	1.67	149.2	95.5	0	300	0	4.59e8	0.0001
5100	12.62	12.62	0	0.81	-0.78	2.38e9	0.72	149.2	40.83	0	300	0	4.61e8	0

Concrete Tension Face Strain
mm/mm
0
-0.0001
-0.0004
-0.0009
-0.0013
-0.0016
-0.0016
-0.0017
-0.0017
-0.0017
-0.0017
-0.0017
-0.0017
-0.0017
-0.0016
-0.0016
-0.0013
-0.0009
-0.0004
-0.0001
0

Permanent

Span 1

	Design Moment		Gross Concrete Stress				Cracked Sect Results							
Locat	Mser	Msmod	P/A	Top	Bottom	Igross Transform	Comp Stress	Kdser	Tension Stress Change	Extra Tension Reinforcement	Maximum Spacing	Maximum Bar Size	Cracked Inertia	Concrete Compression Face Strain
mm	kNm	kNm	MPa	MPa	MPa	mm4	MPa	mm	MPa	mm2	mm	mm	mm4	mm/mm
100	8.41	8.41	0	0.54	-0.52	2.38e9	0.54	151.9	2.85	0	300	0	4.61e8	0
240	19.64	19.64	0	1.25	-1.22	2.38e9	2.49	56.6	63.66	0	300	0	4.59e8	0
416	32.84	32.84	0	2.1	-2.04	2.38e9	4.12	57	105.82	0	300	0	4.61e8	0.0001
592	45.01	45.01	0	2.87	-2.8	2.38e9	5.66	57.3	146.17	0	300	0	4.55e8	0.0002
768	56.16	56.16	0	3.58	-3.49	2.38e9	7.02	57.5	182.54	0	300	0	4.54e8	0.0003
944	66.29	66.29	0	4.22	-4.1	2.39e9	7.92	59.8	197.59	0	249.2	0	4.89e8	0.0003
1120	75.4	75.4	0	4.78	-4.62	2.41e9	8.51	63.6	196.99	0	236.3	0	5.47e8	0.0003
1300	83.65	83.65	0	5.29	-5.08	2.42e9	9.01	66.8	196.26	0	229.9	0	6e8	0.0003
1733	99.14	99.14	0	6.23	-5.92	2.45e9	9.89	72.5	194.57	0	225.2	0	6.97e8	0.0004
2166	108.43	108.43	0	6.79	-6.41	2.47e9	10.4	75.8	193.42	0	225.2	0	7.54e8	0.0004
2600	111.54	111.54	0	6.97	-6.57	2.47e9	10.56	76.8	193.01	0	225.6	0	7.73e8	0.0004
3033	108.45	108.45	0	6.79	-6.41	2.47e9	10.4	75.8	193.42	0	225.2	0	7.54e8	0.0004
3466	99.17	99.17	0	6.23	-5.92	2.45e9	9.9	72.6	194.57	0	225.2	0	6.98e8	0.0004
3900	83.65	83.65	0	5.29	-5.08	2.42e9	9.01	66.8	196.26	0	229.9	0	6e8	0.0003
4076	75.59	75.59	0	4.8	-4.63	2.41e9	8.52	63.7	196.98	0	236.2	0	5.48e8	0.0003

	Design Moment		Gross Concrete Stress				Cracked Sect Results							
Locat	Mser	Msmod	P/A	Top	Bottom	Igross Transform	Comp Stress	Kdser	Tension Stress Change	Extra Tension Reinforcement	Maximum Spacing	Maximum Bar Size	Cracked Inertia	Concrete Compression Face Strain
mm	kNm	kNm	MPa	MPa	MPa	mm4	MPa	mm	MPa	mm2	mm	mm	mm4	mm/mm
4252	66.51	66.51	0	4.23	-4.11	2.39e9	7.94	59.9	197.58	0	248.8	0	4.91e8	0.0003
4428	56.4	56.4	0	3.6	-3.51	2.38e9	7.05	57.5	183.33	0	300	0	4.54e8	0.0003
4604	45.28	45.28	0	2.89	-2.82	2.38e9	5.69	57.3	147.04	0	300	0	4.55e8	0.0002
4780	33.13	33.13	0	2.11	-2.06	2.38e9	4.16	57	106.74	0	300	0	4.61e8	0.0001
4960	19.64	19.64	0	1.25	-1.22	2.38e9	2.49	56.6	63.66	0	300	0	4.59e8	0
5100	8.41	8.41	0	0.54	-0.52	2.38e9	0.54	151.9	2.85	0	300	0	4.61e8	0

Concrete Tension Face Strain
mm/mm
0
-0.0004
-0.0006
-0.0009
-0.0011
-0.0012
-0.0012
-0.0012
-0.0011
-0.0011
-0.0011
-0.0011
-0.0011
-0.0012
-0.0012
-0.0012
-0.0011
-0.0009
-0.0006
-0.0004
0

Shear Design
Beam
Span 1

Locat	V*	Mv*	Mdec	d	Ast	bv	phi Vuc	phi Vut	phi Vu	Phi Vumax	Asv/s	Spacing of Sets		
												4 legs T12	6 legs T12	2 legs T12
mm	kN	kNm	kNm	mm	mm2	mm	kN	kN	kN	kN	mm2/mm	mm	mm	mm
100	184.25	18.79	0	265	1256	1000	897.22	99999	897.22	1325	0.91	198.8	198.8	198.8
240	173.93	43.87	0	265	1256	1000	373.84	99999	373.84	1325	0.91	198.8	198.8	198.8
416	160.96	73.34	0	265	1256	1000	215.68	99999	215.68	1325	0.91	198.8	198.8	198.8
592	147.99	100.52	0	265	1256	1000	169.29	99999	169.29	1325	0.91	198.8	198.8	198.8
768	136.45	119.09	0	265	1256	1000	169.29	99999	169.29	1325	0.91	198.8	198.8	198.8
944	123.48	141.96	0	265	1365.78	1000	174.08	99999	174.08	1325	0.91	198.8	198.8	198.8
1120	110.51	162.56	0	265	1569.18	1000	182.33	99999	182.33	1325	0.91	198.8	198.8	198.8
1300	101.53	164.52	0	265	1757.45	1000	189.34	99999	189.34	1325	0.91	198.8	198.8	198.8
1733	69.62	201.58	0	265	2121.02	1000	201.59	99999	201.59	1325	0.91	198.8	198.8	198.8
2166	44.86	203.12	0	265	2346.33	1000	208.49	99999	208.49	1325	0.91	198.8	198.8	198.8
2600	22.88	189.62	0	265	2422.91	1000	210.73	99999	210.73	1325	0.91	198.8	198.8	198.8
3033	-44.78	203.16	0	265	2346.68	1000	208.5	99999	208.5	1325	0.91	198.8	198.8	198.8
3466	-69.54	201.64	0	265	2121.7	1000	201.61	99999	201.61	1325	0.91	198.8	198.8	198.8
3900	-101.53	164.52	0	265	1757.45	1000	189.34	99999	189.34	1325	0.91	198.8	198.8	198.8
4076	-110.21	163	0	265	1573.59	1000	182.5	99999	182.5	1325	0.91	198.8	198.8	198.8
4252	-123.18	142.46	0	265	1370.6	1000	174.29	99999	174.29	1325	0.91	198.8	198.8	198.8
4428	-136.15	119.64	0	265	1256	1000	169.29	99999	169.29	1325	0.91	198.8	198.8	198.8
4604	-147.69	101.12	0	265	1256	1000	169.29	99999	169.29	1325	0.91	198.8	198.8	198.8
4780	-160.67	73.98	0	265	1256	1000	213.62	99999	213.62	1325	0.91	198.8	198.8	198.8
4960	-173.93	43.87	0	265	1256	1000	373.84	99999	373.84	1325	0.91	198.8	198.8	198.8
5100	-184.25	18.79	0	265	1256	1000	897.22	99999	897.22	1325	0.91	198.8	198.8	198.8

Minimum Legs	Shear Comments
#	A
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel
5	Minimum Steel

Detailed Reinforcement

Span 1

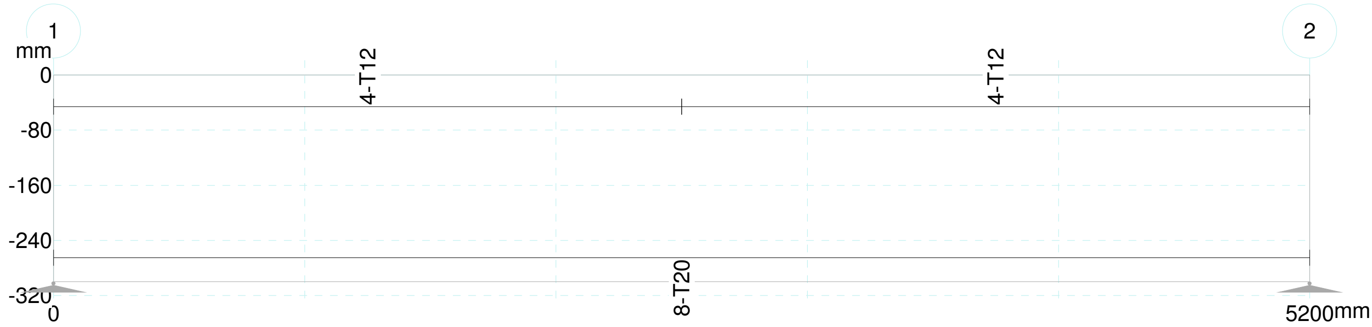
	Top Reinforcement					Bottom Reinforcement				
Locat	Max Space	Area	Depth	Section Width	Rebar Reqd	Max Space	Area	Depth	Section Width	Rebar Reqd
mm	mm	mm2	mm	mm	A	mm	mm2	mm	mm	A
100	0	452	46	1000	4 T12 @ 299.7	300	1256	265	1000	4 T20 @ 297
240	0	452	46	1000	4 T12 @ 299.7	300	1256	265	1000	4 T20 @ 297
416	0	452	46	1000	4 T12 @ 299.7	300	1256	265	1000	4 T20 @ 297
592	0	452	46	1000	4 T12 @ 299.7	300	1265.55	265	1000	5 T20 @ 222.8
768	0	452	46	1000	4 T12 @ 299.7	300	1423.53	265	1000	5 T20 @ 222.8
944	0	452	46	1000	4 T12 @ 299.7	249.2	1635.26	265	1000	6 T20 @ 178.2
1120	0	452	46	1000	4 T12 @ 299.7	236.3	1854.31	265	1000	6 T20 @ 178.2
1300	0	452	46	1000	4 T12 @ 299.7	229.9	2004.11	265	1000	7 T20 @ 148.5
1733	0	452	46	1000	4 T12 @ 299.7	225.2	2268.06	265	1000	8 T20 @ 127.3
2166	0	452	46	1000	4 T12 @ 299.7	225.2	2387.76	265	1000	8 T20 @ 127.3
2600	0	452	46	1000	4 T12 @ 299.7	225.6	2422.91	265	1000	8 T20 @ 127.3
3033	0	452	46	1000	4 T12 @ 299.7	225.2	2387.99	265	1000	8 T20 @ 127.3
3466	0	452	46	1000	4 T12 @ 299.7	225.2	2268.5	265	1000	8 T20 @ 127.3
3900	0	452	46	1000	4 T12 @ 299.7	229.9	2004	265	1000	7 T20 @ 148.5
4076	0	452	46	1000	4 T12 @ 299.7	236.2	1857.59	265	1000	6 T20 @ 178.2
4252	0	452	46	1000	4 T12 @ 299.7	248.8	1641.31	265	1000	6 T20 @ 178.2
4428	0	452	46	1000	4 T12 @ 299.7	300	1427.59	265	1000	5 T20 @ 222.8
4604	0	452	46	1000	4 T12 @ 299.7	300	1269.36	265	1000	5 T20 @ 222.8
4780	0	452	46	1000	4 T12 @ 299.7	300	1256	265	1000	4 T20 @ 297
4960	0	452	46	1000	4 T12 @ 299.7	300	1256	265	1000	4 T20 @ 297
5100	0	452	46	1000	4 T12 @ 299.7	300	1256	265	1000	4 T20 @ 297

Shear Reinforcement				
	Spacing of Sets			
Area	4 legs T12	6 legs T12	2 legs T12	Shear Comments
mm2/mm	mm	mm	mm	A
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel

Shear Reinforcement				
	Spacing of Sets			
Area	4 legs T12	6 legs T12	2 legs T12	Shear Comments
mm2/mm	mm	mm	mm	A
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel
0.91	198.8	198.8	198.8	Minimum Steel

Design Comments:-
- Span - 1 - Reinforcement added at left span contraflexure point for Offset of Bending Moment Diagram for Shear - 313.96mm2
- Span - 1 - Reinforcement added at right span contraflexure point for Offset of Bending Moment Diagram for Shear - 313.96mm2

Reinforcement Layout



STEEL MEMBER DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.04

Section details

Section type — **SHS 100x100x5.0 (Corus Celsius)**

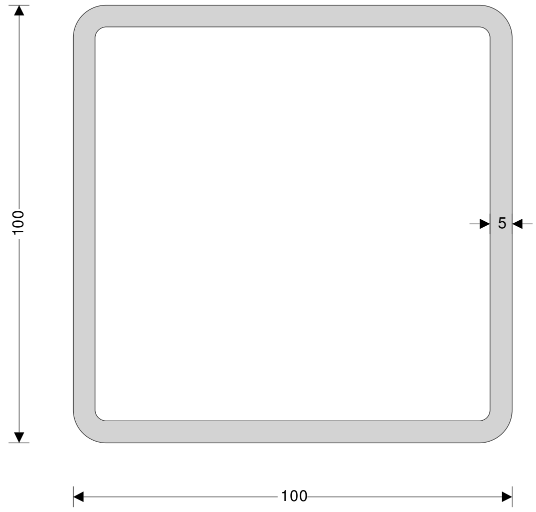
Steel grade — **S275**

From table 9: Design strength p_y

Thickness of element — t = **5.0** mm

Design strength — p_y = **275** N/mm²

Modulus of elasticity — E = **205000** N/mm²



Lateral restraint

Distance between major axis restraints — L_x = **3000** mm

Distance between minor axis restraints — L_y = **3000** mm

Effective length factors

Effective length factor in major axis — K_x = **1.00**

Effective length factor in minor axis — K_y = **1.00**

Effective length factor for lateral-torsional buckling — K_{LT} = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]}$ = **1.00**

Web - major axis - Table 12

Depth of section — d= D - 3 × t = **85** mm

Stress ratios — r1 = min(F_c / (2 × d × t × p_{yw}), 1) = **0.385**

r2 = F_c / (A × p_{yw}) = **0.175**

d / t = 17.0 × ε <= max(64 × ε / (1 + r1), 40 × ε) — Class 1 plastic

Flange - major axis - Table 12

Width of section — b = B - 3 × t = **85** mm

b / t = 17.0 × ε <= 40 × ε — Class 3 semi-compact

Section is class 3 semi-compact

Shear capacity - Section 4.2.3

Design shear force $F_{y,v}$ = **20** kN

$(D - 3 \times t) / t < 70 \times \varepsilon$

Web does not need to be checked for shear buckling

Shear area $A_v = A \times D / (D + B)$ = **937** mm^2

Design shear resistance $P_{y,v} = 0.6 \times p_y \times A_v$ = **154.5** kN

PASS - Design shear resistance exceeds design shear force

Shear capacity - Section 4.2.3

Design shear force $F_{x,v}$ = **20** kN

Shear area $A_v = A_x$ = **937** mm^2

Design shear resistance $P_{x,v} = 0.6 \times p_y \times A_v$ = **154.5** kN

PASS - Design shear resistance exceeds design shear force

Moment capacity - Section 4.2.5

Design bending moment M = **10** kNm

Effective plastic modulus - Section 3.5.6

Limiting value for class 2 compact flange $\beta_{2f} = \min(32 \times \varepsilon, 62 \times \varepsilon - 0.5 \times d / t)$ = **32**

Limiting value for class 3 semi-compact flange $\beta_{3f} = 40 \times \varepsilon$ = **40**

Limiting value for class 2 compact web $\beta_{2w} = \max(80 \times \varepsilon / (1 + r1), 40 \times \varepsilon)$ = **57.761**

Limiting value for class 3 semi-compact web $\beta_{3w} = \max(120 \times \varepsilon / (1 + 2 \times r2), 40 \times \varepsilon)$ = **88.926**

Effective plastic modulus - cl.3.5.6.3

$S_{eff} = \min(Z + (S - Z) \times \min([(\beta_{3w} / (d / t) - 1) / (\beta_{3w} / \beta_{2w} - 1)], [(\beta_{3f} / (b / t) - 1) / (\beta_{3f} / \beta_{2f} - 1)]), S)$ = **66358** mm^3

Moment capacity low shear - cl.4.2.5.2 $M_c = \min(p_y \times S_{eff}, 1.2 \times p_y \times Z)$ = **18.2** kNm

Effective length for lateral-torsional buckling - Section 4.3.5

Effective length for lateral torsional buckling $L_E = 1.0 \times L_y$ = **3000** mm

Slenderness ratio $\lambda = L_E / r_{yy}$ = **77.673**

Equivalent slenderness - Annex B.2.6.1

Torsion constant J = **4394108** mm^4

$\gamma_b = (1 - I_{yy} / I_{xx}) \times (1 - J / (2.6 \times I_{xx}))$ = **0.000**

$\phi_b = [S_{xx}^2 \times \gamma_b / (A \times J)]^{0.5}$ = **0.000**

Ratio - cl.4.3.6.9 $\beta W = S_{eff} / S_{xx}$ = **1.000**

Equivalent slenderness $\lambda_{LT} = 2.25 \times \sqrt{[\phi_b \times \lambda \times \beta W]}$ = **0.000**

Limiting slenderness - Annex B.2.2 $\lambda_{L0} = 0.4 \times (\pi^2 \times E / p_y)^{0.5}$ = **34.310**

$\lambda_{LT} < \lambda_{L0}$ - No allowance need be made for lateral-torsional buckling

Buckling resistance moment - Section 4.3.6.4

Bending strength $p_b = p_y$ = **275** N/mm^2

Buckling resistance moment $M_b = p_b \times S_{eff}$ = **18.2** kNm

PASS - Moment capacity exceeds design bending moment

Compression members - Section 4.7

Design compression force F_c = **90** kN

Effective length for major (x-x) axis buckling - Section 4.7.3

Effective length for buckling $L_{Ex} = L_x \times K_x$ = **3000** mm

Slenderness ratio - cl.4.7.2 $\lambda_x = L_{Ex} / r_{xx}$ = **77.673**

Compressive strength - Section 4.7.5

Limiting slenderness $\lambda_0 = 0.2 \times (\pi^2 \times E / p_y)^{0.5}$ = **17.155**

Strut curve - Table 23 a

Robertson constant α_x = **2.0**

Perry factor $\eta_x = \alpha_x \times (\lambda_x - \lambda_0) / 1000$ = **0.121**

Euler stress $p_{Ex} = \pi^2 \times E / \lambda_x^2$ = **335.4** N/mm^2

$\phi_x = (p_y + (\eta_x + 1) \times p_{Ex}) / 2$ = **325.5** N/mm^2

Compressive strength - Annex C.1 $p_{cx} = p_{Ex} \times p_y / (\phi_x + (\phi_x^2 - p_{Ex} \times p_y)^{0.5})$ = **208.4** N/mm^2

Compression resistance - Section 4.7.4

Compression resistance - cl.4.7.4 $P_{cx} = A \times p_{cx}$ = **390.3** kN

PASS - Compression resistance exceeds design compression force

Effective length for minor (y-y) axis buckling - Section 4.7.3

Effective length for buckling $L_{Ey} = L_y \times K_y$ = **3000** mm

Slenderness ratio - cl.4.7.2 $\lambda_y = L_{Ey} / r_{yy}$ = **77.673**

Compressive strength - Section 4.7.5

Limiting slenderness $\lambda_0 = 0.2 \times (\pi^2 \times E / p_y)^{0.5}$ = **17.155**

Strut curve - Table 23 a

Robertson constant α_y = **2.0**

Perry factor $\eta_y = \alpha_y \times (\lambda_y - \lambda_0) / 1000$ = **0.121**

Euler stress $p_{Ey} = \pi^2 \times E / \lambda_y^2$ = **335.4** N/mm^2

$\phi_y = (p_y + (\eta_y + 1) \times p_{Ey}) / 2$ = **325.5** N/mm^2

Compressive strength - Annex C.1 $p_{cy} = p_{Ey} \times p_y / (\phi_y + (\phi_y^2 - p_{Ey} \times p_y)^{0.5})$ = **208.4** N/mm^2

Compression resistance - Section 4.7.4

Compression resistance - cl.4.7.4 $P_{cy} = A \times p_{cy}$ = **390.3** kN

PASS - Compression resistance exceeds design compression force

Compression members with moments - Section 4.8.3

Comb.compression & bending check - cl.4.8.3.2 $F_c / (A \times p_y) + M / M_c$ = **0.723**

PASS - Combined bending and compression check is satisfied

Member buckling resistance - Section 4.8.3.3

Max major axis moment governing M_b $M_{LT} = M_x$ = **10.00** kNm

Equivalent uniform moment factor for major axis flexural buckling

m_x = **1.000**

m_y = **1.000**

Buckling resistance checks - cl.4.8.3.3.3 $F_c / P_{cx} + m_x \times M / M_c \times (1 + 0.5 \times F_c / P_{cx})$ = **0.842**

$F_c / P_{cy} + 0.5 \times m_{LT} \times M_{LT} / M_{cx}$ = **0.505**

PASS - Member buckling resistance checks are satisfied

SLAB DESIGN

→ Uplift. between underpin toes

Span = 5·6m − 1·4×2
= 2·8m

GWL = 2·0m highest water level @ ground level in front garden.

Uplift = (10×2·0)×1·6 − (0·25×24)
26 kNm/m width.

Cap M = 393 mm² × 500 × (250−30) × 0·85
= 36·7kNm ✓ OK.

→ Global Uplift.

Uplift = (5·6 + 2×0·215) × 2·0m × 10 (≈ 6m)
= 120kN

Structure W = (0·25 + 0·05) × 24 × 6 ← slab + screed
+ (0·215 × 18 × 11m × 80%) × 2 walls
↖ average building height
+ (0·5m × 1·4 × 24) × 2 ← slab thickening

= 145 kN > 120kN ✓ OK.

· Screed + floors + roof buildups conservatively ignored.

→ 250mm Slab
A393 mesh flying ends.

Appendix D

Example Past Projects

21 Wilton Street	Complete overhaul of a listed house in Belgravia, including pool, gym, media room etc. within a new basement.
17 Phillimore Gardens	Refurbishing a listed house and constructing a new basement with swimming pool under the garden and part of the house.
44 Grove End Road	Extensive refurbishment of a listed building plus construction of a basement swimming pool and car park.
7 Wilton Crescent	Rebuilding a mews house to include double storey basement with swimming pool plus renovation and rooftop extension of listed house.
15 Thurloe Square	Refurbishment of a listed house and construction of a basement extension.
7 St James Square	Construction of a two-storey basement with swimming pool under a grade 2 listed house designed by Lutyens.
2 Alma Terrace	Construction of a basement under the full footprint of the house and garden. The house above remains occupied and the work is done using a tunnelling method.
12a-14 Cheyne Row	Construction of a new basement under a central courtyard of a collection of houses.
44 Markham Square	Refurbishment and extension of a house including new basement.
15 Addison Crescent	Construction of a deep basement with swimming pool under an existing house.
40 St Petersburg Place	Alterations to house and mews house featuring new basement.
23a Earls Court Square	A basement extension under the house to include a gym and 20m lap pool.
22 Frognal Way	Retaining a listed 1970's modernist house and constructing a new basement with swimming pool under the house and garden.
4 Frognal Way	Refurbishment of an existing house including an extension and new basement with swimming pool.
20 Rutland Mews South	Construction of a new basement under an existing house.