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4388/BIS/003/AB

June 2020

Basement Impact Statement for the Proposed Basement Extension

at

46 Agamemnon Road
London
NW6 1EN

Synopsis

The property is a three-storey terrace house with an existing partial basement, which we assume was an old coal cellar, under the ground floor hallway. It is of traditional construction with timber floors and roof spanning between load-bearing masonry external walls and internal walls or steel beams installed during the refurbishment works in circa 2015.

The original house consists of a main terraced section as well as an outrigger located on the rear left hand side. The refurbishment work carried out at the property included a rear single story wrap-around extension at ground floor, installation of a new second floor and dormer construction at roof level. The works included the opening up of the ground floor space, with the installation of a series of structural frames and supporting beams. The structure was designed with the construction of a future basement in mind and as such it is the intension that the existing house, from ground floor upwards, will be left untouched and inhabited during the proposed construction works.

The proposal discussed herein is to extend the existing basement across the full width of the property, from the front elevation to approximately the line of the original rear extension of the terrace. There is also a lightwell proposed for part of the front garden.

Trial pits were dug within the existing basement in March 2020 by Oakland Site Investigations. The logs show that the existing footings are corbelled brickwork, extending 0.5m below the existing basement level to the party wall at No. 44 Agamemnon Road. As this type of foundation is common for the age of the property and other properties we have experience with on Agamemnon Road, we assume that the footings to the party wall at No. 48 Agamemnon Road will be shallow corbelled brickwork, approximately 0.5m below ground floor level.

The existing central ground beam within the property is currently supported at each party wall as well as on a temporary stub column, just inboard of the existing basement. This beam has been designed by the previous engineer to span the full width of the property and therefore the proposal is for the stub column and its foundation to be removed. It is assumed that the bearings of the existing beam at each party wall will need to be upgraded before the removal of the stub column, and also that the load should not be fully transferred to the walls until the reinforced concrete retaining walls under have been completed.

Appraisal

This appraisal of the basement construction has been carried out for the purposes of making a planning application for the proposed works. Should the planning application be approved, a full appraisal of the existing structure would need to be carried out and a full design of the substructure alterations would then take place.

This appraisal contains a brief method statement, preliminary sketch proposals for the basement works, as well as preliminary calculations for the basement retaining walls.

Flood Risk

With reference to the Environmental Agency's Flood Risk Map, the application property is outside any flood risk zone. It is also shown as a "very low risk" of flooding from rivers and seas, with "very low" meaning that it has a 1 in 1000 (0.1%) of flooding each year. The site is on higher ground than the areas that historically experienced flooding, most recently in 1975. As such no Flood Risk Assessment is therefore deemed required.

Flood records dating back to 1927 show no recorded incidence of flooding at this site. Flood barriers protect the site with crest heights above calculated worse case tidal levels.

Surface Water

The Environmental Agency's risk from flooding from surface water is very low meaning that it has a 1 in 1000 (0.1%) of flooding each year.

The proposed development comprises the enlargement of a lower ground floor, and the addition of a light well. The extension will provide an enlarged living space for the dwelling house. There is no material increase in hard surfacing or roof areas as a result of the development. The enlargement will occupy an area which is currently hard surfaced. As part of the site drainage, the surface water flows (volume of rainfall and peak run-off) will not be changed from the existing route, or result in changes to the quality of the surface water received by the adjoining properties or watercourses.

Surface waters will be discharged to the existing combined drainage system.

Foul waters will be discharged to the existing combined drainage system.

The site is not within the risk areas of West and South Hampstead, and is not below the static water level of a nearby feature.

Groundwater/Risk of Flooding from Reservoirs

With reference to the Environmental Agency's Flood Risk Map, the site is not in a Groundwater protection zone, and it is extremely unlikely to be at risk from flooding from reservoirs.

The site is not directly above an aquifer. It is not within 100m of a watercourse or spring, nor is the site within the catchment of the ponds of Hampstead Heath. Also the lowest point of the excavation (allowing for any drainage and foundation space under the basement floor) is not close to, or lower than, the mean water level of any local pond or spring line.

Water was not noted to be present in the trial pit logs and was not encountered in the window sample.

Generally

All gaps to accommodate services such as gas, electricity and telephone cables to the lower ground and ground floor will be sealed with silicone sealant.

Brickwork joints and cracks will be re-pointed, and all joists will be sealed between new walls and doors.

Non-return valves will be installed at all connection pipes to the main sewer to prevent backing up of foul waters should the outlet become submerged under extreme flood conditions.

The drainage system will be fitted with a positive pumped device in order to protect the development from sewer flooding.

Low level up-stands will be constructed around the lightwell to reduce the risk of surface water ingress.

A rodable rainwater gulley will be installed in the base of the lightwell.
The basement will be tanked to prevent water ingress of groundwater and surface water.

The proposed works will not have any effect on the watercourse, floodplain or its flood defences nor impede any access to flood defences and management facilities.

These measures are intended to protect the building and its contents and to safeguard the occupiers of the building.

Temporary Works

The Contractor will be responsible for the design of the temporary works for both the basement construction and superstructure works. The following method statement and suggested construction sequencing shown on the sketches should be developed and finalised by the Contractor prior to works beginning. The temporary works would need to be designed to minimise ground movement and any effects on the adjoining properties. The Contractor's method statement and temporary works design should be reviewed and approved by the design engineer prior to any works taking place.

During excavation, ground movement should be regularly monitored, as is standard practice. We would recommend a specialist company carry out the monitoring works.

Should works be carried out in line with the proposed method statement, we believe there would be minimal damage to any adjacent buildings, in line with *Category 1 – Very Slight* on the Burland Scale. However, we would certainly advise that an experienced builder is used with all relevant insurance to carry out the works. We would also suggest that Party Walls Awards are to be in place with all relevant neighbours such that, in the unlikely event that additional damage is caused, it will be repaired.

We also believe that the structural stability of both the property being underpinned, as well as all adjacent properties, would be maintained if the method statement outlined below is followed.

Basement Construction

The works would involve the underpinning of the existing external and party ground floor walls in order to minimise disruption to neighbouring properties. Internal walls are to be supported by steel beams spanning between the underpinning. Retaining walls would also be constructed to form the lowered front lightwell. Further retaining walls would be constructed to form the rear of the basement. All of these retaining walls should be constructed using an underpinning sequence so as to minimise disruption to the adjoining properties. Further to this, sequencing of the construction will need to be planned around maintaining occupancy of the building from ground floor level and above, with minimal works to be carried out in the existing dwelling.

The underpinning would consist generally of short sections of reinforced concrete retaining walls, excavated in sequence and tied together with dowel bars. They would be designed to carry both the vertical loads of the walls above, as well as lateral loads from the adjoining soil. Temporary propping at the base of the retaining walls should be installed and maintained until the central basement slab has been cast and reached its full working strength. This will minimise forward movement of the retaining walls and hence minimise damage to adjoining properties. It is assumed at this stage that neither of the adjoining properties has excavated a basement but this will be confirmed prior to the full design taking place.

Following review of the British Geological Survey maps (1:50,000 scale), we have assumed the founding soil to be London Clay for the purposes of the design of the proposed basement. The founding soil appears to be relatively homogenous in the surrounding area and we therefore do not believe the soil will be unstable. We have also assumed the water table to be one metre above basement slab for the purposes of this structural appraisal. We would recommend a site investigation be carried out prior to construction so as to determine the exact make-up of the founding soils and water table level.

Enabling Works

The site is to be suitably hoarded to prevent unauthorised access.

Licenses for skips and conveyors are to be obtained and displayed in suitable locations.

Design Standards and Reference Documents

The relevant Eurocodes, Building Regulations and Codes of Practice should be used in the design.

Design Parameters

The internal steelwork and underpinning should be designed for an imposed floor load of 1.5 kN/m^2, as well as calculated dead loads. The retaining wall to the lightwell in the front courtyard should be designed for an imposed load of 5 kN/m^2.

We would propose an allowable bearing pressure of 100 kN/m^2 for London Clay, the assumed founding soil.

PRELIMINARY METHOD STATEMENT

Preliminary Outline Construction Sequence

1. Underpin front elevation with sacrificial mass concrete, in sequence marked as 'a' on drawings (see also underpinning sequence note below). Backfill with well compacted material after each pin.

2. Install temporary steel beam under front wall of bay at ground level spanning between underpins.

3. Form lightwell in reinforced concrete retaining walls in underpinning sequence marked as 'b' on drawings. Install temporary props as necessary until permanent ties to return walls and front elevation of property are complete.

4. Underpin party wall to No. 44 Agamemnon Road (in existing basement) in sequence marked as 'b' on drawings.

5. Prop existing central ground floor beam and upgrade existing beam bearing at No. 44 Agamemnon Road.

6. Underpin party wall to No. 48 Agamemnon Road in sequence marked as 'c' on drawings (Note. Method assumed as tunnelling due to maintained occupancy of residence above). Ensure 48hrs from casting one pin and excavating for the next pin.

7. Prop existing central ground floor beam and upgrade existing beam bearing at No. 48 Agamemnon Road.

8. Underpin existing rear ground beam with mass concrete, in sequence marked as 'd' on drawings.

9. Cast reinforced concrete retaining wall to front of rear ground beam foundation in underpinning sequence marked as 'e' on drawings.

10. Remove stub column under central ground beam.

11. Excavate central berm (including the internal original basement masonry walls and pad foundation from stub column), installing props as excavation progresses.

12. Cast basement slab.

13. Install new steel beams to support chimney breasts at ground floor.

14. Tie walls to ground floor using straps.

15. Remove props, monitoring for movement.

16. Demolish mass concrete underpinning to front elevation and replace with masonry/glazing as per architects design, propping wall above as necessary.

Underpinning Sequence

1. Underpinning to be carried out in standard 1, 3, 5, 2, 4 sequence. See sketches for suggested layout.

2. Each leg is to be excavated in bays not exceeding 1.0m in length, concreted and pinned tight to existing footing before commencing next leg. Similarly numbered bays can be carried out consecutively.

3. The construction of each underpinning block shall be commenced immediately after the bottom of the excavation has been exposed. The bottom shall be sealed with concrete blinding immediately after inspection has shown it to be satisfactory.

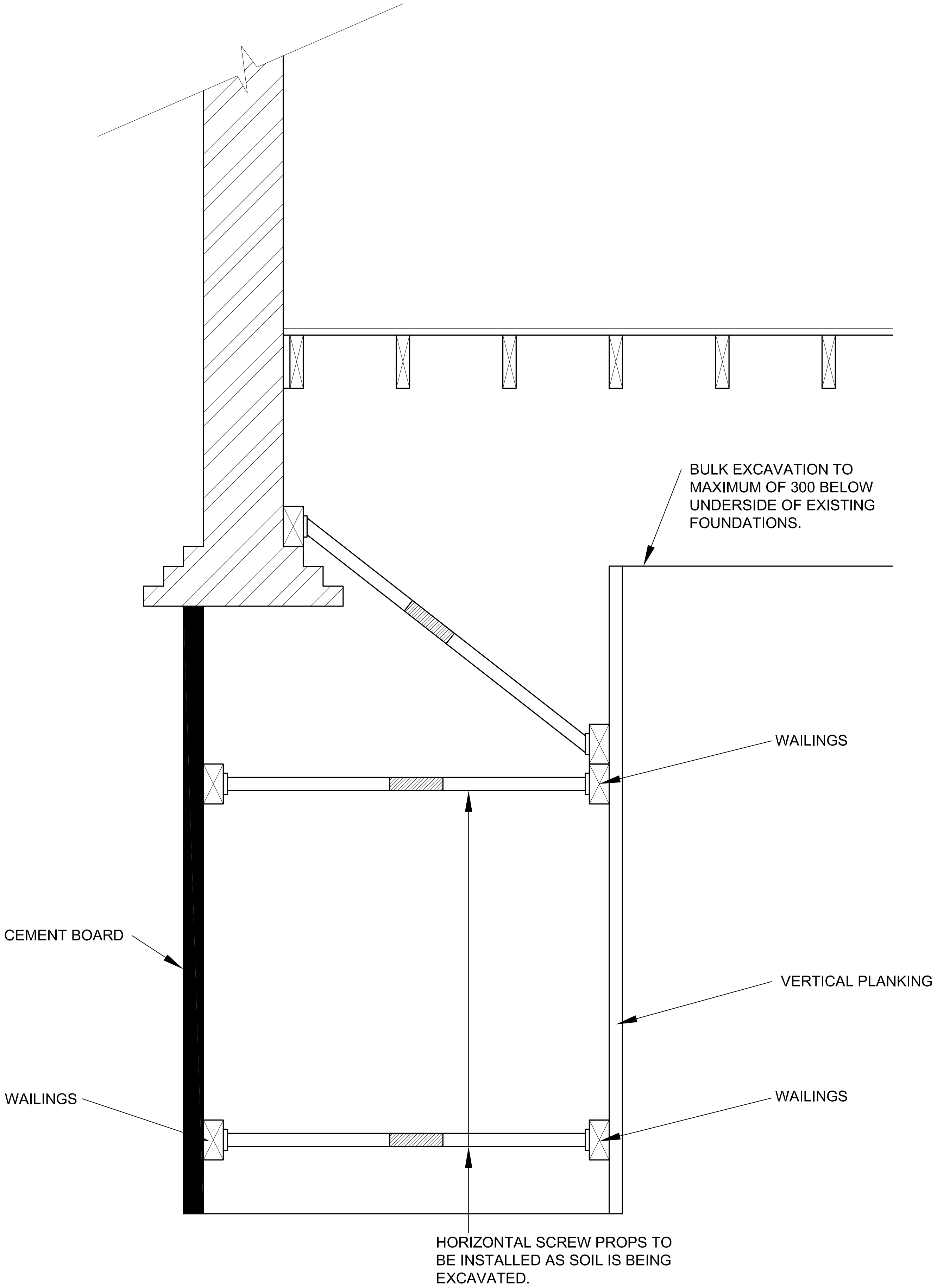
4. The underside of the existing footing shall be thoroughly cleaned.

5. At least 24 hours after concrete pour, semi-dry pinning sand/cement pack to be rammed in hard.

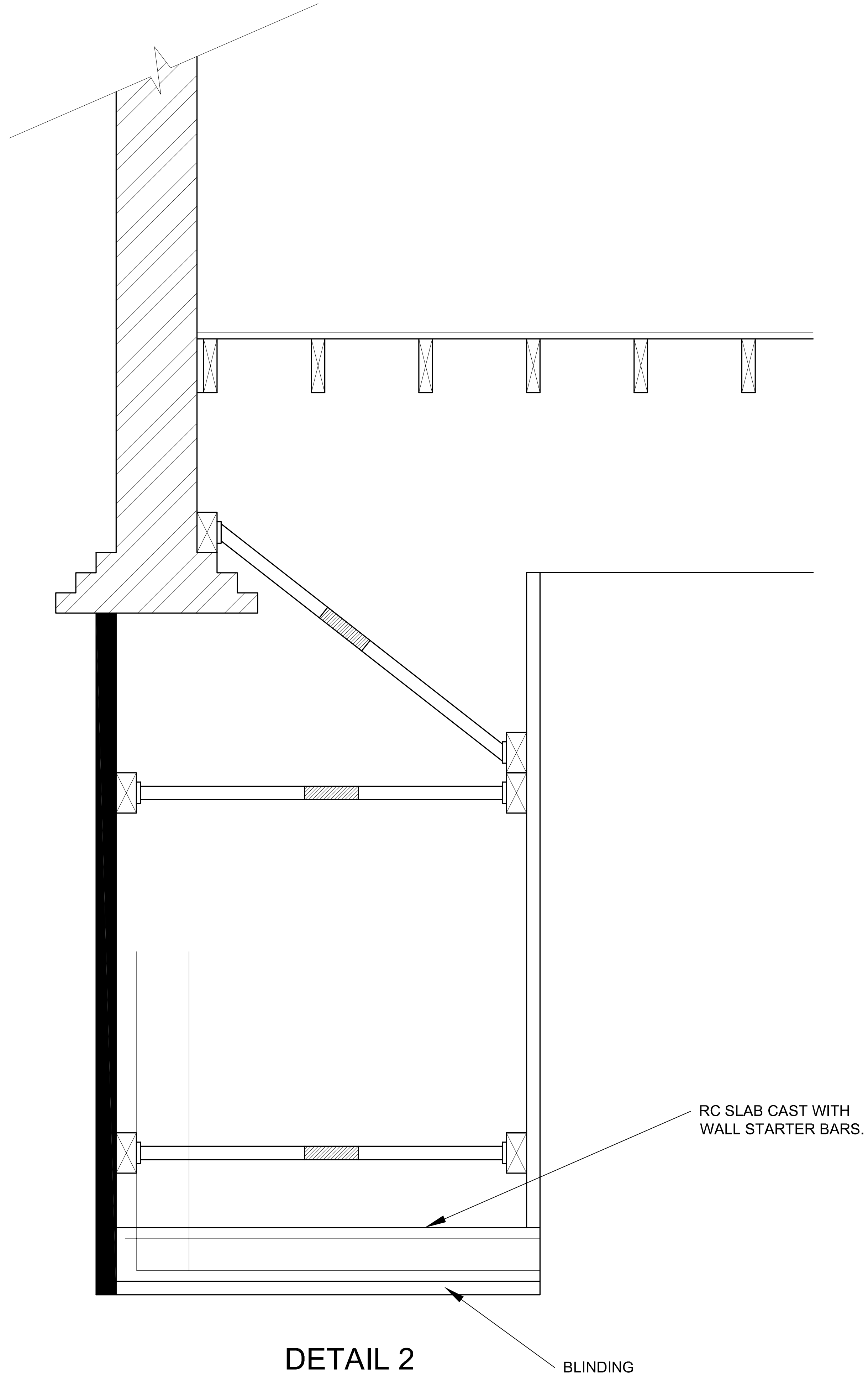
6. At least 48 hours to elapse before excavation of next pin in sequence.

7. Sides of previously poured pins to be thoroughly cleaned and joined together with 20mm. diameter dowel bars, 1.0m long.

8. Concrete to be grade C40 minimum.



DETAIL 1



DETAIL 2

Notes

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Revisions

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Client
Mr & Mrs Rosen

Address
46 AGAMEMNON ROAD
LONDON
NW6 1EN

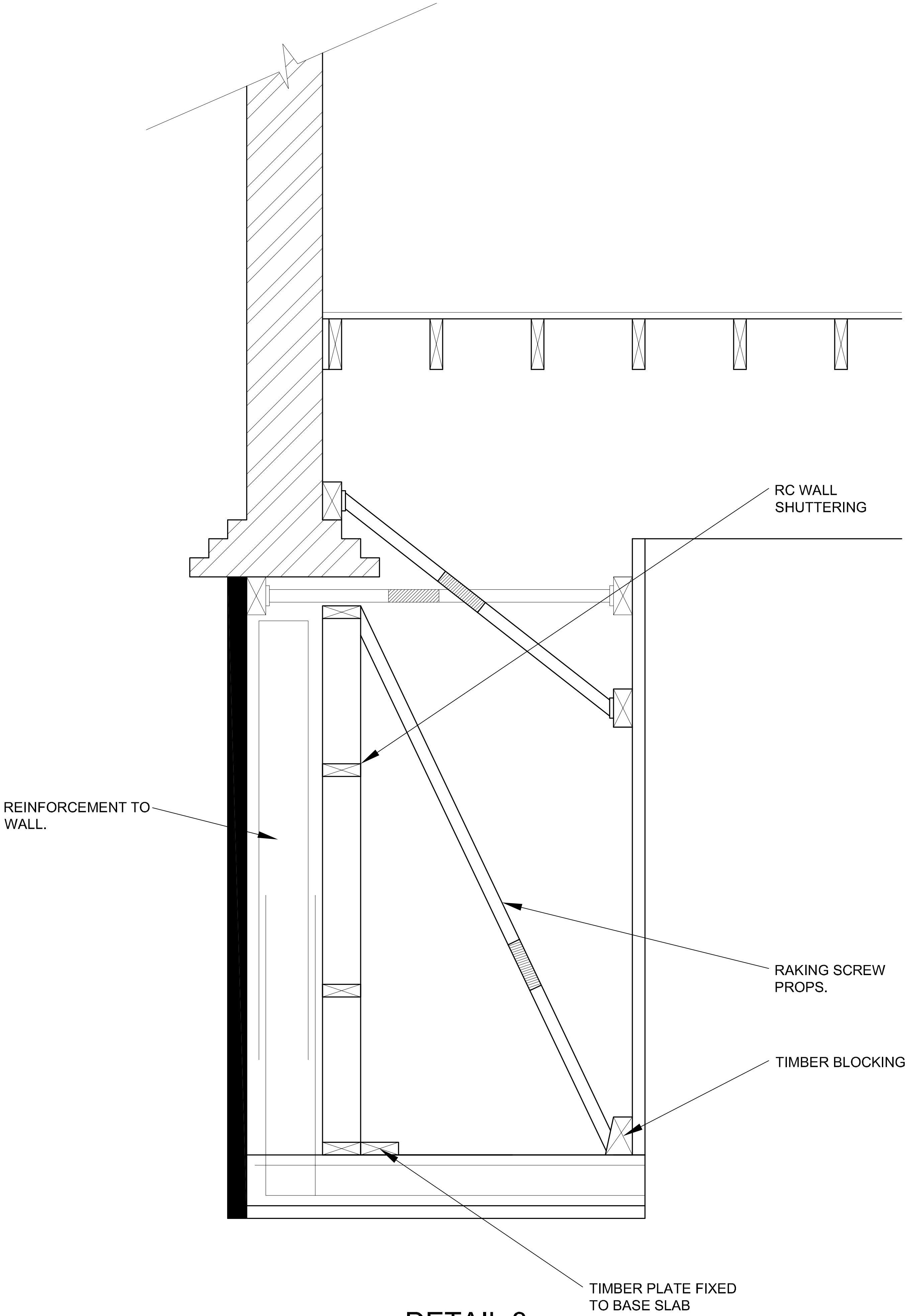
Drawing Title
CONSTRUCTION OF UNDERPINNING FOR NEW BASEMENT.

Date
JUN '20

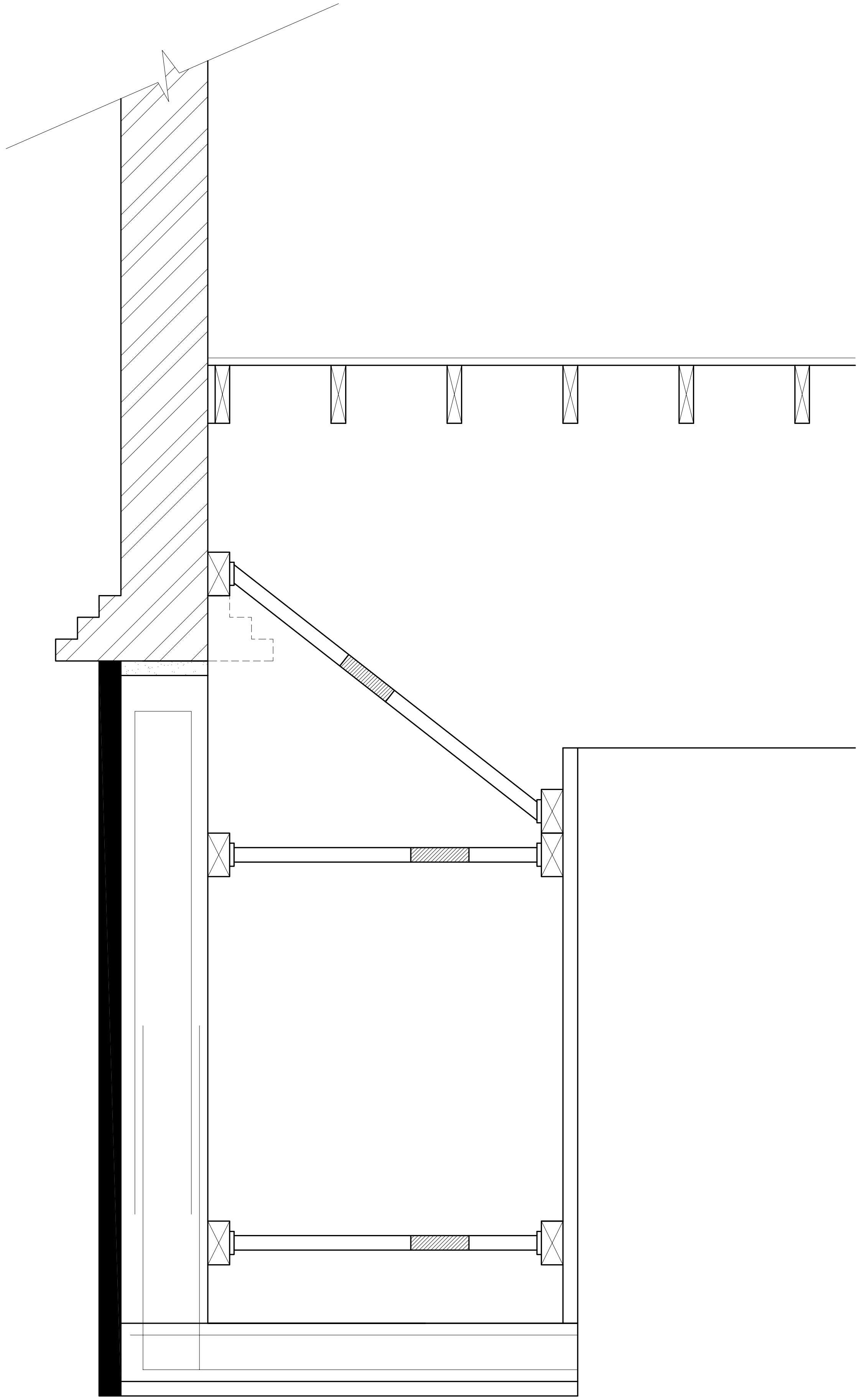
Scale

Drawing Number
4388 - SK 01

Revision
-



DETAIL 3
SCALE 1:20



DETAIL 4
SCALE 1:20

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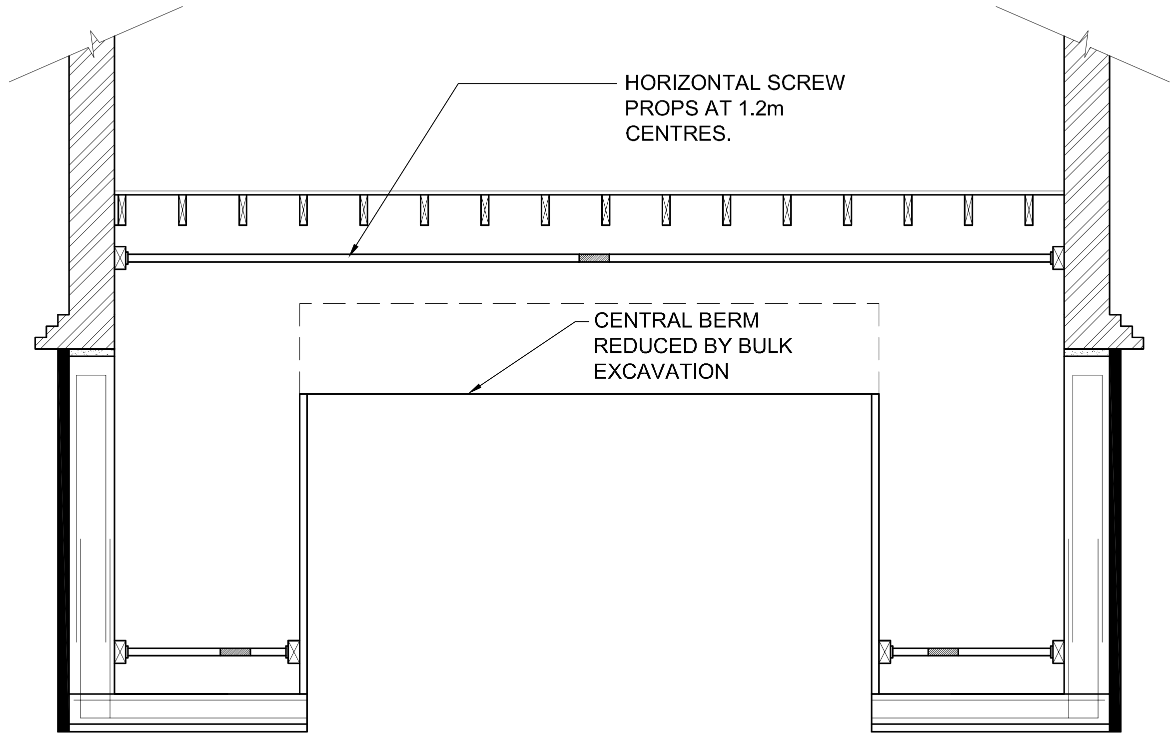
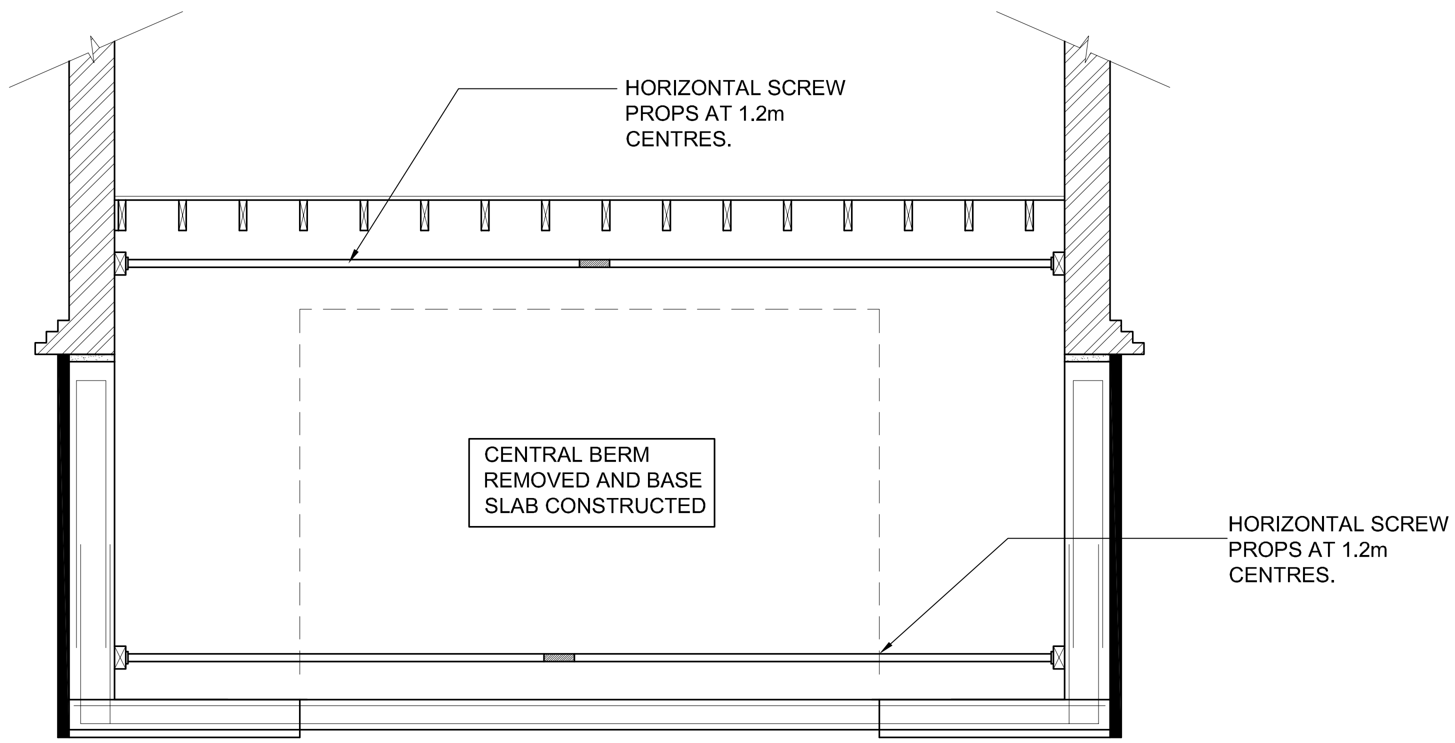


DETAIL 5



DETAIL 6

METHOD STATEMENT

1) EXCAVATE ACCESS PIT AND UNDERMINE EXISTING FOUNDATION FOR FIRST UNDERPIN IN ACCORDANCE WITH THE SEQUENCE SHOWN ON THE DRAWING. INSTALL TEMPORARY PLANKING AND STRUTTING AS SOIL IS BEING EXCAVATED. BLIND EXCAVATION BASE WITH 75mm CONCRETE.

2) INSTALL PREFORMED REINFORCEMENT CAGE TO BASE AND WALL AND CAST BASE SLAB.

3) INSTALL WALL REINFORCEMENTAND FRONT SHUTTER, ADAPT PLANKING AND PROPS AND CAST CONCRETE UNDERPIN AND CURE FOR A MINIMUM OF 24 HOURS.

4) STRIP SHUTTERING AND INSTALL TEMPORARY PROPS. DRY PACK BETWEEN TOP OF NEW UNDERPIN AND EXISTING FOUNDATIONS WITH 3:1 SAND/CEMENT AND CONBEX100 ANTI SHRINK ADDITIVE.

5) EXCAVATE ACCESS PIT AND UNDERMINE EXISTING FOUNDATIONS FOR NEXT UNDERPIN IN ACCORDANCE WITH THE SEQUENCE SHOWN ON THE DRAWING. INSTALL TEMPORARY PLANKING AND STRUTTING AS NECESSARY.

6) REPEAT STEPS 2 TO 7 UNTIL ALL UNDERPINNING HAS BEEN COMPLETED.

7) BULK EXCAVATE CENTRAL BERM AND INSTALL TOP AND BOTTOM HORIZONTAL PROPS.

8) EXCAVATE CENTRAL BASE, BLIND EXCAVATION WITH 75mm CONCRETE AND INSTALL PREFORMED REINFORCEMENT CAGE. CAREFULLY CUT BACK CORBEL BRICKWORK FOUNDATION.

9) CAST CONCRETE TO FORM NEW BASEMENT FLOOR SLAB AND ALLOW TO CURE FOR 7 DAYS.

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Drawing Title: CONSTRUCTION OF UNDERPINNING FOR NEW BASEMENT.

Date: JUN '20

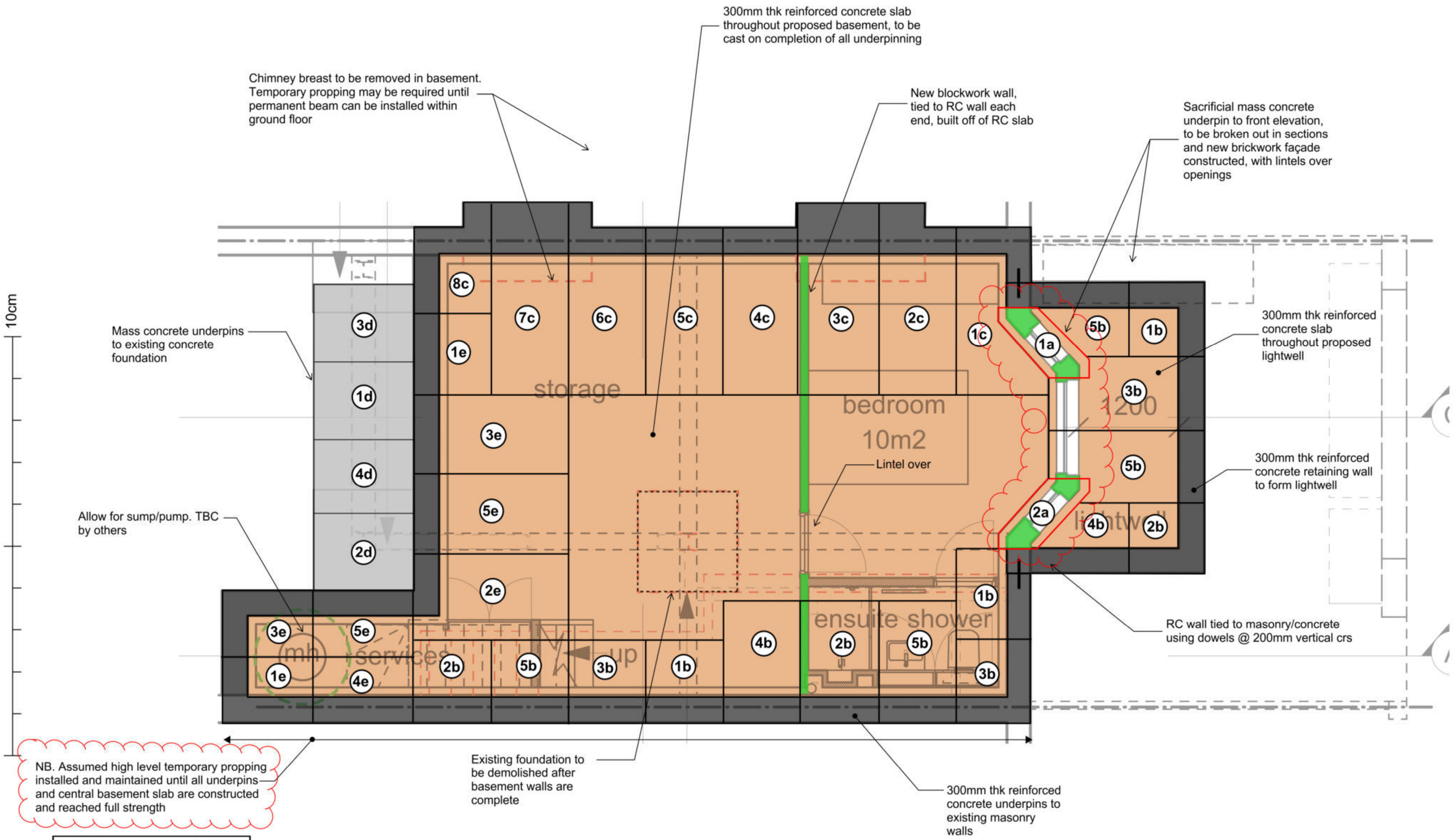
Scale:

Drawing Number: 4388 - SK 03

Revision: -

PRELIMINARY SKETCH PROPOSALS

10cm SCALE WITH CAUTION use both scale bars to check for reduction or distortion



Preliminary sequence only - to be developed by the contractor

(1a) Indicates proposed underpinning sequence. Complete all sections marked 'a', before starting those marked 'b'. Complete all sections marked 'b' before starting those marked 'c', and so on.

a - Sacrificial mass concrete underpin to front elevation to be completed first
b - Front lightwell to be formed and reinforced concrete underpinning to existing basement party wall at No. 44
c - Reinforced concrete underpinning to existing party wall at No. 48 in tunnelling sequence, ensuring 48hrs between pins
d - Mass concrete underpin to existing ground beam
e- Reinforced concrete retaining wall to rear of proposed basement

NB. Proposed sequence allows for the property to remain occupied during the works, and avoids demolition of the ground floor

0 1 2 3 4 5 10m

Notes
- Waterproofing to specialist design and detail
- Drainage design by others

PRELIMINARY FOR PLANNING

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Client
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Address
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Drawing Title
Proposed Preliminary Basement Floor Plan

Date
June 2020

Scale
1:50 @ A3

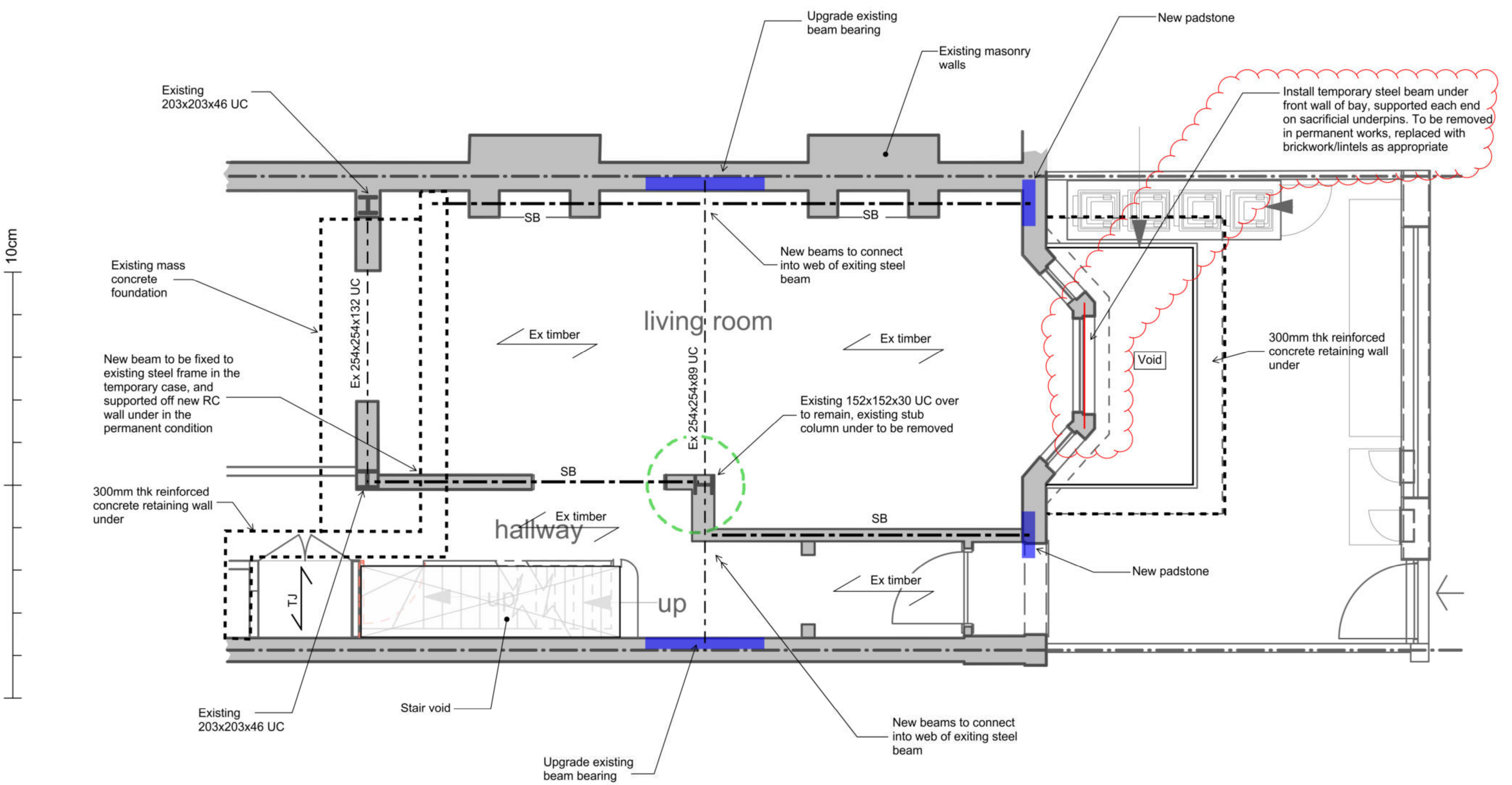
Drawing Number
4388_SK04

Revision
A

10cm SCALE WITH CAUTION use both scale bars to check for reduction or distortion

KEY

Ex Existing
SB Steel beam
TJ Timber joists



Existing stub column under beam to be removed only after beam bearings have been upgraded and reinforced underpinning is complete.

NB. Proposed sequence allows for the property to remain occupied during the works, and avoids demolition of the ground floor

0 1 2 3 4 5 10m

Notes
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Drawing Title
Proposed Preliminary Ground Floor Plan

Date
June 2020

Scale
1:50 @ A3

Drawing Number
4388_SK05

Revision
A

PRELIMINARY CALCULATIONS

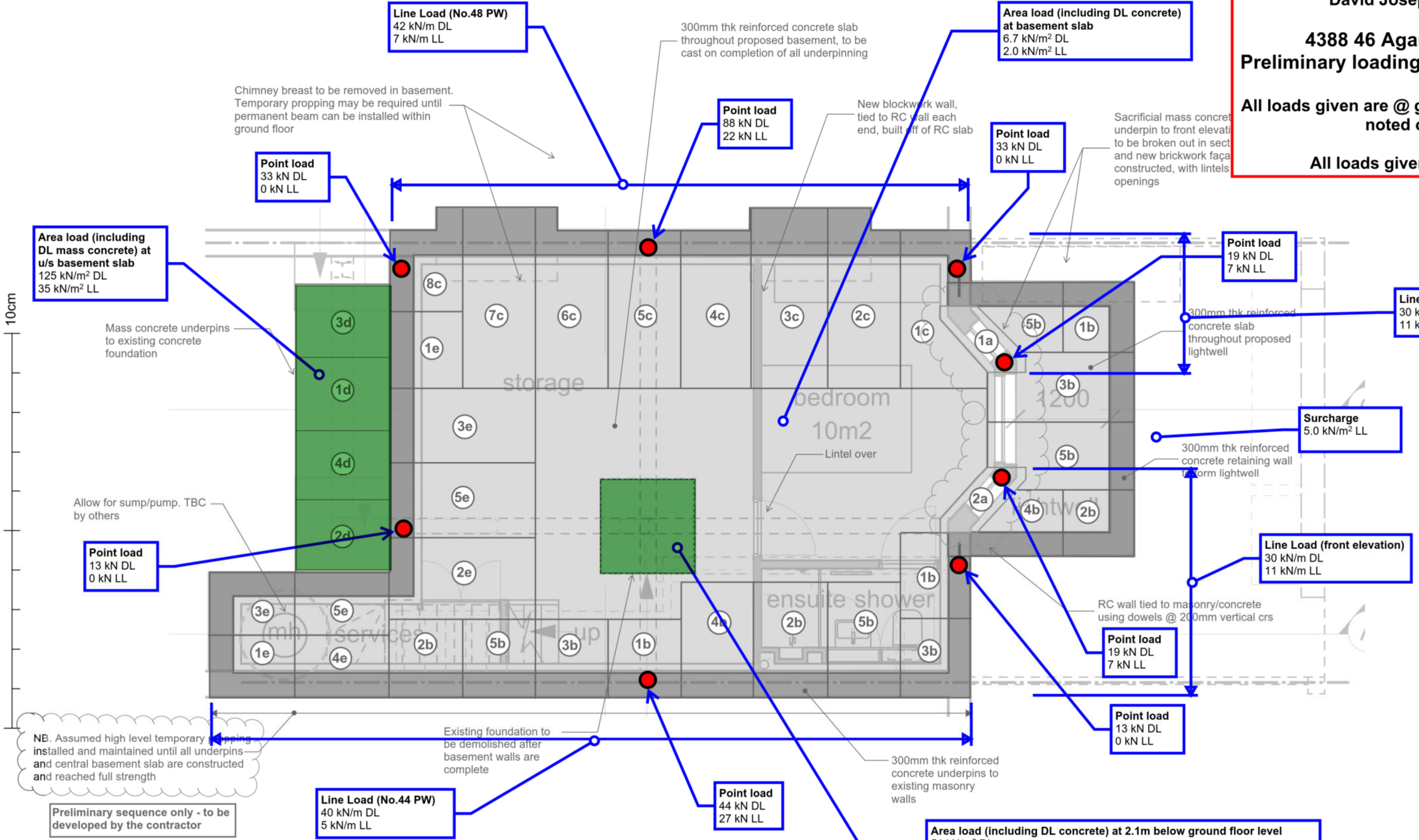
10cm SCALE WITH CAUTION use both scale bars to check for reduction or distortion

David Joseph Consulting

4388 46 Agamemnon Road
Preliminary loadings for ground analysis

All loads given are @ ground floor level, unless noted otherwise

All loads given are unfactored



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0 1 2 3 4 5 10m

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Proposed Preliminary Basement Floor Plan

Date
June 2020

Scale
1:50 @ A3

Drawing Number
4388_SK04

Revision
A

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Project:	46 Agamemnon Road, London		Job No.	4388
Engineer:	AB	Date: June 2020	Page:	PC/1

LOADINGS USED IN PRELIMINARY DESIGN:

Masonry wall (215 THK) = 4.5 kN/m² DL
Masonry wall (105 THK) = 2.3 kN/m² DL

Surcharge @ front garden = 5 kN/m² LL
Include 0.5 kN/m² LL for partitions.

PREVIOUS WORKS LOADINGS:

Taken from N&K Property Services submission

Loadings used	kN/m²
DEAD	
Flat Roof, including Ceiling Joists, plasterboard & skim:	0.85
Pitched Roof as above on plan:	0.85
Ceiling Joists, plasterboard & skim:	0.30
Stud wall / Partitions, including plasterboard & skim:	0.35
Dormer Stud wall, including tile, ply, insulation, plasterboard & skim:	1.00
Floor with ceiling, Dead (General):	0.50
Concrete 1m deep:	23.60
IMPOSED	
Roof flat- snow:	0.75
Roof pitched- snow:	0.60
Wind:	0.65
Floor:	1.50

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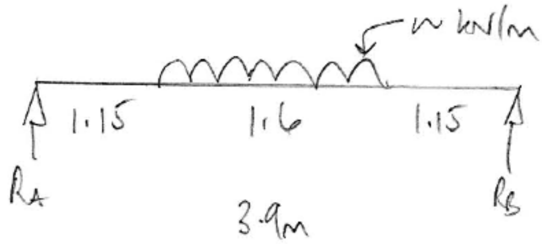
CHIMNEY SUPPORT BEAM, GROUND FLOOR (PRELIM).

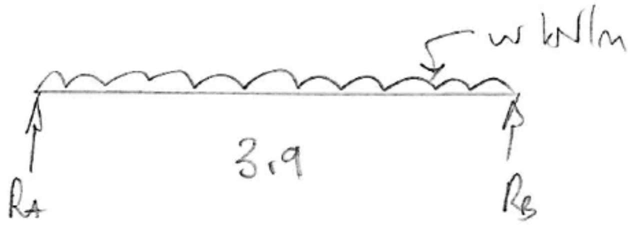


conservatively assume full height of chimney breast loads beam.

∴ $w = 4.5\ kN/m^2 \times 9.2m\ (say) = 41.4\ kN/m$ DL

$R_A = R_B = \frac{1.6 \times 41.4}{2} \approx$ 33 kN DL.

WALL SUPPORT BEAM, GROUND FLOOR (PRELIM)



Assume wall is masonry, ground – first

∴ $w = 2.3\ kN/m^2 \times 2.8m\ (say) = 6.4\ kN/m$ DL

$R_A = R_B = \frac{3.9 \times 6.4}{2} \approx$ 13 kN DL

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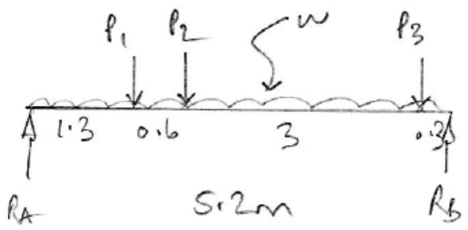
EXISTING CENTRAL GROUND BEAM



Additional loads being added to existing beam from chimney and ground floor walls.

loads from previous engineers calculations:

$w = 4.9$ kN/m DL, 7.5 kN/m LL

$P_2 = 14$ kN DL, 9.2 kN LL

Additional loads:

$P_1 = 13$ kN DL (wall beam)

$P_2 = 13$ kN DL (wall beam)

$P_3 = 2 \times 33$ kN DL (chimney support beam)

$$\therefore R_A = \frac{4.9 \times 5.2}{2} + \frac{13 \times 3.9}{5.2} + \frac{(14+13) \times 3.3}{5.2} + \frac{66 \times 0.3}{5.2} \approx \underline{44 \text{ kN DL}}$$

$$= \frac{7.5 \times 5.2}{2} + \frac{9.2 \times 3.9}{5.2} \approx \underline{27 \text{ kN LL}}$$

$$R_B = (4.9 \times 5.2) + 13 + 13 + 14 + (2 \times 33) - 44 \approx \underline{88 \text{ kN DL}}$$

$$= (7.5 \times 5.2) + 9.2 - 27 \approx \underline{22 \text{ kN LL}}$$

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EXISTING CENTRAL PAD BEARING PRESSURE

from previous engineers calculations:

unfactored column load = 58 kN ← Assume 40% LL

unfactored concrete load = 6.2 kN

Existing base = 0.9m x 0.9m

∴ Area load @ u/s base:

$$\frac{(58 \times 0.6) + 6.2}{0.9 \times 0.9} \approx 51 \text{ kN DL}$$

$$\frac{58 \times 0.4}{0.9 \times 0.9} \approx 29 \text{ kN LL}$$

EXISTING REAR FRAME BEARING PRESSURE

From previous engineers calculations:

Load from frame (ult) = 167 + 234 = 401 kN

Assume ÷1.5 to SLS = 267 kN

Assume 40% LL, ∴ DL = 160 kN, LL = 107 kN

base = 0.9m x 3.4m

∴ Area load = 160/0.9x3.4 ≈ 53 kN DL

107/0.9x3.4 ≈ 35 kN LL

underpin existing base to u/s basement slab,

∴ concrete of base = 24 kN/m³ x 3m = 72 kN/m² DL

Total Area load @ u/s basement slab

= 53 + 72 = 125 kN/m² DL

= 35 kN/m² LL

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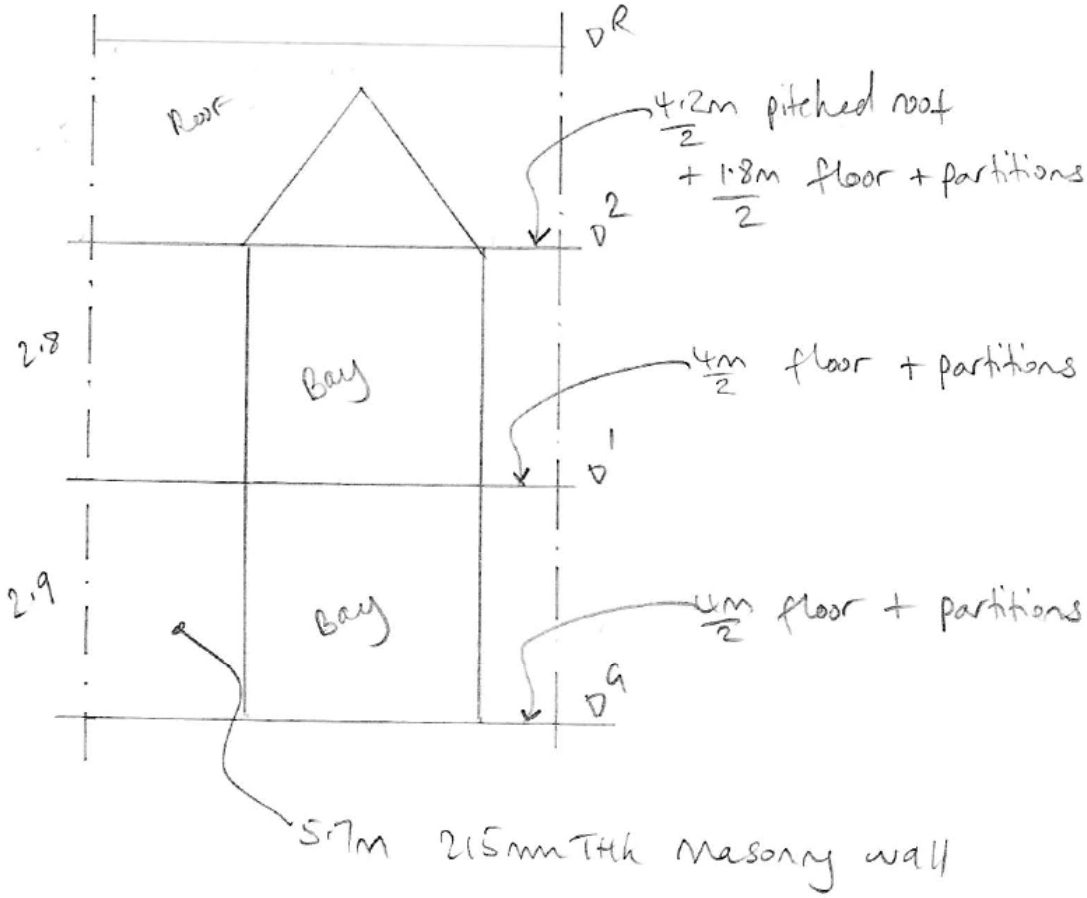
Engineer:	AB	Date:	June 2020	Page:	PC/5

UDL ON FRONT ELEVATION



	DL	LL
WALL	25.7	–
@ 2ND	1.8 0.5	1.3 1.8
@ 1ST	1.0	4.0
@ GROUND	1.0	4.0
	30 kN/m	11.1 kN/m

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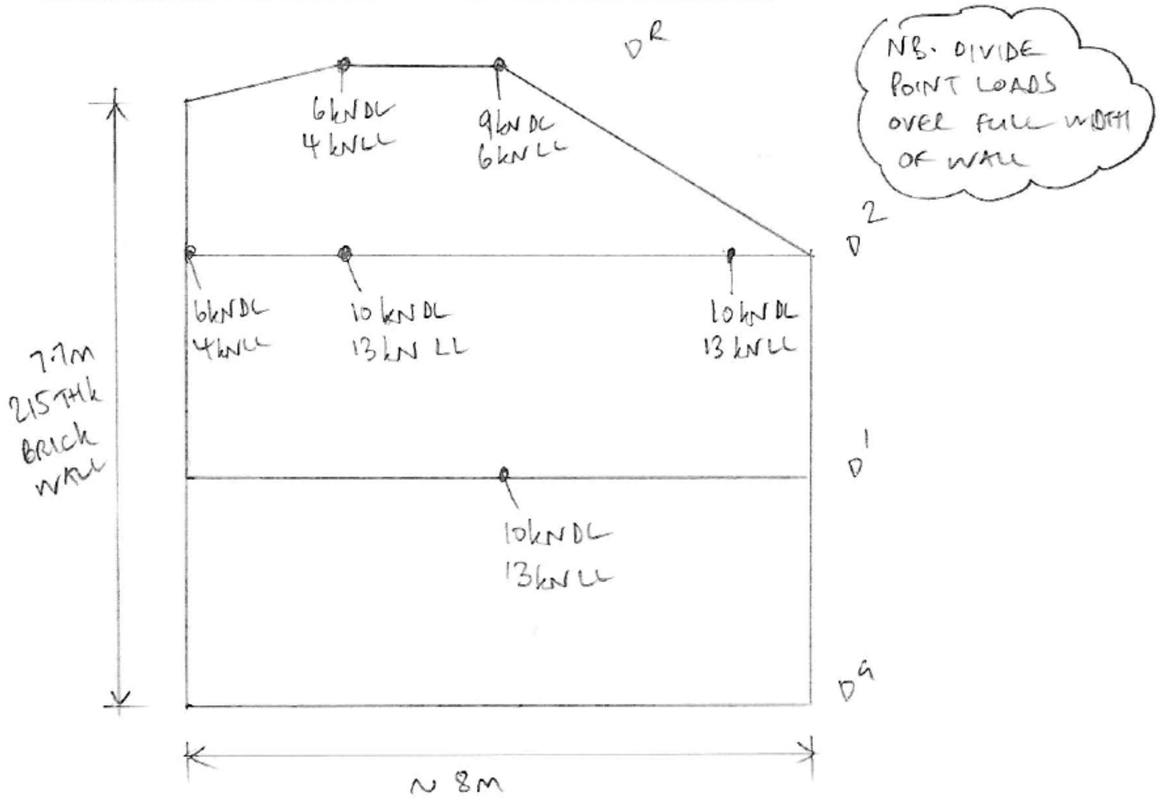
Project:	46 Agamemnon Road, London		Job No.	4388
Engineer:	AB	Date: June 2020	Page:	PC/6

UDL ON No 48 PARTY WALL



POINT LOADS PROVIDED ARE FROM PREVIOUS ENGINEERS CALCULATIONS.

	DL	LL
WALL	34.7	–
@ R	0.8 1.2	0.5 0.8
@ 2	0.8 1.3 1.3	0.5 1.6 1.6
@ 1	1.3	1.6
	41.4 kN/m	6.6 kN/m

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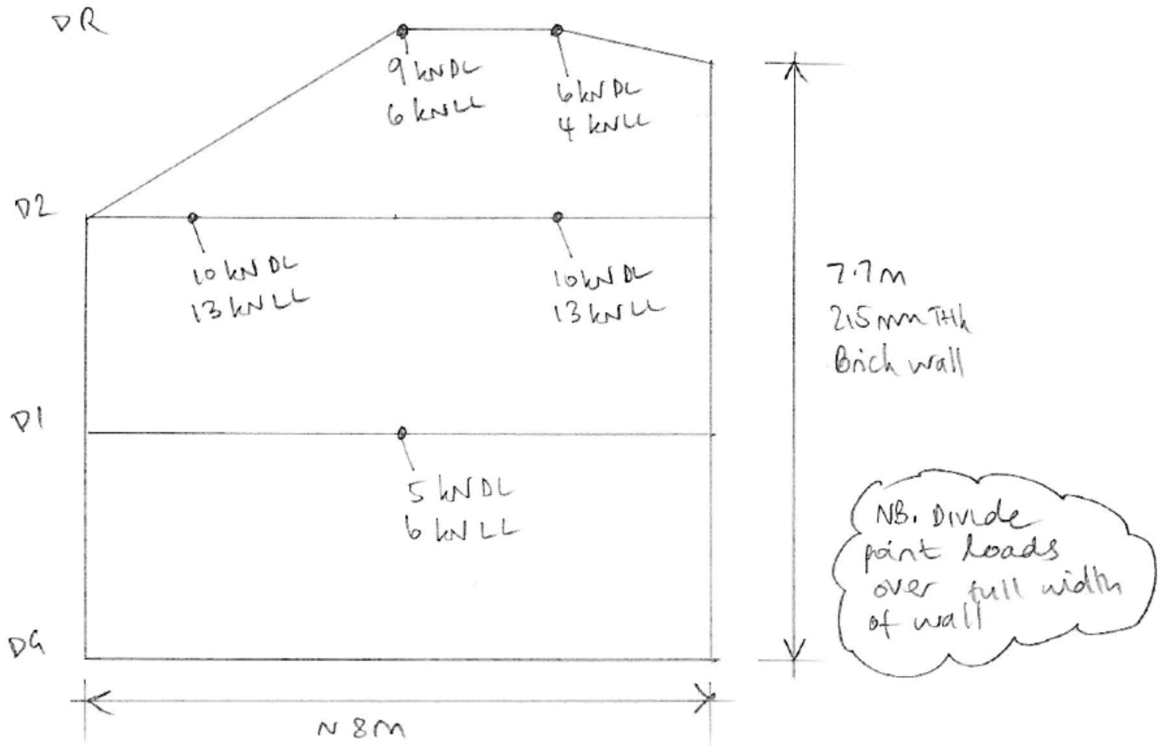
Project: 46 Agamemnon Road, London		Job No. 4388
Engineer: AB	Date: June 2020	Page: PC/7

UDL ON Nº 44 PARTY WALL

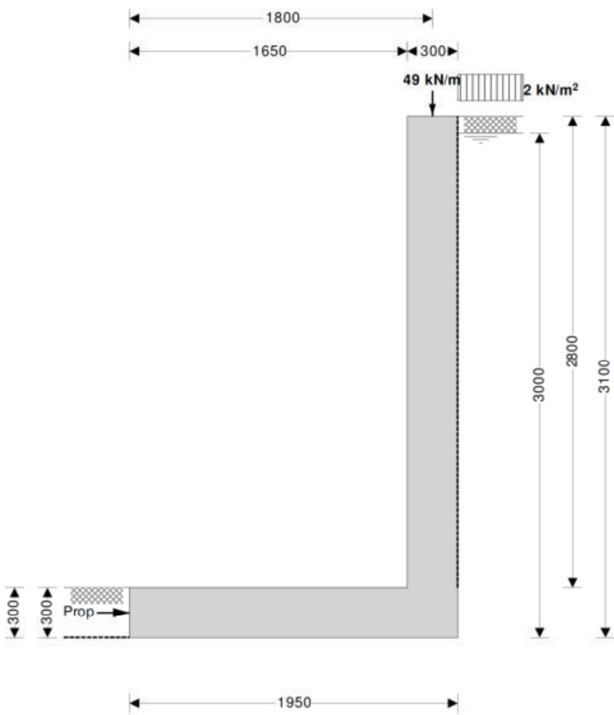


Point loads provided are from previous engineers calculations

	DL	LL
WALL	34.7	–
@ R	1.2 0.8	0.8 0.5
@ 2	1.3 1.3	1.6 1.6
@ 1	0.7	0.8
	39.3 kN/m	5.3 kN/m

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} = **2800** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **1650** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1950** 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	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3100** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **300** mm
Height of ground water behind wall	h_{water} = **3000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **2700** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3100** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Project 46 Agamemnon Road, London				Job no. 4388	
Calcs for Preliminary Basement Underpin				Start page no./Revision RW/2 - A	
Calcs by AB	Calcs date 16/06/2020	Checked by	Checked date	Approved by	Approved date

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Saturated density of retained material — γ_s = **21.0** kN/m³

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

Angle of wall friction — δ = **18.6** deg

Base material details

Stiff clay

Moist density — γ_{mb} = **20.0** 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 = **0.419**

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 — $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan — Surcharge = **1.5** kN/m²

Applied vertical dead load on wall — W_{dead} = **42.0** kN/m

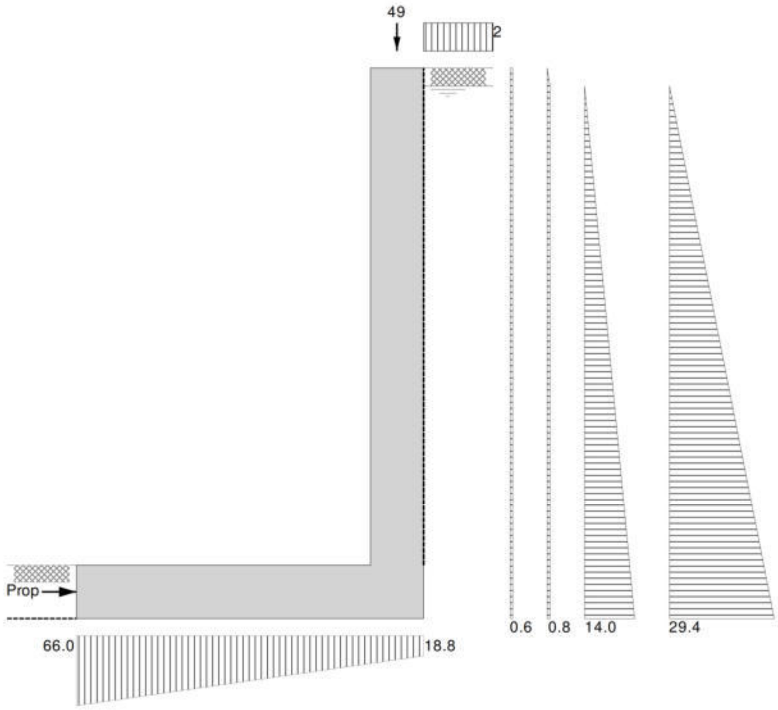
Applied vertical live load on wall — W_{live} = **7.0** kN/m

Position of applied vertical load on wall — l_{load} = **1800** 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	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **19.8** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **13.8** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **49** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + W_v$ = **82.6** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **1.9** kN/m
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **0** kN/m
Moist backfill below water table	$F_{m\_b} = K_a \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **2.3** kN/m
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **21.1** kN/m
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **44.1** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **69.5** kN/m

Calculate propping force

Propping force	$F_{prop} = \max(F_{total} - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$
	F_{prop} = **44.0** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **3** kNm/m
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **0.1** kNm/m
Moist backfill below water table	$M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **3.4** kNm/m
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **21.1** kNm/m
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **44.1** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **71.7** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **35.7** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **13.5** kNm/m
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load}$ = **75.6** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **124.7** kNm/m

Check bearing pressure

Design vertical live load	$M_{live} = W_{live} \times l_{load}$ = **12.6** kNm/m
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{live}$ = **65.6** kNm/m
Total vertical reaction	$R = W_{total}$ = **82.6** kN/m
Distance to reaction	$x_{bar} = M_{total} / R$ = **794** mm
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar})$ = **181** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **66** kN/m²
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **18.8** 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **27.8** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **19.3** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **70** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **117.1** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **4.4** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **0.1** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **4.5** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **41.6** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **61.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **112.3** kN/m

Calculate propping force

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

F_{prop_f} = **76.7** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **6.8** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **0.2** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **6.7** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **41.6** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **61.8** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **117.1** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **50** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **18.8** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **126** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **194.8** kNm/m

Factored bearing pressure

Total moment for bearing $M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **77.7** kNm/m

Total vertical reaction $R_f = W_{total\_f}$ = **117.1** kN/m

Distance to reaction $x_{bar\_f} = M_{total\_f} / R_f$ = **663** mm

Eccentricity of reaction $e_f = abs((l_{base} / 2) - x_{bar\_f})$ = **312** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **117.6** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **2.5** kN/m²

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **59.03** kN/m²/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **20.2** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **11.3** kN/m²

Bearing pressure at stem / heel — $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **2.5** 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 — $c_{toe} =$ **40** mm

Calculate shear for toe design

Shear from bearing pressure — $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **113.7** kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **16.4** kN/m

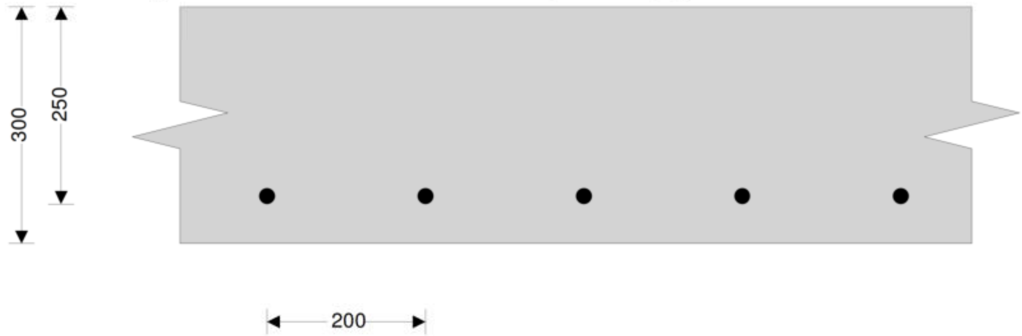
Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **97.3** kN/m

Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **133.1** kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **16.1** kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **117.1** kNm/m



Check toe in bending

Width of toe — $b =$ **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **250.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.047**

Compression reinforcement is not required

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

$z_{toe} =$ **236** mm

Area of tension reinforcement required — $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **1139** mm^2/m

Minimum area of tension reinforcement — $A_{s\_toe\_min} = k \times b \times t_{base} =$ **390** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **1139** mm^2/m

Reinforcement provided — **20 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_toe\_prov} =$ **1571** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe}) =$ **0.389** 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 — $v_{c\_toe} =$ **0.712** 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/mm²

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

Wall details

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

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

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

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds})$ = **4** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **0.1** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **4** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **33.7** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **50.1** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} + F_{s\_m\_b\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f}$ = **15.1** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2$ = **6.1** kNm/m

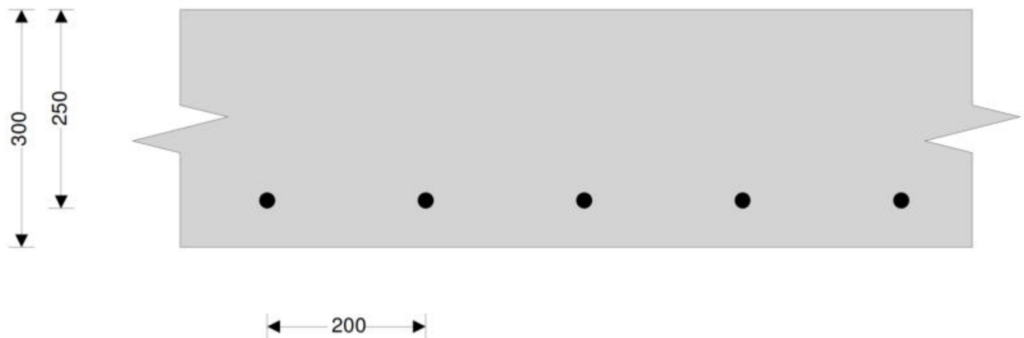
Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **0.2** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times h_{sat} / 2$ = **5.4** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3$ = **30.3** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3$ = **45.1** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **87.2** kNm/m



Check wall stem in bending

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

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **250.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.035**

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} = **237** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **844** mm²/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **390** mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **844** mm²/m

Reinforcement provided **20 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s\_stem\_prov}$ = **1571** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.060** 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_stem} = **0.712** N/mm^2

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

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas}$ = **7**

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **179.0** N/mm^2

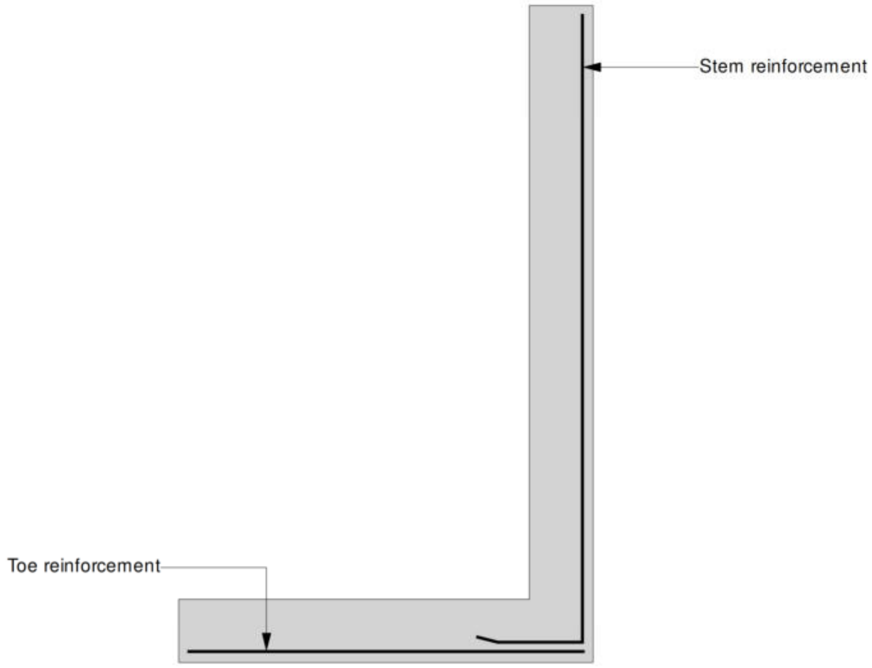
Modification factor $factor_{tens} = \min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.63**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **11.43**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **11.20**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 20 mm dia.@ 200 mm centres - (1571 mm^2/m)
Stem bars - 20 mm dia.@ 200 mm centres - (1571 mm^2/m)