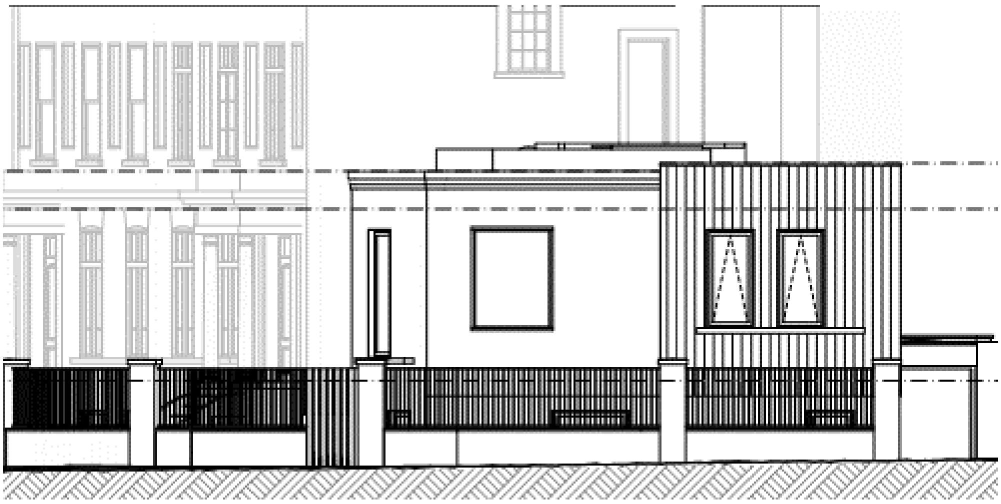
engineersHRW

39A PRIORY TERRACE
LONDON NW6 4DG

STRUCTURAL ENGINEER'S STATEMENT



This report was written/compiled by Brett Scott BE(Hons) and reviewed by Simon Robinson CEng MIStructE of engineersHRW

Signed .... Date 07/05/2020

Job Number: 2015

STRUCTURAL ENGINEER'S STATEMENT

This Structural Engineer's Statement has been prepared for and on behalf of our client, Old West Hampstead Estates Ltd, based on the planning proposals by SHH Architects (drawing references listed in section 8.3.2). It is for the use of the client, the client's professional advisers and London Borough of Camden and is for their use only. The report should not be used for any purposes other than for which it was considered. The report should be read in conjunction with Engineers HRW Structural drawings (drawing references listed in 8.3.1), Desk Study and Site Investigation Report including BIA by GEA.

1.0 Introduction

1.1 Engineers HRW have been asked to consider the engineering issues surrounding the proposed construction works to support the planning application.

1.2 The proposals comprise the construction of new house with a basement on a grassed area adjacent 39 Priory Terrace. It incorporates one half of an existing garage.

1.3 This report has been prepared in compliance with Camden's CPG Basements 2018 requirements for basement extensions. It is the equivalent of Appendix 5 of the Camden BIA proforma and signed off by a Chartered Structural Engineer (MIStructE) and includes proposals for a sequence of construction. A desk study and site-specific soils investigation have been carried out by GEA and signed off by a Chartered Geologist and Hydrologist.

2.0 Site Information

The site is located within the London Borough of Camden, approximately 375 m southwest of Kilburn High Road London Underground Station and 775 m south of West Hampstead London Underground Station. It fronts onto Abbey Road to the north and is bounded by Priory Terrace to the east, by No 39 Priory Terrace, a four-storey end of terrace house with a lower ground floor level and rear and front gardens, to the south and by a single storey garage to the west.

The site is in the Priory Road Conservation area. It consists of a grassed area and one half of an existing double garage.

Figure 1 - Extract from Camden Conservation Areas Map

2.1 Existing Building

The existing garage building is of uncertain date however a driveway is indicated on the historic maps from the 1950s and garages from the 1970s. The structure is load-bearing masonry and a timber roof. The foundation and ground floor slab details are assumed these a ground bearing slab and mass concrete strips that are not of significant depths.

The adjacent structure at No 39 Priory Terrace appears to be traditionally constructed, with load-bearing external solid brickwork walls, with assumed timber floors and timber roof.

A newer building, Priory Lodge, on Abbey Road is on the far side of the garage to be retained. It is assumed to be a loadbearing masonry structure with timber floors.

2.2 Geotechnical Ground Conditions

2.2.1 Geology

A detailed Geotechnical Site Investigation has been carried out. Refer to GEA Desk Study and Ground Investigation Report dated April 2020. The British Geological Survey indicates that the site is directly underlain by the London Clay Formation.

The exploratory borehole and trial pits revealed that ground conditions were generally consistent with the geological records and known history of the area and comprised Made Ground up to a depth of 1.0m underlain by the London Clay Formation. The London Clay initially comprised firm becoming stiff fissured brown clay, extending to a depth of 8.50 m. Below this depth, stiff fissured bluish grey clay was encountered and extended to the full depth of the investigation, of 15.00 m.

The results of laboratory plasticity index tests indicate the clay to be of high-volume change potential and the results of triaxial undrained compressive strength tests indicate the clay to be of moderate becoming high and very high strength.

2.2.2 Groundwater

Groundwater was not encountered during drilling. Groundwater has subsequently been measured within the standpipe at depths of 2.50 m and 2.60 m during two monitoring visits carried out three weeks and four weeks after installation.

3.3.3 Monitoring of the borehole showed depth to ground water of 2.5m however this is likely to be caused by seepages in the made ground.

Significant groundwater inflows are not likely to be encountered in construction of the basement extension however perched water will be encountered in the made ground. The deepest excavation will be 4.5m.

2.2.3 Contamination

The results of the contamination testing have indicated the presence of no elevated concentrations of contaminants within the single sample of made ground tested with all concentrations recorded as being below the screening value. As a result, the made ground is considered to be free from contamination that could cause a risk to any potential receptors and as such a requirement for remedial measures is not envisaged. However it would be prudent for a watching brief to be maintained during the ground works and for additional sampling and contamination testing to be carried out in proposed areas of soft landscaping to confirm the absence of contamination in these areas.

2.3 Trees

There are no trees affected by the development or influence the design of the foundations.

Any shallow foundations design will assume a high volume change potential clay with allowance for restricted planting as the NHBC guidance.

2.4 Flood Risk

A site-specific Flood Risk assessment has been carried out, see Infrastruct CS Report dated 12th February.

2.4.1 Fluvial Flood Risk

The proposed development site lies entirely within flood zone 1 which is classified as land assessed as having a less than 1 in 1000 annual probability of river or sea flooding and is appropriate to all uses of land.

2.4.2 Surface Water Flood Risk

The risk of flooding due to overland flood flows is considered low by the Environment Agency. The surface water flood data for the site, shown below, indicates that there is medium flood risk immediately to the north of the site, near the garages and along Abbey Road, but very low risk within the site itself. There is currently a wall protection to the site from water runoff which will be maintained.

2.4.3 Design Implications

Based on the above there is a low risk of flooding at this site. Therefore no special measures are required apart from a non-return valve to the drainage as detailed in the FRA.

3.0 Proposed Structural Works

3.1 Introduction

The proposed development of the site involves removing one half of the existing garage and constructing a new house with a basement. The basement will involve excavation within a significant portion of the site to a maximum depth of 4.5m. The excavation will be formed within a reinforced underpinned existing wall, piled retaining walls and reinforced walls constructed in hit and miss sequence.

The new structure will a concrete frame throughout to provide a robust flexible layout.

3.2 Demolition Works

It is proposed that all demolition works will be carried out in accordance with BS 6187 'Code of practice for demolition' and an appropriately skilled and experienced contractor is to be appointed. The works are to be carefully sequenced and undertaken and the contractor is to provide full temporary works and supervision to ensure that the stability of the remaining structure and surrounding structures are maintained at all times.

3.3 New Basement Structure

3.3.1 The new basement structure is to consist of an underpinned existing wall, new reinforced concrete retaining walls and contiguous piled walls. This variation in construction types is in response to the particular requirements at each boundary. The floors will be reinforced concrete slabs supported by the walls and internal columns. The structure will be fully suspended on piles to allow for the impact of heave and water uplift.

3.3.2 Half of the existing garage will be removed, and the existing internal wall will be supported by the new basement. No support will be taken from this wall for the new structure.

3.3.4 Due to the depth of excavation there will be minor heave due to the unloading of the London Clay. Compressible material below the basement slab will allow for this heave to be unrestrained and place no load on the structure.

3.3.5 The presence of ground water was established during the excavation of borehole 1 (see section 2.2.2). Monitoring showed water at a depth of 2.5m below ground however this is likely to be caused by seepages in the made ground. Therefore the need to control significant amounts of water during the construction period is unlikely given the proposed depth of excavation.

3.3.6 The concrete structure will be designed to BS8110 with full top and bottom reinforcement to all sections. The concrete in itself is not a watertight / waterproof construction and in order to achieve a Grade 3 'habitable' basement in accordance with BS8102 a combination of tanking with an internal drained cavity system will be provided. However the final waterproofing system is yet to be agreed with the architect.

3.3.7 The proposed reinforced concrete basement form is classified as a "robust" structure and will be designed to accommodate any lateral loading that will develop.

4.0 Control of Movement

The proposed basement scheme and method of construction are of a typical form for which we are confident that resulting ground movements can be controlled in both the temporary and permanent condition. Top down construction has been adopted to limit the need for temporary propping, see the construction sequence drawings.

4.1 Vertical Movement

Vertical movement resulting from heave of the clay strata below the basement slab following excavation will be in the order of 9mm at the centre of the basement reducing to 3 to 7mm at the edges. Compressible material below the basement slab will allow for this heave to be unrestrained and place no load on the structure.

4.2 Horizontal Movement

Horizontal deflection to the perimeter of the basement will be limited by casting the underpins and retaining walls in short sections. Where possible a contiguous piled wall has been adopted. This is designed to be propped by the ground floor and basement slabs. Total horizontal movement of 10mm is anticipated due to installation of pins and excavation.

4.3 Ground Movement Analysis

A ground movement analysis has been carried out by GEA. Based on this analysis 39 Priory Terrace and Priory Lodge are expected suffer damage from Category 0(Negligible) to Category 1(Slight). This is below the limit required by the Camden CPG. The adjacent garage will suffer damage slightly higher than this. This assessment is however conservative and repair works are assumed to be required during the works to separate the garages.

5.0 Superstructure

5.1 The superstructure is a concrete frame of flat slabs supported by reinforced concrete columns. This allows for a roof garden and flexible room layouts at each floor.

6.0 SUDs and Drainage

6.1.1 In accordance with the London Plan surface water run-off should be managed as close to its source as possible. The London Plan states that all new developments should aim to reduce run-off to Greenfield rates "utilising SUDS unless there are practical reasons for not doing so". A Flood Risk Assessment has been carried out by Infrastruct CS and a preliminary drainage scheme produced.

The following drainage hierarchy was used to assess the possibility of implementing SUDS at the site:

1. Store rainwater for later use.
2. Use infiltration techniques, such as porous surfaces in no-clay areas.
3. Attenuate rainwater in ponds or open water features for gradual release.
4. Attenuate rainwater in tanks or sealed water features for gradual release.
5. Discharge rainwater direct to a watercourse.
6. Discharge rainwater to a surface water sewer/drain.
7. Discharge rainwater to a combined sewer.

6.1.2 Rainwater Harvesting and Green roofs
The capacity of rainwater harvesting systems to attenuate rainwater depends on the water use within the building. If there is no activity in the building and the harvester is full, no attenuation will be provided during a subsequent storm event. In the worst-case scenario, the rainwater harvester will provide no attenuation.

6.1.3 Infiltration techniques
The site investigation shows that the site is underlain by London Clay which is unsuitable for the use of infiltration techniques.

6.1.4 Attenuation techniques
In accordance with the London Plan, surface water should be attenuated to Greenfield run-off rates before draining to the public sewers. In this case tanked attenuation is provided within the garden. In addition a small amount of green roof is also adopted.

6.1.5 Discharge to watercourse
This solution would not be feasible as there are no watercourses near the site.

6.1.6 Discharge to surface water sewer/drain
This solution would not be feasible as the public sewer running in Priory Terrace is combined.

6.1.7 Discharge to a combined sewer
The site will be discharged via a new connection to the combined sewer in Priory Terrace. The surface water will be attenuated to a green field rate of 2l/s.

6.2.1 Drainage
The development proposals will seek to discharge foul water from the development site into the existing combined drainage network running along Priory Terrace, to the east of the property. This will be subject to a Section 106 consents from Local Water Authority, Thames Water. Flows into this system will be via a gravity fed connection.

A pre-development enquiry has been made to Thames Water although at the time of writing no response has been received. No capacity issues are envisaged as it is the head of the line.

7.0 Temporary Works

7.0.1 Temporary Works

The contractor will be responsible for the design, erection, and maintenance of all temporary works in accordance with all relevant British Standards. The contractor will be contractually obligated to appoint a qualified temporary works engineer to provide adequate temporary works and supervision to ensure that the stability of the existing structure, excavations and surrounding structures are maintained at all times. The proposed scheme requires limited temporary works.

7.0.2 Submissions

The contractor will be required to submit full proposals, method statements and calculations to the engineer and all appropriate parties (party wall surveyors, AIP etc.) for approval prior to the start of any works on site.

The contractor will also be required to appoint a Temporary Works Co-ordinator for the duration of the contract in accordance with the specification and BS 5975.

7.0.3 Monitoring

All items of temporary works and surrounding structures should be monitored in a manner and frequency commensurate with the construction activity taking place. As a minimum the monitoring should include a daily full visual survey of all temporary works and surrounding structures and a weekly measured survey using fixed survey points during the main basement works, subject to proposed construction sequence, party wall agreement, etc.

8.0 Method Statement / Sequence of Works – Basement Construction

Construction methodology and temporary works assumed in the design as described below and on drawing 2015-HRW-XX-ZZ-DR-S-900. These will be superseded by the contractor's proposals.

1. Install piles, contiguous piles at perimeter together with internal plunge columns.
2. Construct reinforced concrete underpins beneath the existing garage.
3. Construct reinforced concrete retaining wall adjacent the footpath in underpinning sequence.
4. Construct the ground floor together with the capping beam therefore providing restraint to the top of the retaining walls.
5. Excavate to formation level.
6. Cast basement slab on compressible material.
7. Basement structure complete for construction of superstructure and fit out.

9.0 Design Criteria

9.1 Code of Practice

Structural use of Concrete BS 8110-1:1997

Structural use of Concrete BS 8110-3:1985

Code of practice for foundations BS 8004

Structural use of Steel BS 5950-1:2000

Structural use of Timber BS 5628-2:2002

Structural Use of Masonry BS 5628-1:2005

Loading for Buildings BS 6399: Part 1:1996, Part 2:1997

9.2 Loading – Imposed loadings to BS 6399

Domestic areas = 1.5 kN/m2

Roof (flat with no access) = 0.75 kN/m2

Roof (pitched) = 0.6 kN/m2

9.3 List of relevant drawings and reports

9.3.1 eHRW Drawings:

2015-HRW-XX-00-DR-S-102
2015-HRW-XX-01-DR-S-103
2015-HRW-XX-B1-DR-S-101
2015-HRW-XX-RF-DR-S-104
2015-HRW-XX-XX-DR-S-200
2015-HRW-XX-XX-DR-S-201
2015-HRW-XX-ZZ-DR-S-900
2015-HRW-XX-ZZ-DR-S-901

9.3.2 Architects Drawings (not included in SES)

(919)000_ P01
(919)001_ P01
(919)020_ P01
(919)210_ P01
(919)211_ P01
(919)310_ P01

9.3.3 GEA Report (not included in SES)

Desk Study and Ground Investigation Report J20012 dated April 2020

9.3.4 Infrastruct CE Report & Drawing (not included in SES)

3832-39PR-ICS-XX-RP-C-07.001 Flood Risk Assessment and Drainage Strategy
2015-XX-XXX-DR-C-0500 Drainage Design Drawing

9.3.5 Preliminary Calculations

10.0 Conclusion

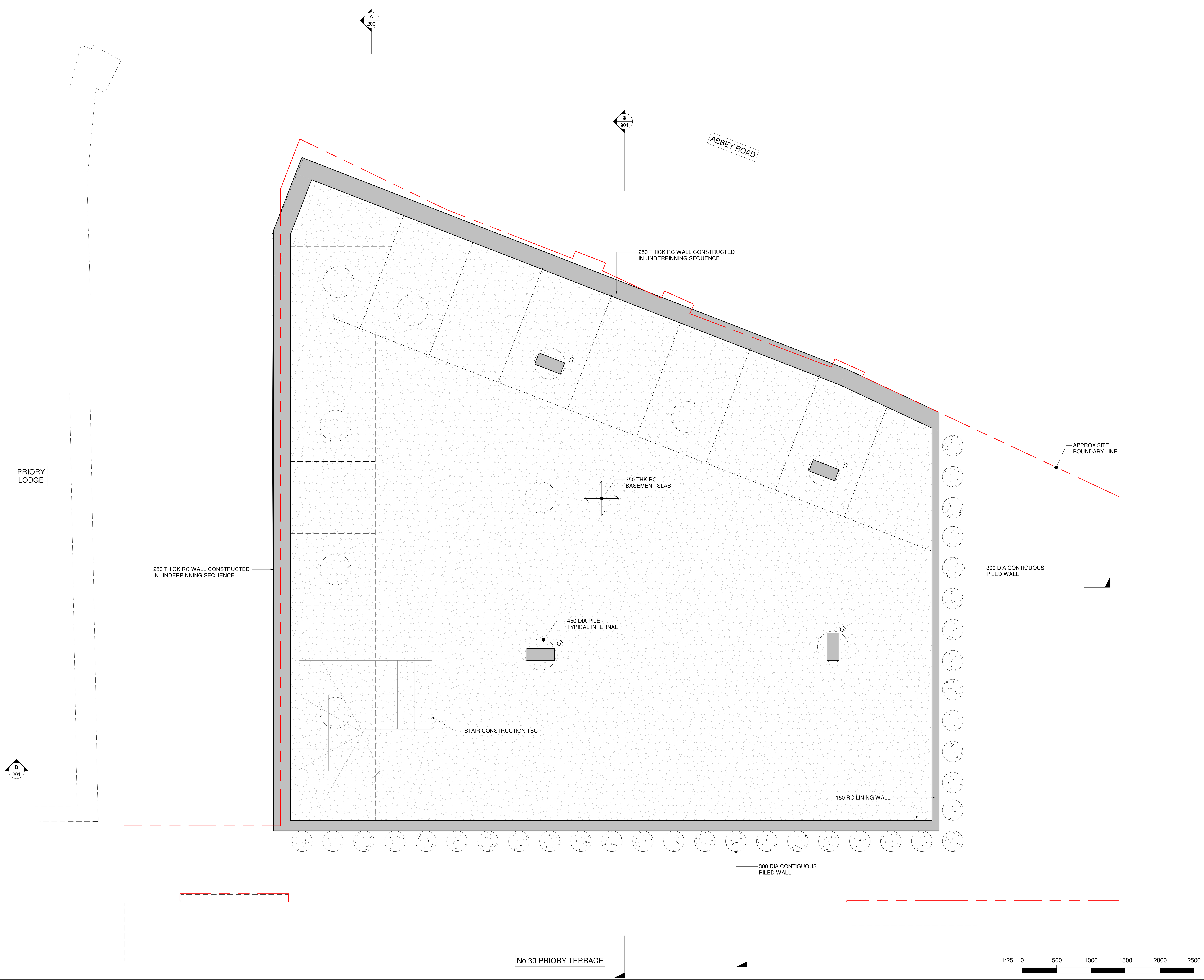
The following has been carried out in preparing this Structural Engineers Statement: -

- A desk study followed by a full site investigation were undertaken to establish ground conditions and groundwater levels.
- A full engineering scheme design was developed considering the surrounding structures and site constraints. This includes a sequence of construction.

Based on the above we are satisfied that the scheme is viable and is designed and can be constructed in accordance with Camden Council's CPG Basements dated 2018. An AIP for the retaining wall supporting the pavement will be required following planning.

APPENDIX I

EngineersHRW Drawings



NOTES

1. DO NOT SCALE FROM THIS DRAWING
2. THESE DRAWINGS ARE TO BE READ IN CONJUNCTION WITH ARCHITECTS AND OTHER CONSULTANTS INFORMATION

Legend

DENOTES EXISTING MASONRY TO BE RETAINED

DENOTES 200 THK RC WALL UNO.

DENOTES STRUCTURE UNDER

Column Schedule

REF	SIZE	GRADE
C1	175 x 400mm	RC32/40

Rev	Date	Amendments	By	Chk'd
P3	05.05.20	ISSUED FOR INFORMATION	SL	BS
P2	17.03.20	ISSUED FOR INFORMATION	SL	BS
P1	06.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:
Abbey Road, London, NW6 4DG

Drawing title:
Proposed Basement General Arrangement

Scale at A1:	Drawn by:	Date:	Chk'd by:
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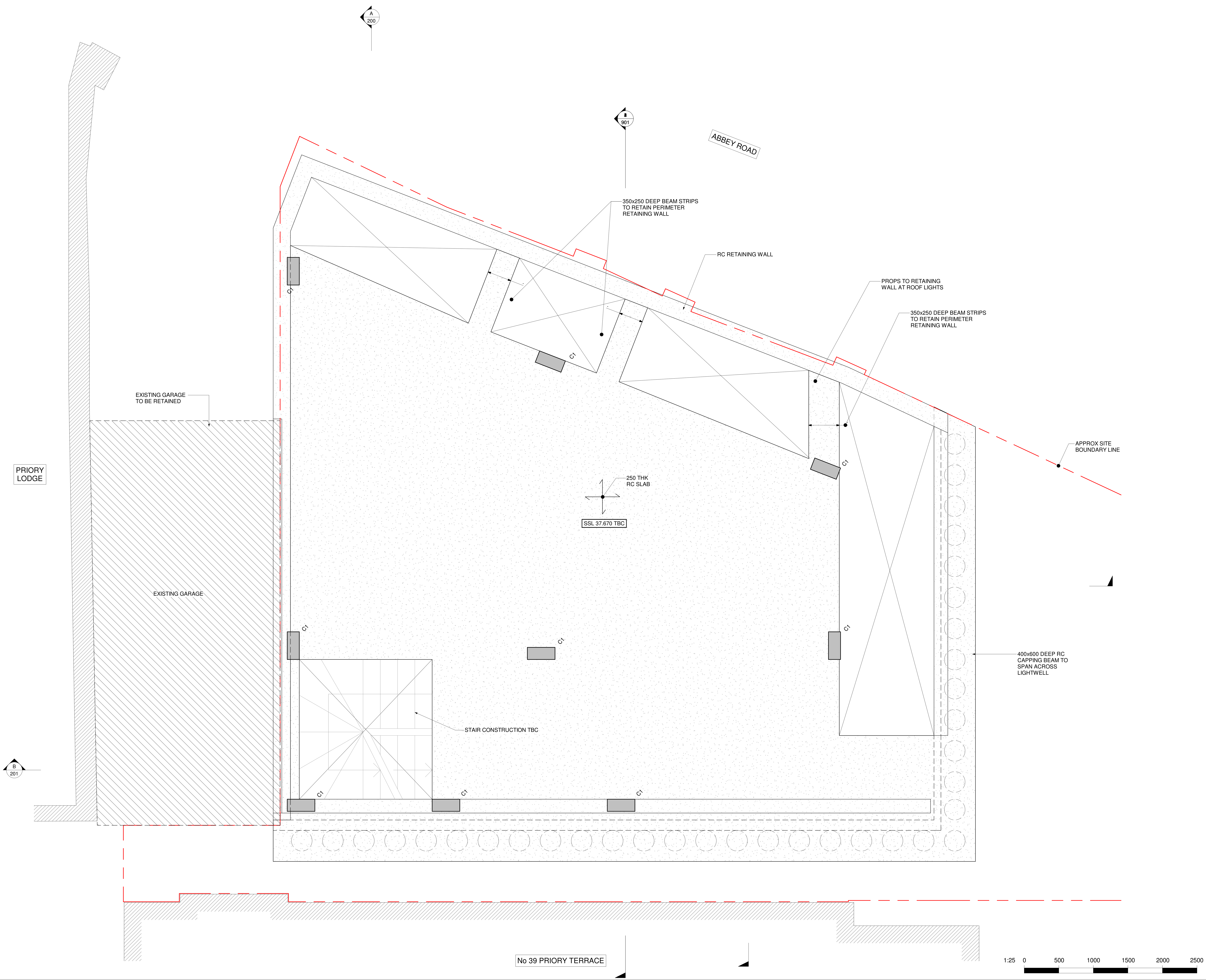
Status: S2 — Purpose For Issue: INFORMATION

Drawing Number: **2015-HRW-XX-B1-DR-S-101** Rev: **P3**



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Legend

- DENOTES EXISTING MASONRY TO BE RETAINED
- DENOTES 200 THK RC WALL UNO.
- DENOTES STRUCTURE UNDER

Column Schedule

REF	SIZE	GRADE
C1	175 x 400mm	RC32/40

Rev	Date	Amendments	By	Chk'd
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P2	17.03.20	ISSUED FOR INFORMATION	SL	BS
P1	06.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:
Abbey Road, London, NW6 4DG

Drawing title:
Proposed Ground Floor General Arrangement

Scale at A1:	Drawn by:	Date:	Chk'd by:
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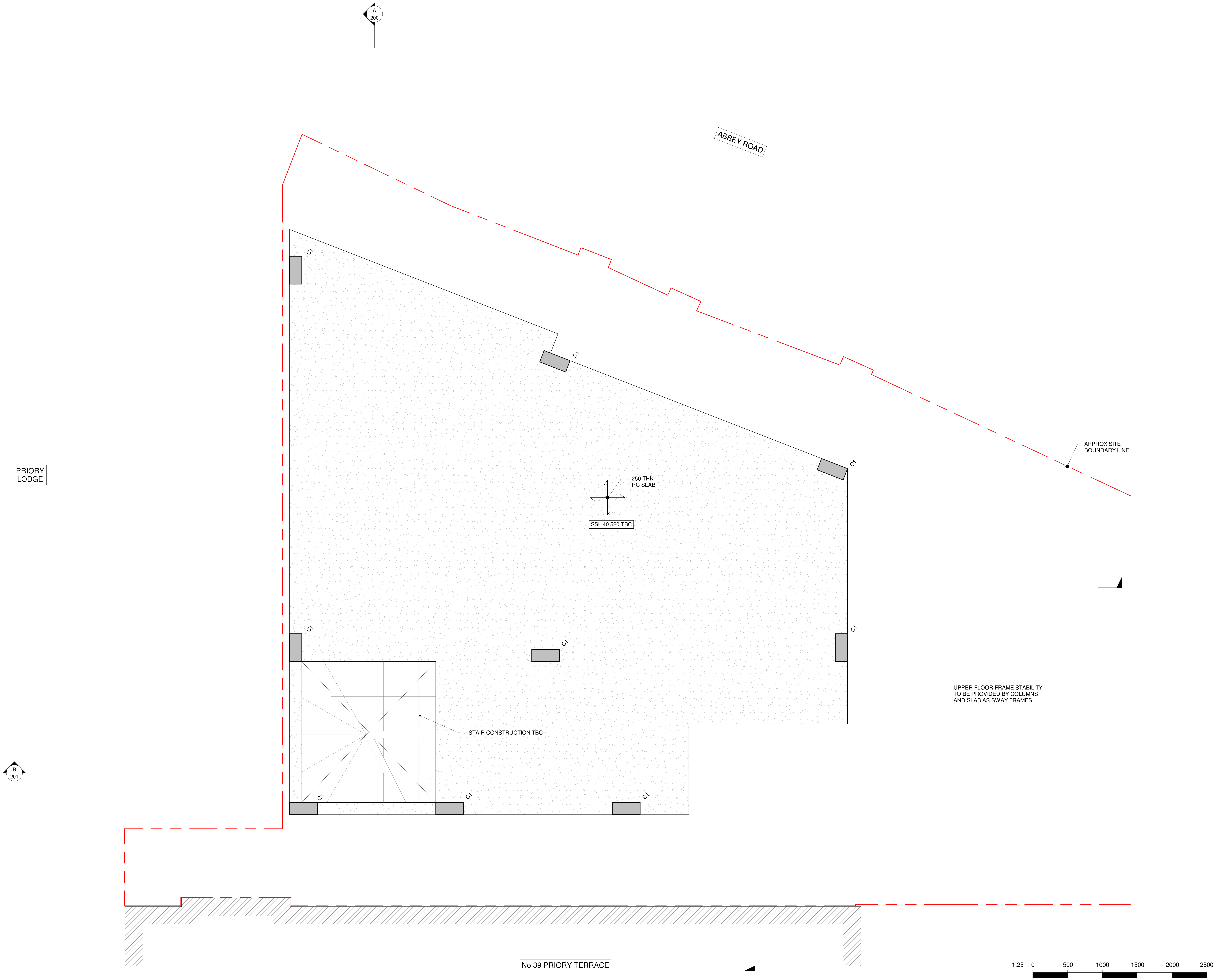

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Legend

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- DENOTES 200 THK RC WALL UNO.
- DENOTES STRUCTURE UNDER

Column Schedule

REF	SIZE	GRADE
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Rev	Date	Amendments	By	Chk'd
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P2	17.03.20	ISSUED FOR INFORMATION	SL	BS
P1	06.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:

Abbey Road, London, NW6 4DG

Drawing title:

Proposed First Floor General Arrangement

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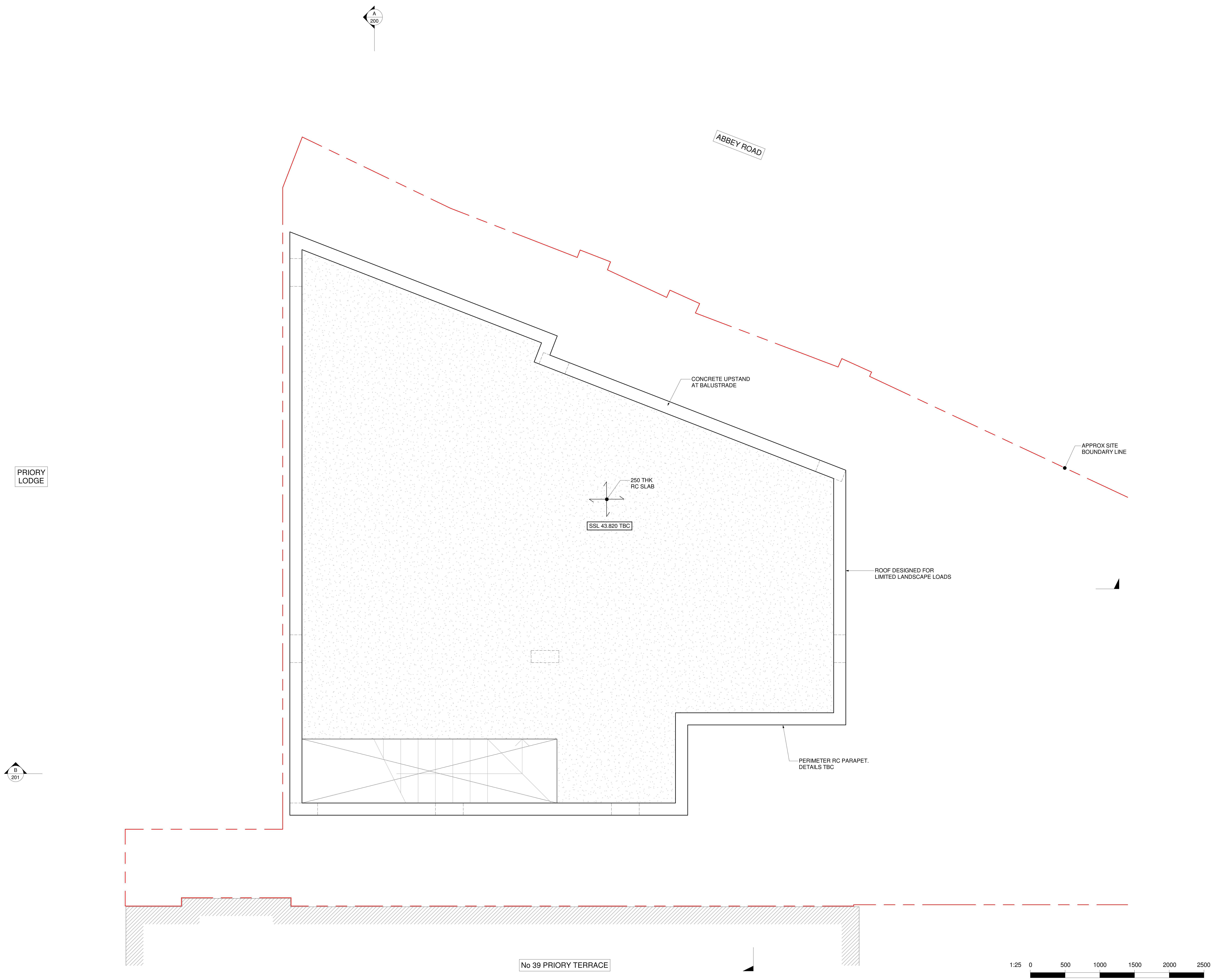

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Legend

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DENOTES 200 THK RC WALL UNO.

DENOTES STRUCTURE UNDER

Column Schedule

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P2	17.03.20	ISSUED FOR INFORMATION	SL	BS
P1	06.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:

Abbey Road, London, NW6 4DG

Drawing title:

Proposed
Roof
General Arrangement

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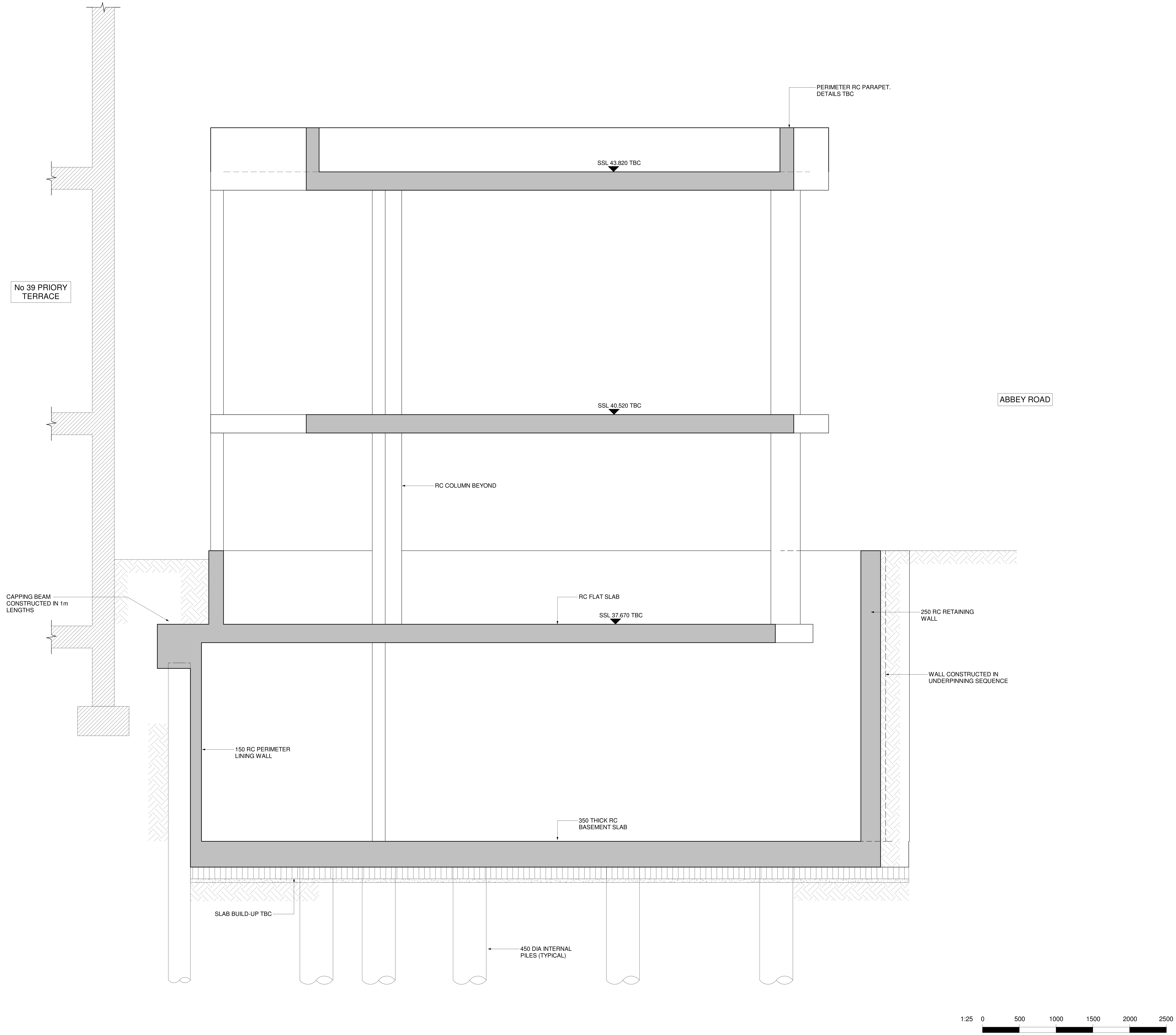

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P2	17.03.20	ISSUED FOR INFORMATION	SL	BS
P1	06.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:

Abbey Road, London, NW6 4DG

Drawing title:

Proposed Section A-A

Scale at A1:	Drawn by:	Date:	Chk'd by:
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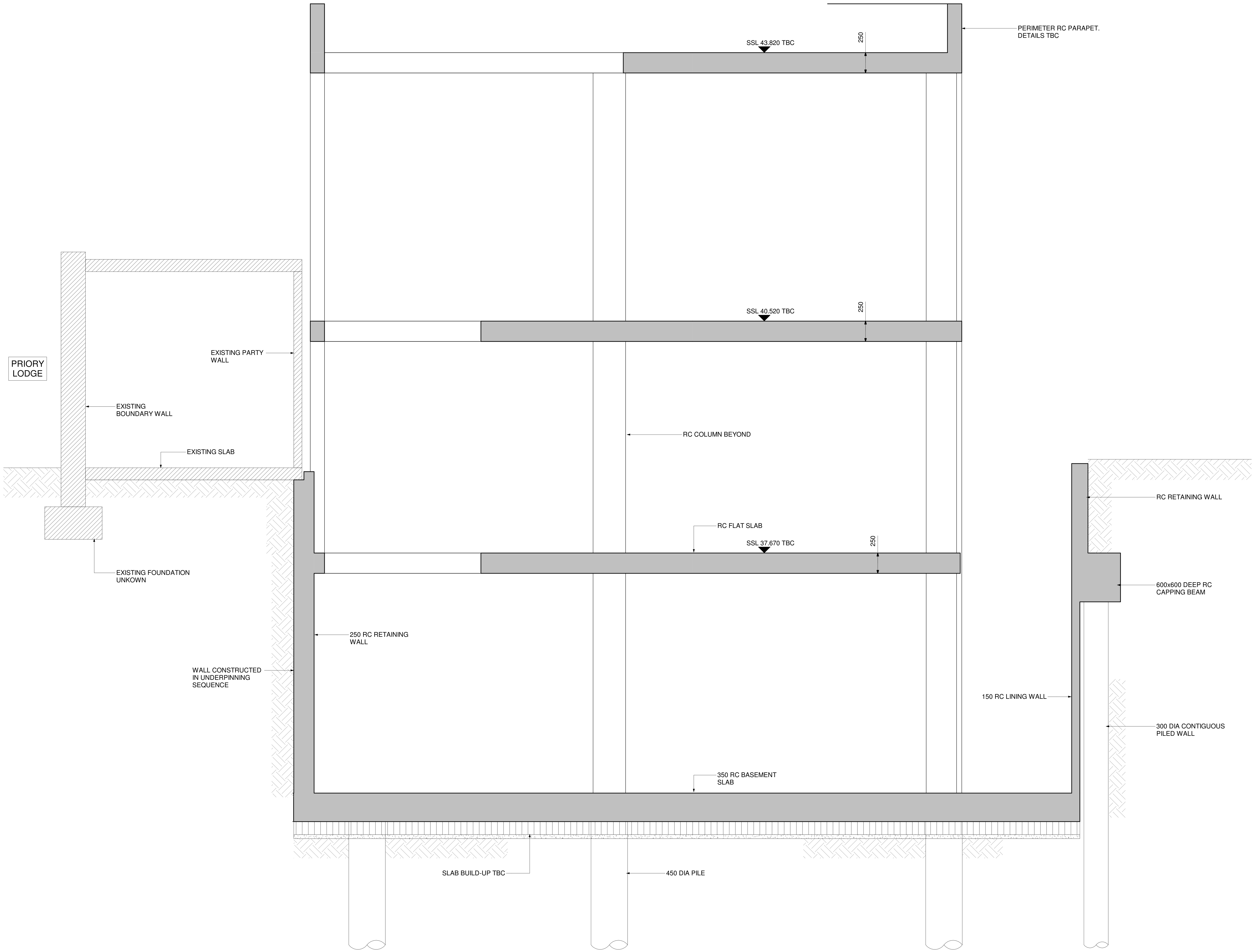

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P2	17.03.20	ISSUED FOR INFORMATION	SL	BS
P1	06.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:

Abbey Road, London, NW6 4DG

Drawing title:

Proposed
Section B-B

Scale at A1:	Drawn by:	Date:	Chk'd by:
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Status: Purpose For Issue:

S2 INFORMATION

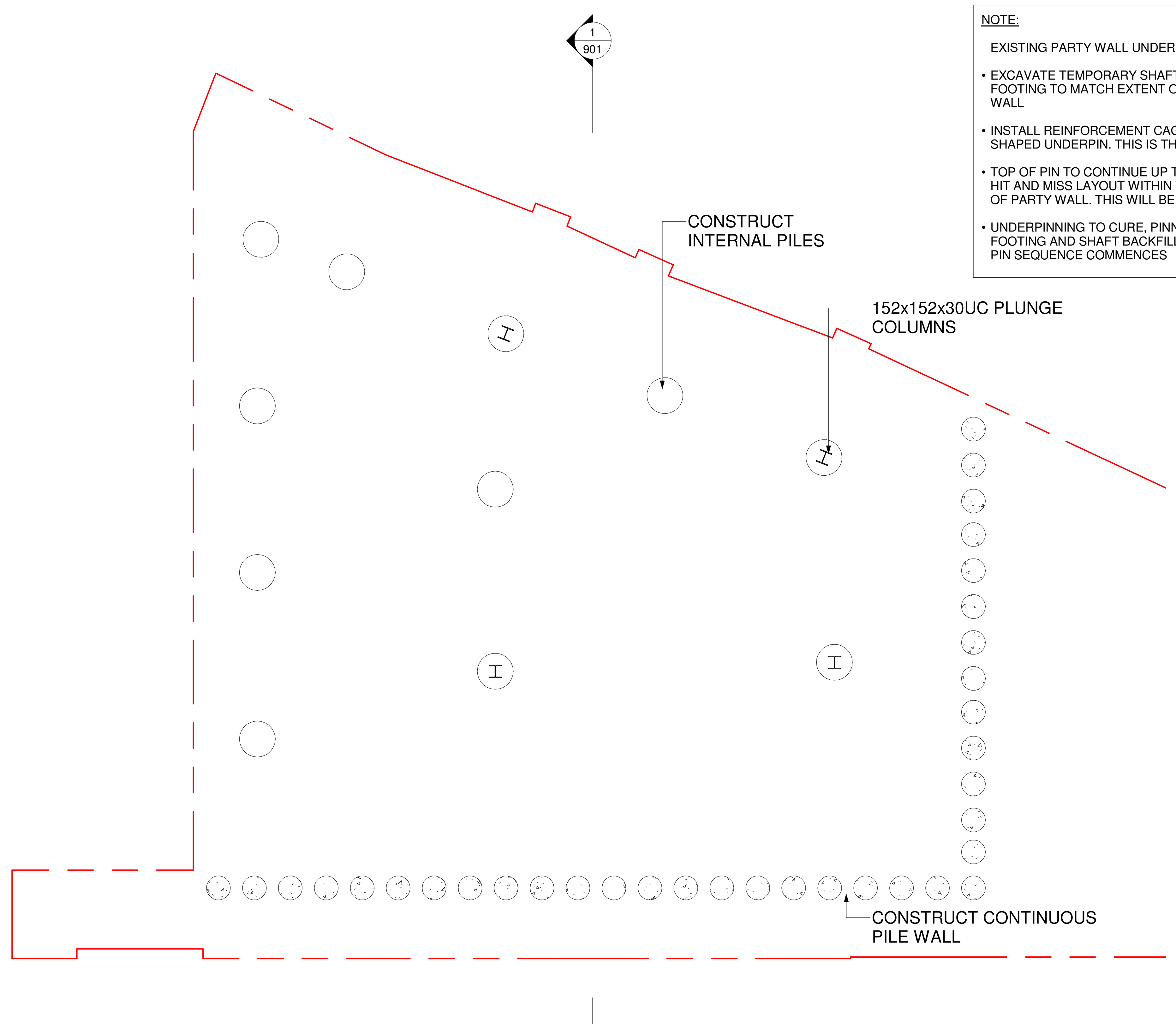
Drawing Number: **2015-HRW-XX-XX-DR-S-201**

Rev: **P3**

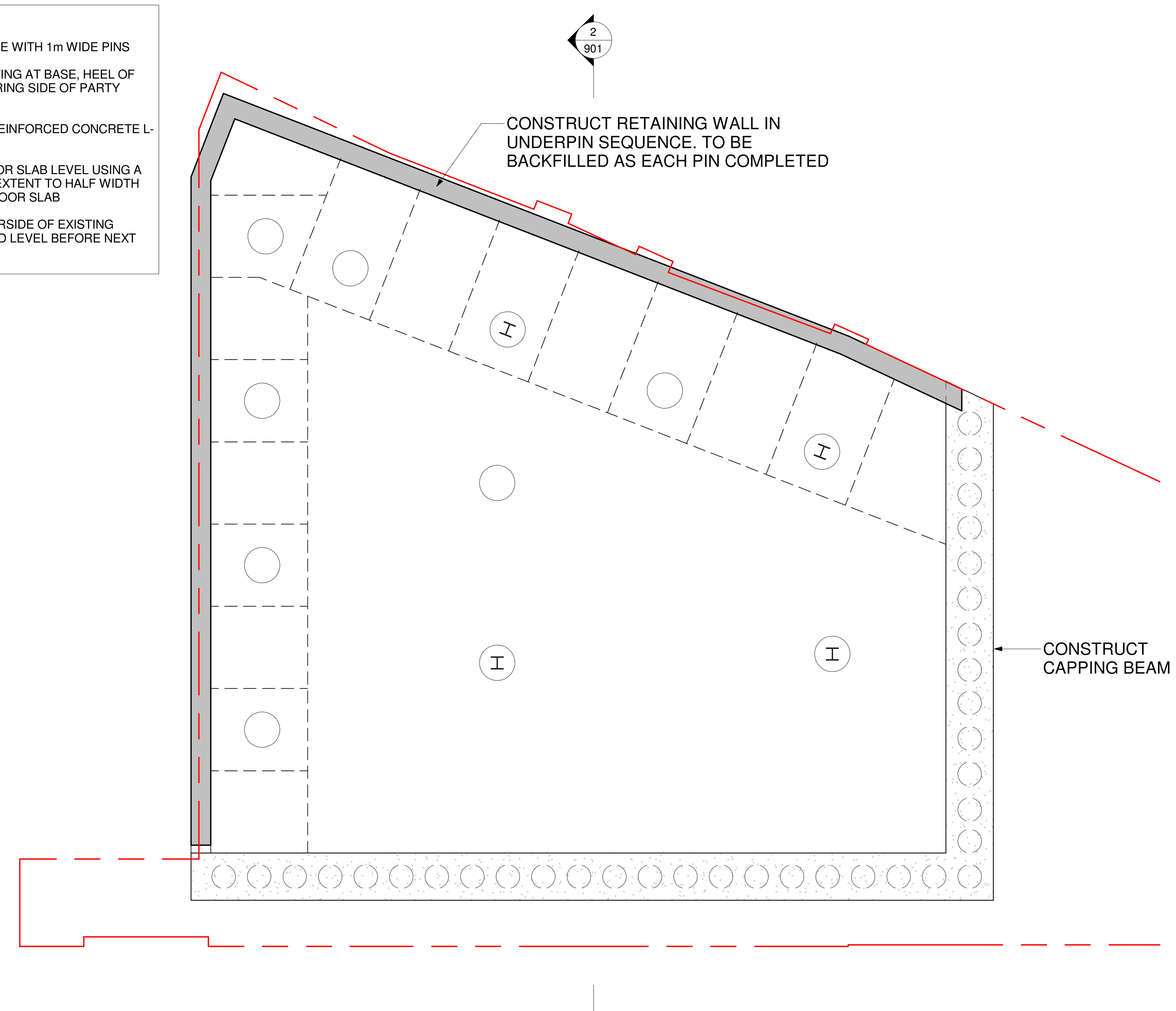
NOTE:

EXISTING PARTY WALL UNDERPINNED IN A TYPICAL 5 PIN SEQUENCE WITH 1m WIDE PINS

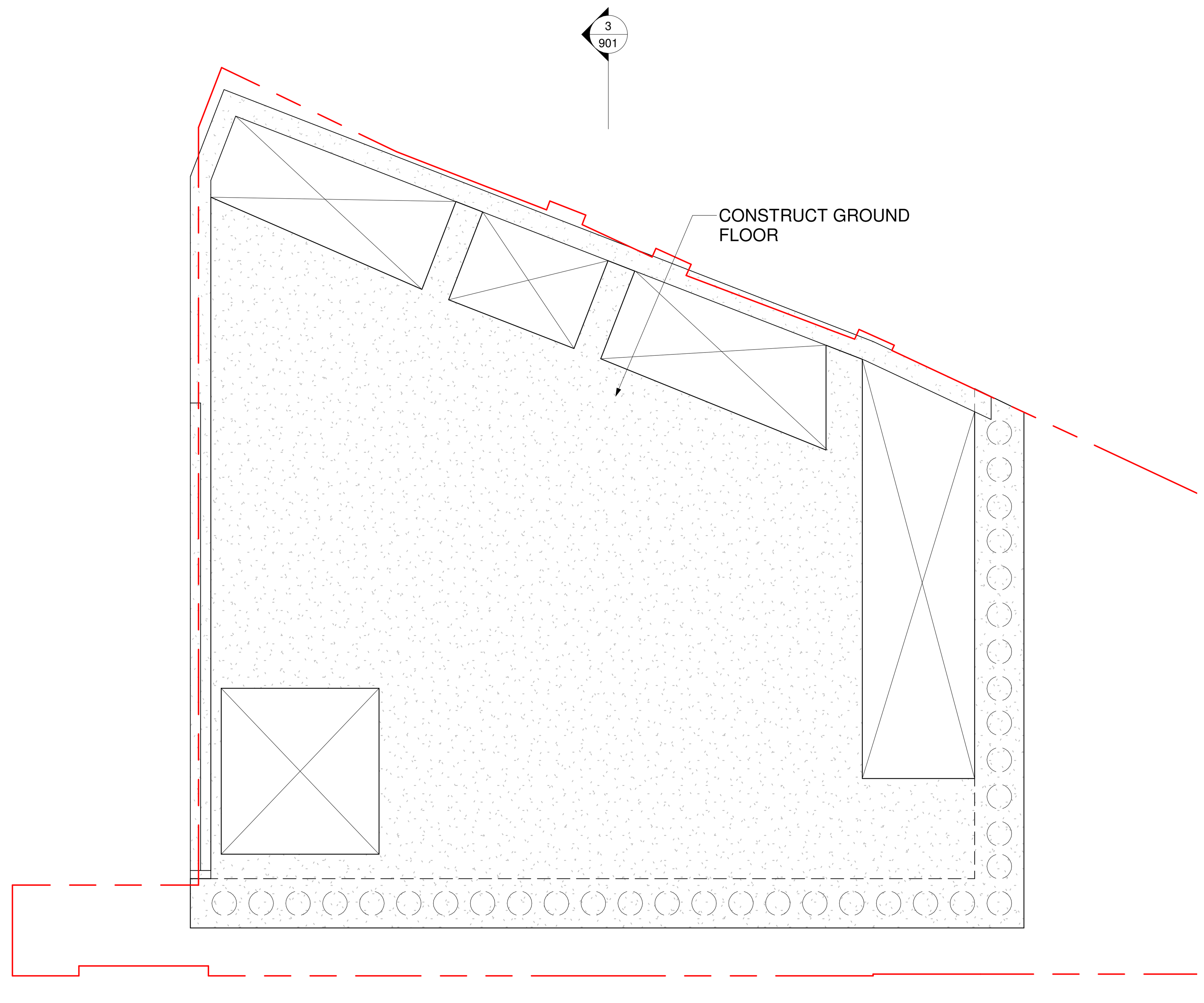
- EXCAVATE TEMPORARY SHAFT AND PLACE MASS CONCRETE FOOTING AT BASE, HEEL OF FOOTING TO MATCH EXTENT OF EXISTING FOOTING TO NEIGHBOURING SIDE OF PARTY WALL
- INSTALL REINFORCEMENT CAGE AND CAST CONCRETE TO FORM REINFORCED CONCRETE L-SHAPED UNDERPIN. THIS IS THE PERMAMENT RETAINING WALL
- TOP OF PIN TO CONTINUE UP TO TOP OF PROPOSED GROUND FLOOR SLAB LEVEL USING A HIT AND MISS LAYOUT WITHIN THE EXISTING MASONRY. MAXIMUM EXTENT TO HALF WIDTH OF PARTY WALL. THIS WILL BE USED TO SUPPORT THE GROUND FLOOR SLAB
- UNDERPINNING TO CURE, PINNING UP COMPLETED TO MEET UNDERSIDE OF EXISTING FOOTING AND SHAFT BACKFILLED AND COMPACTED UP TO GROUND LEVEL BEFORE NEXT PIN SEQUENCE COMMENCES



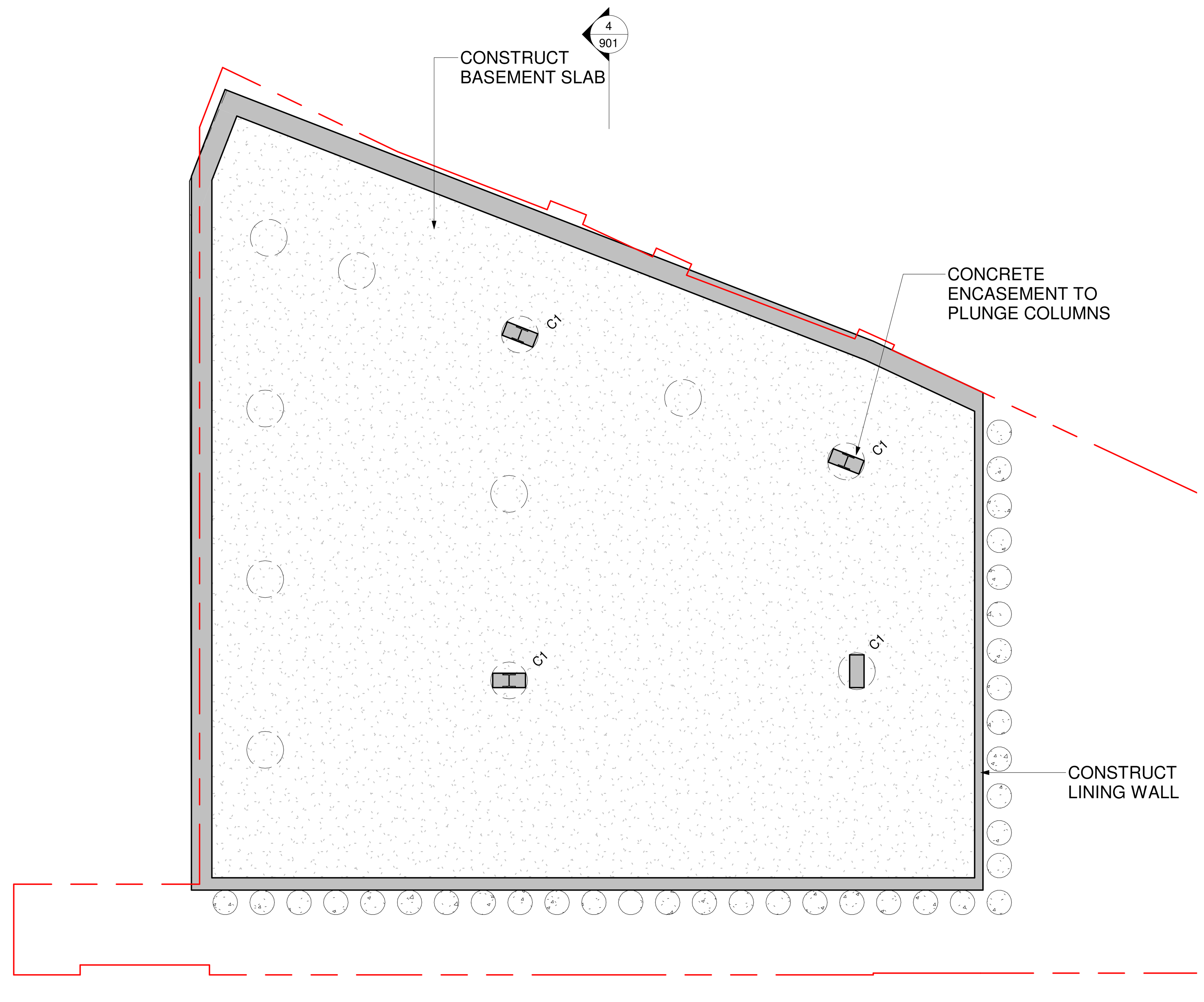
Plan - Stage 1



Plan - Stage 2



Plan - Stage 3



Plan - Stage 4

NOTES

1. DO NOT SCALE FROM THIS DRAWING
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3. EXISTING STRUCTURE SHOWN INCLUDING PARTY WALLS IS BASED ON INITIAL INFORMATION AND SHOULD BE CONSIDERED AS INDICATIVE AND TO BE CONFIRMED ON SITE

ALLOW FOR GROUND WATER DEWATERING SYSTEM DURING BASEMENT CONSTRUCTION. GROUND INVESTIGATION STANDPIPE FOUND GROUND WATER LEVEL - 1.20m BELOW EXISTING GROUND LEVEL.
GIVEN THE PRESENCE OF A NON-AQUIFER BELOW THE SITE IT IS LIKELY THAT THE GROUNDWATER RECORDED WITHIN THESE SOILS RELATES TO PERCHED WATER WITHIN THE MADE GROUND AND WATER WITHIN MORE PERMEABLE POCKETS IN THE CLAY AND IS RECHARGED VIA INTERMITTENT SEEPAGES FROM SURFACE WATER ASSOCIATED WITH WEATHER CONDITIONS RATHER THAN ANY LARGE SCALE SUBTERRANEAN GROUNDWATER FLOW

Rev	Date	Amendments	By	Chk'd
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P1	24.03.20	ISSUED FOR INFORMATION	SL	BS

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Project:
Abbey Road, London, NW6 4DG

Drawing title:
Construction Sequence

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Status: S2 Purpose For Issue: **PRELIMINARY**

Drawing Number: **2015-HRW-XX-ZZ-DR-S-900** Rev: **P2**

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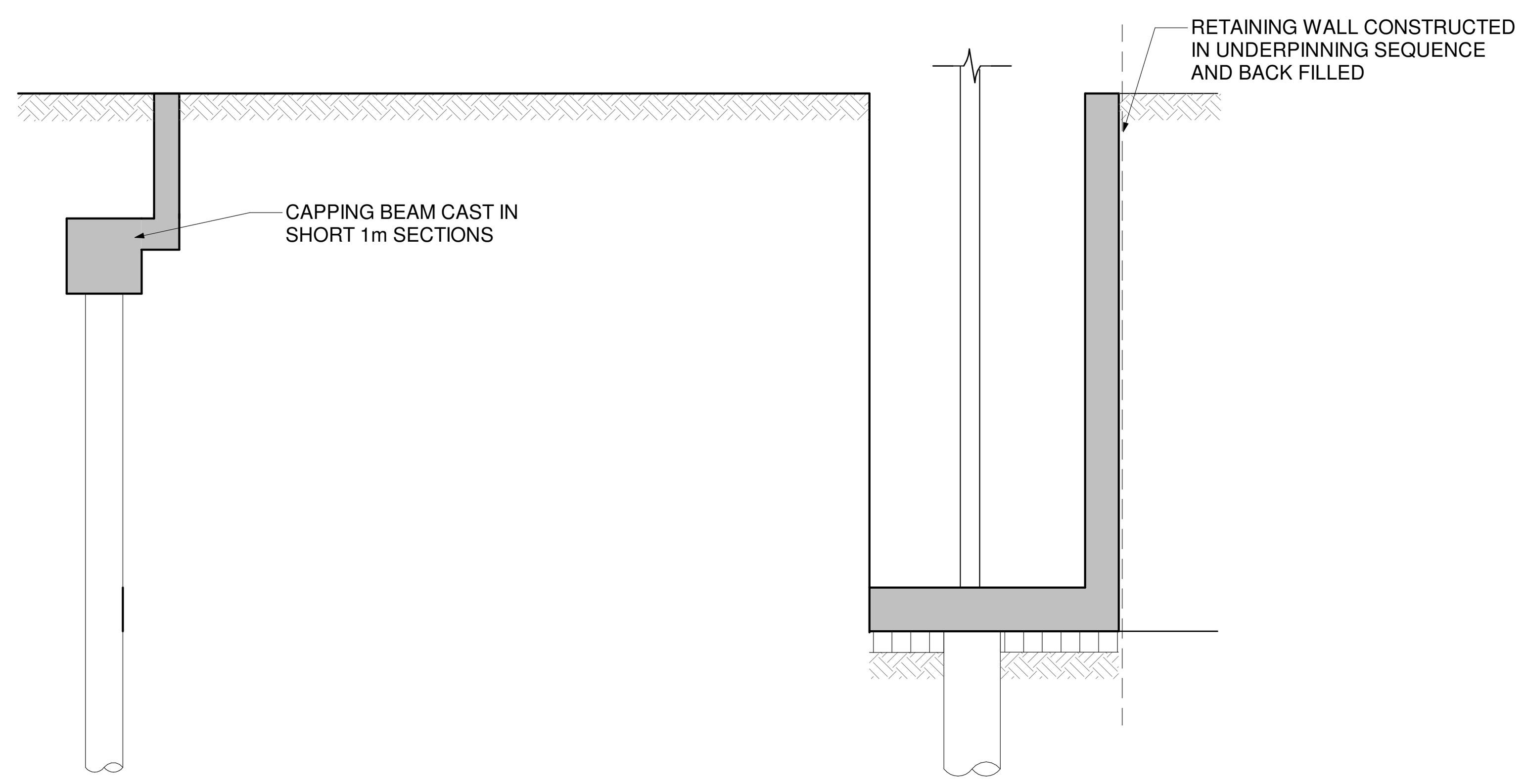

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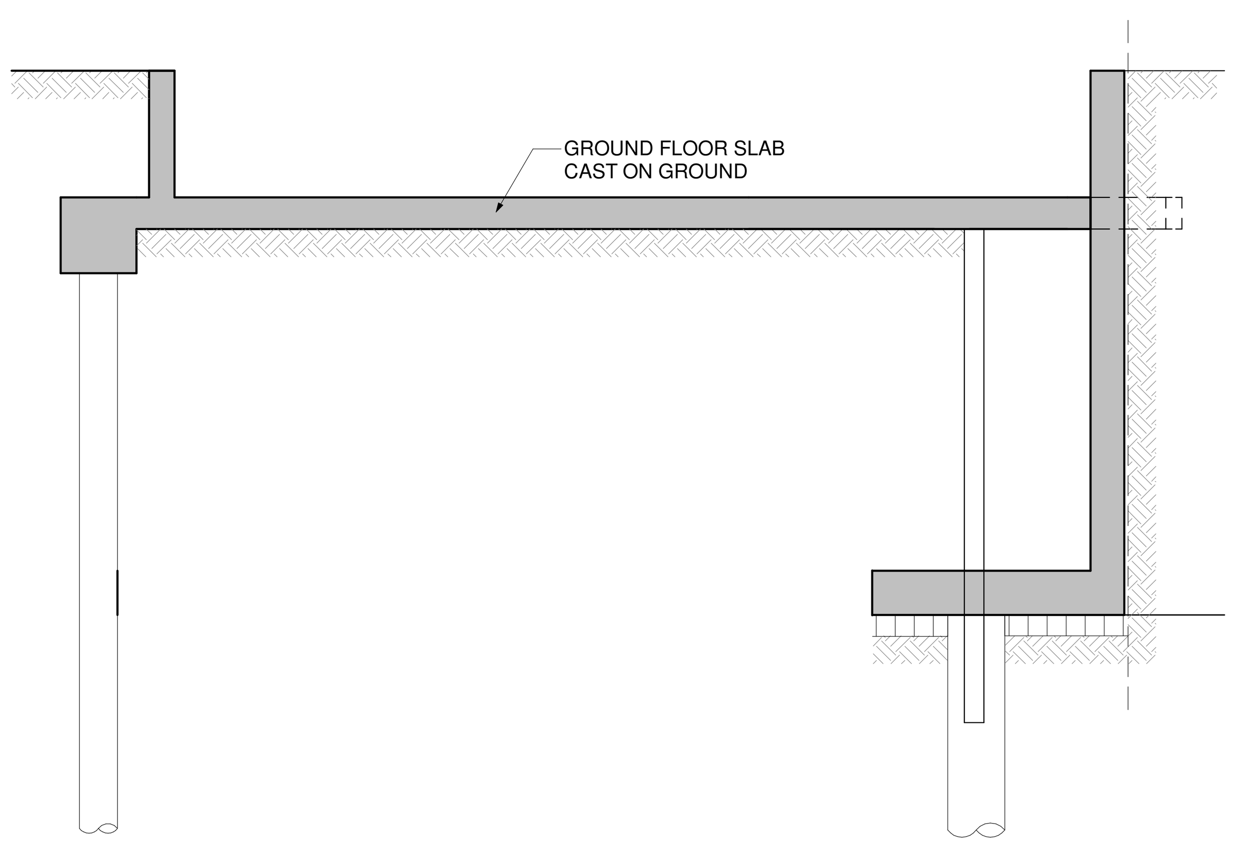
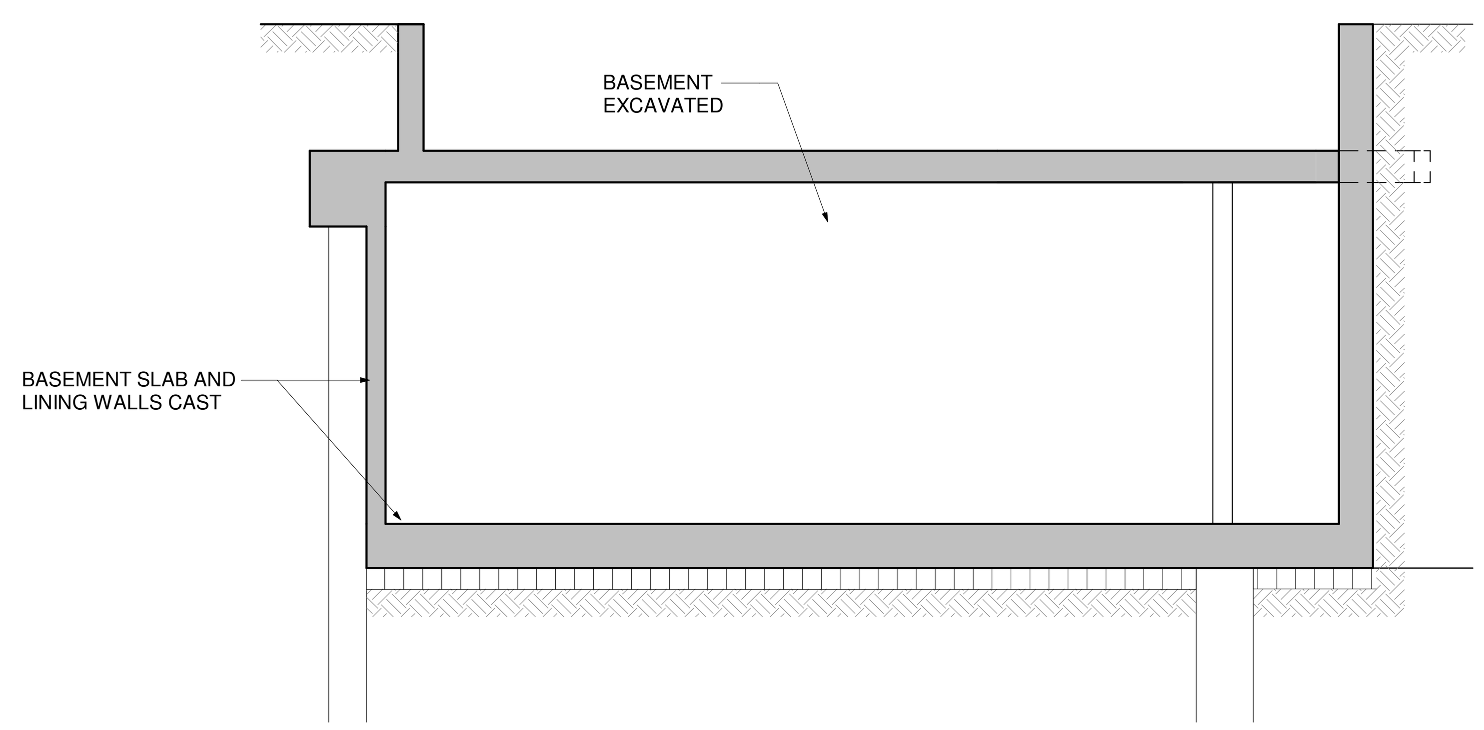
Scale 1 : 50



Section 3 - 3
Scale 1 : 50



Section 4 - 4
Scale 1 : 50

Rev	Date	Amendments	By	Chk'd
P2	05.05.20	ISSUED FOR INFORMATION	SL	BS

engineersHRW
London 0207 407 9575 Oxford 01865 957360 www.ehrw.co.uk

Project:
Abbey Road, London, NW6 4DG

Drawing title:
Construction Sequence Sections

Scale at A1:	Drawn by:	Date:	Chk'd by:
1 : 50	SL	05/05/2020	BS

Status: Purpose For Issue:
S2 PRELIMINARY

Drawing Number: **2015-HRW-XX-ZZ-DR-S-901**
Rev: **P1**

APPENDIX II

EngineersHRW Calculation

engineersHRW

Job No.	2015
Sheet No.	1.1
Revision	
Member Location	
Job Title	PRIORY TERRACE
Drawing Ref.	
Section	RETAINING WALLS
Made by	BJ
Date	4/20
Checked	

RETAINING WALLS

Preliminary design of perimeter retaining walls for the basement at 39a Priory Terrace.

Site investigation report shows the site to be underlain by London Clay.

Soil properties density 1950 kg/m³

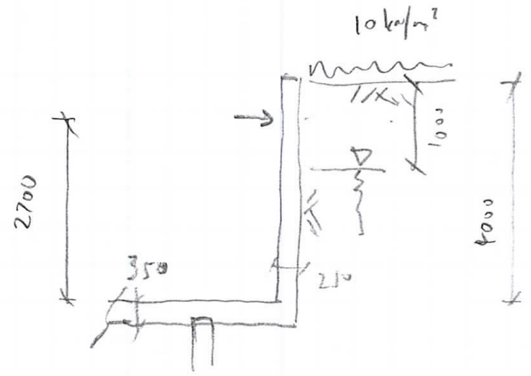
Ø 23°

Loads –

Retaining wall on the pavement elevation will govern.

Design for a surcharge of 10 kN/m²

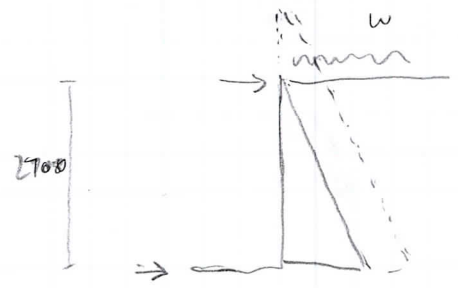
Advice in site investigation is to design for a water level 1m below ground level.



SECTION

engineersHRW	Job No. 2015	Sheet No. 1.2	Revision
	Member Location		
Job Title: PRIORY TERRACE	Drawing Ref.		
Section: RETAINING WALL	Made by BJ	Date 4/20	Checked

Wall Analysis



Computer programme does not allow variable prop height. Increase surcharge to allow for this

$w = 10 + 1.3 \times 19.5$
$= 35\ kN/m^2$

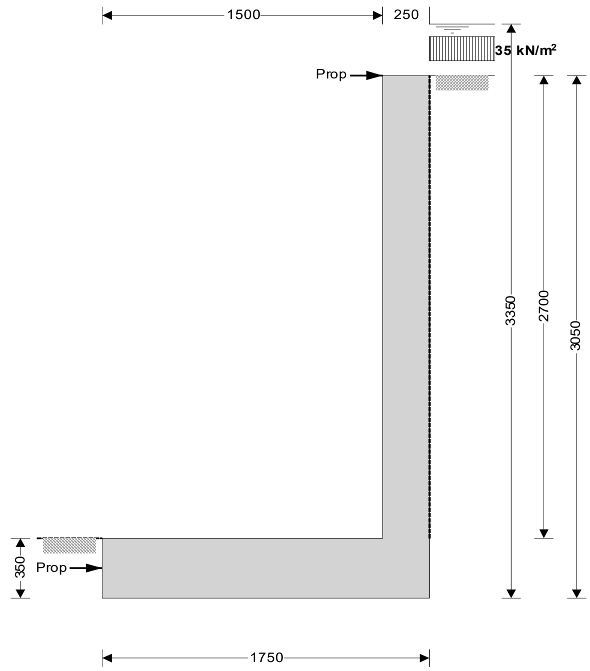
See following computer output for results.

250 mm stem is sufficient for capacity & deflection.

H16 @ 150 c/c required each face.

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **2700** mm
Thickness of wall stem	t_{wall} = **250** mm
Length of toe	l_{toe} = **1500** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1750** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **800** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3050** 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} = **3350** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **3000** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3050** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material γ_m = **19.5** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **23.0** deg

Angle of wall friction δ = **0.0** deg

Base material details

Stiff clay

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

Design shear strength ϕ'_b = **23.0** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **100** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.438}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{3.932}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.609**

Loading details

Surcharge load on plan Surcharge = **35.0** kN/m^2

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

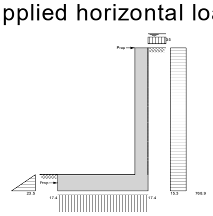
Applied vertical live load on wall W_{live} = **0.0** kN/m

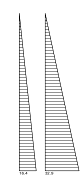
Position of applied vertical load on wall l_{load} = **0** mm

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

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

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





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

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **15.9** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **14.5** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base}$ = **30.4** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \text{Surcharge} \times h_{eff}$ = **46.8** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2$ = **0.4** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **27.5** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **55** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_s + F_{water}$ = **129.7** kN/m

Calculate total propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.1** kN/m

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

F_{prop} = **115.4** kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **71.3** kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **1.2** kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **30.7** kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **61.5** kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_s + M_{water}$ = **164.8** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **25.9** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2$ = **12.6** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base}$ = **38.5** kNm/m

Check bearing pressure

Total vertical reaction — $R = W_{total}$ = **30.4** kN/m

Distance to reaction — $x_{bar} = l_{base} / 2$ = **875** mm

Eccentricity of reaction — $e = \text{abs}((l_{base} / 2) - x_{bar})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **17.4** kN/m²

Bearing pressure at heel — $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **17.4** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **46.127** kN/m

Propping force to base of wall — $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **69.243** kN/m

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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **22.3** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **20.2** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f}$ = **42.5** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **104.1** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **0.7** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **53.6** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **77.1** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{s\_f} + F_{water\_f}$ = **235.4** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **5.8** kN/m

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

F_{prop_f} = **215.4** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **158.7** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **2.4** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **59.8** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **86.1** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{s\_f} + M_{water\_f}$ = **307** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **36.2** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **17.7** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f}$ = **53.9** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **42.5** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **875** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **24.3** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **24.3** kN/m²

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m²/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **24.3** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **24.3** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **24.3** kN/m²

Tekla Tedds EngineersHRW Unit 10 Blue Lion Place 237 Long Lane London SE1 4PU	Project Priory Terrace			Job no. 2015	
	Calcs for Retaining Wall			Start page no./Revision 5	
	Calcs by BDS	Calcs date 27/04/2020	Checked by	Checked date	Approved by	Approved date

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **87.852** kN/m

Propping force to base of wall — $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **127.514** kN/m

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 — $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **36.5** kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **17.3** kN/m

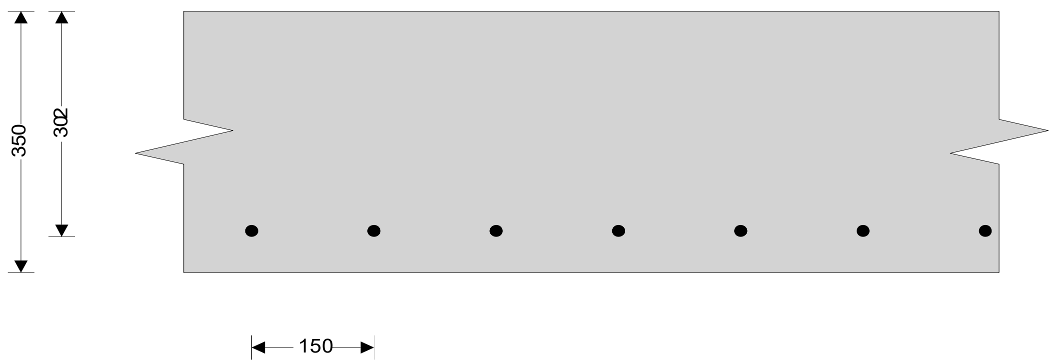
Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **19.1** kN/m

Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **32.1** kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **15.3** kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **16.8** kNm/m



Check toe in bending

Width of toe — b = **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **302.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.005**

Compression reinforcement is not required

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

$z_{toe} =$ **287** mm

Area of tension reinforcement required — $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **135** mm^2/m

Minimum area of tension reinforcement — $A_{s\_toe\_min} = k \times b \times t_{base} =$ **455** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **455** mm^2/m

Reinforcement provided — **16 mm dia.bars @ 150 mm centres**

Area of reinforcement provided — $A_{s\_toe\_prov} =$ **1340** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) =$ **0.063** 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 $v_{c\_toe} =$ **0.605** N/mm²

$v_{toe} < v_{c\_toe}$ - 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 $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds}) =$ **92.1** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 =$ **0.7** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 =$ **43** kN/m

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

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 =$ **57.6** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) =$ **32.7** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) =$ **47.1** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_s\_f} + V_{s\_water\_f} =$ **137.4** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 =$ **33.1** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2)-(15 \times a_l \times L)+(20 \times L^2))/(60 \times L^2) =$ **16.1** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2)-(15 \times a_l \times L)+(20 \times L^2))/(60 \times L^2) =$ **23.2**

kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} =$ **72.4** kNm/m

Calculate moment for wall design

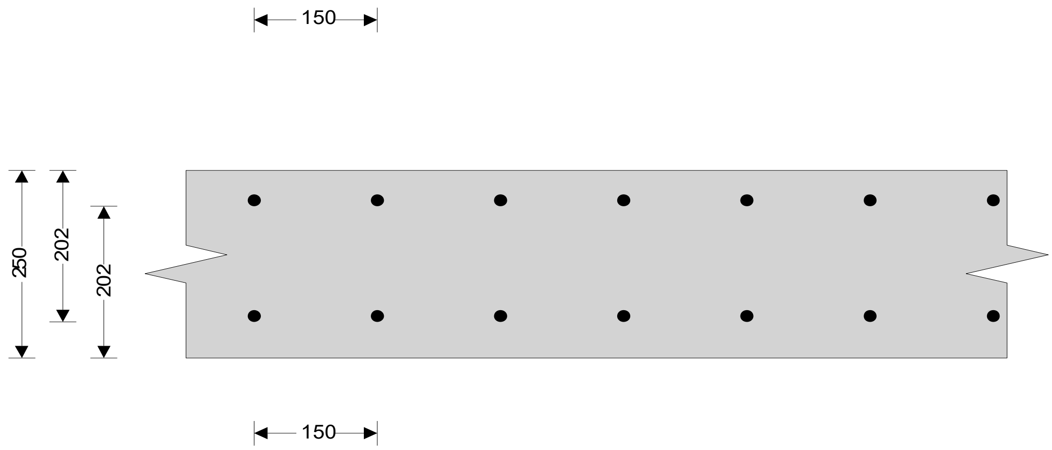
Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 =$ **18.6** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L)-a_l)/(20 \times L^3)-(x-b_l)^3 / (3 \times a_l^2)] =$ **7.5** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L)-a_l)/(20 \times L^3)-(x-b_l)^3 / (3 \times a_l^2)] =$ **10.7**

kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_s} + M_{w\_water} =$ **36.8** kNm/m



Check wall stem in bending

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

Depth of reinforcement: $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **202.0** mm

Constant: $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.044**

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} = **191** mm

Area of tension reinforcement required: $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **869** mm^2/m

Minimum area of tension reinforcement: $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **325** mm^2/m

Area of tension reinforcement required: $A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **869** mm^2/m

Reinforcement provided: **16 mm dia.bars @ 150 mm centres**

Area of reinforcement provided: $A_{s\_stem\_prov}$ = **1340** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress: $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.680** 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} = **0.765** N/mm^2

v_{stem} < v_{c_stem} - No shear reinforcement required

Check mid height of wall in bending

Depth of reinforcement: $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **202.0** mm

Constant: $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.023**

Compression reinforcement is not required

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

z_{wall} = **192** mm

Area of tension reinforcement required: $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **441** mm^2/m

Minimum area of tension reinforcement: $A_{s\_wall\_min} = k \times b \times t_{wall}$ = **325** mm^2/m

Area of tension reinforcement required: $A_{s\_wall\_req} = \text{Max}(A_{s\_wall\_des}, A_{s\_wall\_min})$ = **441** mm^2/m

Reinforcement provided: **16 mm dia.bars @ 150 mm centres**

Area of reinforcement provided: $A_{s\_wall\_prov}$ = **1340** mm^2/m

PASS - Reinforcement provided to the retaining wall at mid height is adequate

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas}$ = **20**

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **216.2** N/mm²

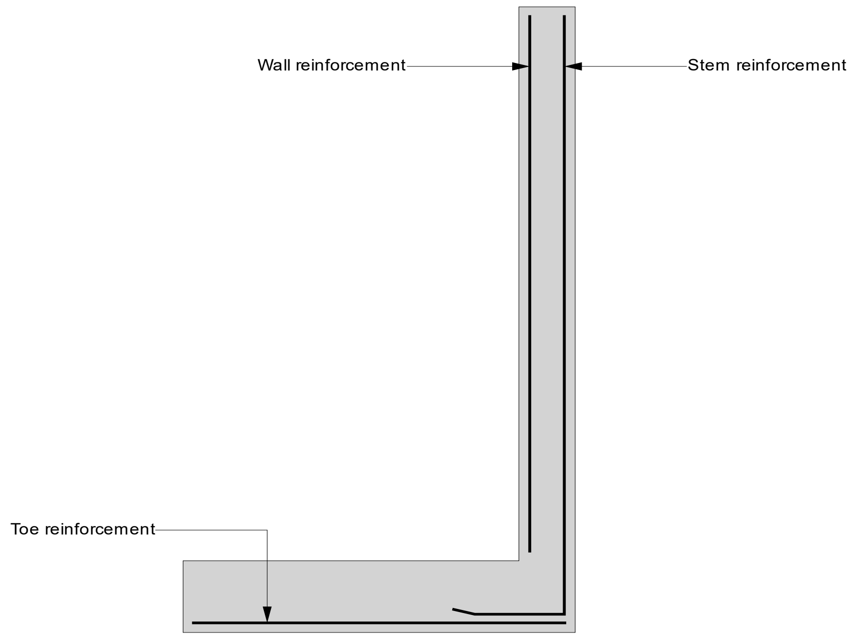
Modification factor $factor_{tens} = min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.36**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **27.25**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **13.37**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 150 mm centres - (1340 mm^2/m)
Wall bars - 16 mm dia.@ 150 mm centres - (1340 mm^2/m)
Stem bars - 16 mm dia.@ 150 mm centres - (1340 mm^2/m)